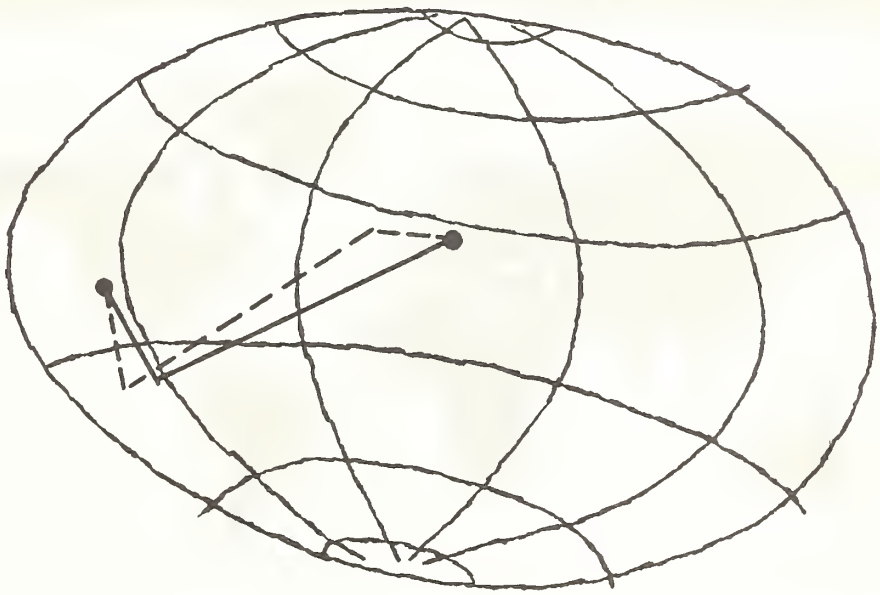
SHIPPING TESTS with CALIFORNIA CITRUS FRUIT from Los Angeles to Rotterdam



UNITED STATES DEPARTMENT OF AGRICULTURE
Washington, D.C.

Marketing Research Report No. 219
Marketing Research Division Agricultural Marketing Service

PREFACE

This study of shipping California citrus fruit overseas is part of a broad program of research to achieve more efficient distribution of our farm products. The purpose of one phase of this research is to evaluate, improve, and maintain the quality of food in transit and while it is moving through marketing channels.

Adoption of fiberboard containers introduced a transit refrigeration problem because of the insulating properties of fiberboard and because these containers were stowed more compactly, which retarded the circulation of the refrigerated air. As a result, spoilage of the fruit, particularly oranges, in these shipments increased. This increase in spoilage during shipment and after arrival at destination has caused dissatisfaction among the exporters and European receivers.

This study has provided information on how to reduce spoilage of fruit. It is hoped that this information will help to solve the problems of transporting overseas citrus fruit packed in fiberboard containers.

ACKNOWLEDGMENTS

Grateful acknowledgment is made to the following:

The Interocean Steamship Corporation and Captain Joh. Kjaerstad and Chief Engineer Konrad Knudson of the MS. Sandanger.

The Holland American Line and Captain J. P. Dekkeer and Chief Engineer H. J. J. Blom of the MS. Duivendyk.

G. F. Sainsbury, agricultural engineer, U.S. Department of Agriculture, who accompanied the shipment and was in charge of the test on one of the ships.

Sunkist Growers, Inc., who contributed all the test fruit, and J. R. MacRill, of the Sunkist Field Laboratory, who helped select it and gave valuable aid in carrying out the tests.

Carl Waldaphel, of the Sunkist Field Laboratory, and G. L. Rygg, Harlan Barber, and Paul R. Harding, Jr., of the Agricultural Marketing Service staff in Pomona, Calif., for preparation and loading of the test fruit.

FEBRUARY 1958

For sale by the Superintendent of Documents
U. S. Government Printing Office
Washington 25, D. C.
Price 25 cents

SHIPPING TESTS WITH CALIFORNIA CITRUS FRUIT

From Los Angeles to Rotterdam

By E. M. Harvey, senior plant physiologist, and
E. P. Atrops, associate plant physiologist
Quality Maintenance and Improvement Section

SUMMARY

Detailed observations of six shipments of California oranges, grapefruit, and lemons from Los Angeles to Rotterdam, April to September 1955, indicate that some of the problems concerned with maintaining and expanding the European market can be solved through better selection of fruit and improved handling and refrigeration before, during, and after shipment.

Thorough precooling before loading into the refrigerated ships is the most urgent need. Most commercial refrigerated ships are not equipped to cool warm fruit sufficiently after loading.

The tests show that strict adherence to the best handling procedures already known to the industry can solve the problems of bruising and other damage that occurs during handling. When transported on ships with adequate refrigeration facilities, test oranges of high carrying quality arrived at destination in excellent condition and retained their quality satisfactorily for 3 weeks.

As a result of the observations made during these tests, the following recommendations have been made:

1. Early season oranges of top quality should be selected for overseas shipment. A good selection becomes more and more difficult as the season advances.

2. Technical information to guide European receivers in selecting lots that can safely be held for later sale would eliminate some of their dissatisfaction.

3. Changes should be made in stowage patterns and ventilation facilities if fiberboard cartons are used. Improvements in the cartons would also be helpful.

4. Shipside precooling facilities are needed to provide for adequate cooling of the fruit before loading.

INTRODUCTION

In 1928-32, some overseas shipping tests, similar to the tests reported here, were made on citrus fruit. Before these earlier tests spoilage in shipments to Europe was excessive. Refrigerated ships were being used, but they generally lacked

mechanically forced air circulation. The fresh air for the refrigerated cargo was obtained periodically by setting up vent sails to force air down into the holds. No logical stowage plan existed, mostly because there was no forced air circulating system which necessitated a special stowage pattern. Many lower holds were 18 to 22 feet deep, and in these the crates were stacked as high as their sturdiness would permit.

The results of those export shipping tests furnished guidance for alterations in refrigerative equipment to provide better transport conditions for citrus fruit. In many ships refrigerated chambers were constructed in deep lower holds. Such chambers allowed control of temperature and air circulation, which was not possible in large refrigerated holds of irregular shape. Specifications of conditions which seemed most desirable for transporting citrus fruit were prepared for guidance of chief engineers of the ships.

These alterations to provide better transport conditions were designed for citrus fruit packed in standard wooden crates. That they solved the problem reasonably well is indicated by the fact that the industry requested no further overseas tests from about 1934 until 1954, when the fiberboard carton was used extensively for exporting oranges.

Exportation of non-precooled oranges in cartons in large shipments brought back the similar problem of more than 20 years ago. The flat surfaces of cartons suggested an opportunity for economical stowage, which appealed to both the shipowners and the stevedore companies. The results again were excessive decay on arrival at destination and an appeal for study of the factors responsible for the losses (fig. 1). The first step in the present study was a series of overseas shipping tests to determine the temperatures in cargoes of citrus fruit, especially oranges in cartons. The next step was to relate these temperatures to the condition of the fruit and then to suggest improvements in refrigeration.

MAKEUP OF TESTS

Six overseas shipping tests were made on ships leaving Los Angeles between April 14 and August 6 and sailing to Rotterdam. Research workers accompanied the cargo to its destination on the 3d and 6th tests. The ships were representative of those available to the citrus industry in refrigeration capacity, ranging from somewhat below average to above average. (See appendix.)

The test cartons of citrus fruit were under experimental control from 1 to 5 days before loading in the ship until the end of the holding period at destination. Test fruit was inspected at loading, placed in selected locations in the cargoes, and inspected 3 times at destination.

Temperature of the air in the cartons and in the cargo compartments in all tests was recorded with 30-day thermographs that were small enough to be placed

Figure 1.--Examples of bad condition of oranges on arrival in Rotterdam. Note how the decayed fruit and the unsightly spores in the fruit ruin the appearance of the entire contents of the carton. (BN-5126)

in the cartons without displacing more than about 2 fruits. Additional temperatures in the cartons and holds of accompanied tests (that is, tests 3 and 6) were determined by means of thermocouples and electric resistance thermometers.

"False floors" were used between the 7th and 8th or the 8th and 9th layers in tests 1, 3, and 6. The floors were constructed of 1- by 6-inch lumber, with the first course laid fore and aft and the second athwartship (fig. 2). The boards in each course were spaced approximately 3 inches apart. Also, fences were constructed in these ships of the same material and placed athwartship between rows of cartons. The vertical boards in the fences were cut so that they helped to support the false floors, and the horizontal boards aided air circulation athwartship. The spacing of these fences varied from 30 to 60 inches according to the type of load.

No false floors were used in tests 2, 4, and 5; instead, 1- by 2-inch strips of dunnage were placed vertically 18 inches apart, athwartship, between 30-inch bonded unit rows of cartons. (These bonded unit rows consisted of 2 rows of cartons--in 1 row the cartons were placed end to end athwartship and in the other row the cartons were placed side by side, so that one end of the cartons in the latter row rested against the sides of the cartons in the first row.)

The dates given for each of the 6 tests indicate the period from the beginning of loading of the test fruit to its unloading at Rotterdam, but for convenience in presenting results it is divided into (1) day of loading, (2) day of sailing, (3) 5th day after sailing, (4) 10th day, and (5) arrival. The overall period conforms closely with that of the commercial citrus fruit cargo billed to Rotterdam.

Figure 2.--Loading cartons of oranges in a square of the ship's hold. (BN-5125)

The ambient air and sea temperatures during tests 3 and 6 are presented in figure 3. The shipping routes from southern California to Europe via the Panama Canal expose ships to continuous tropical temperatures for 12 or more days. The graphs show temperature averages above 80° F. for 2 weeks during the southern traverse of the route. The consequent requirement for more refrigeration and the greatly decreased efficiency of the equipment create serious difficulty in maintaining satisfactory transit temperatures.

RESULTS

Valencia Oranges

Test No. 1.--Test 1 was made on Ship A, April 9 to May 11. The date of departure was April 14.

The test fruit and commercial cargo were rather early midseason Valencia oranges from central California citrus districts. All the fruit came to the pier in open, stake-side trucks, much of it 5 days before loading. Outside air temperatures

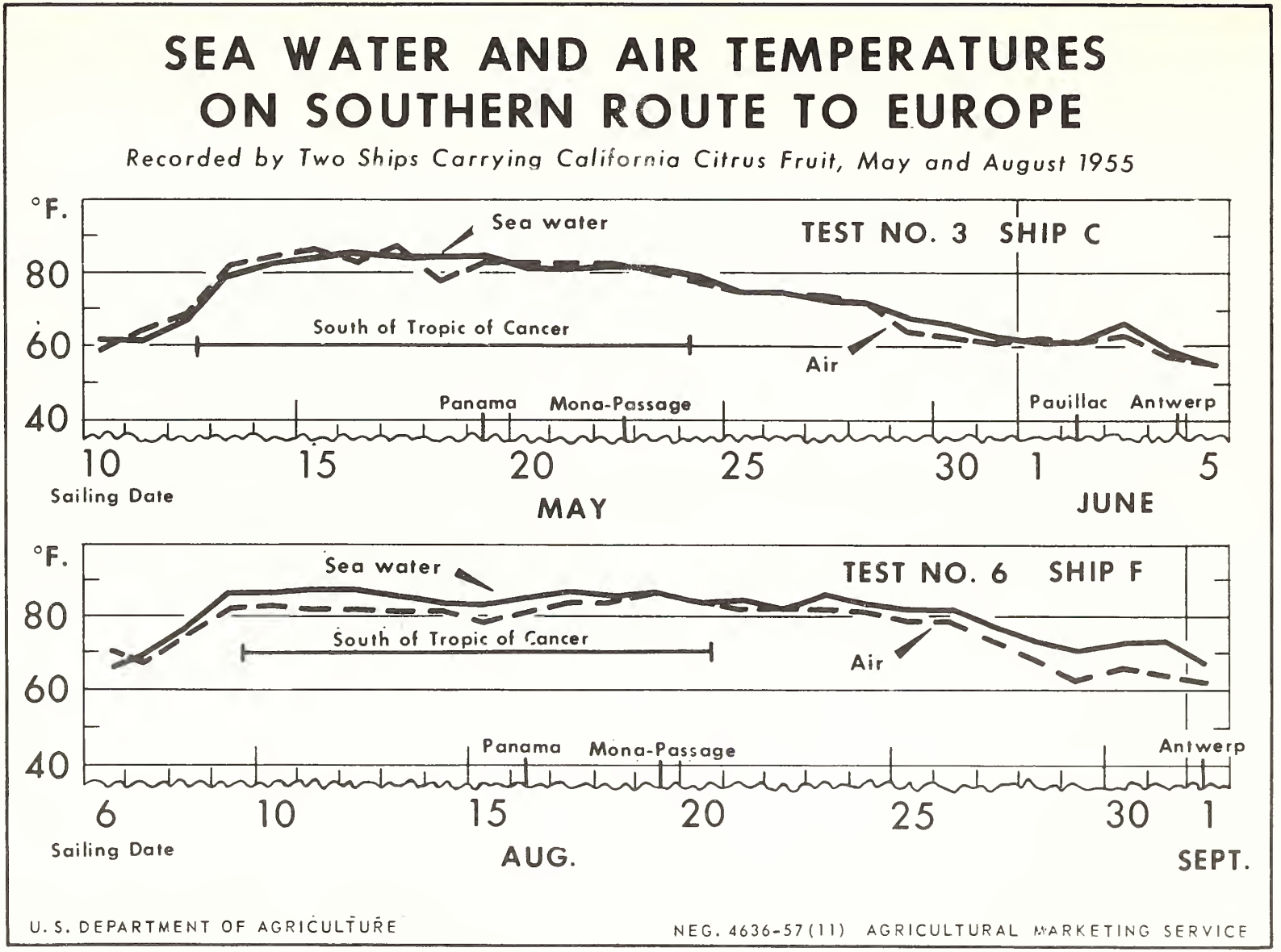

SEA WATER AND AIR TEMPERATURES
ON SOUTHERN ROUTE TO EUROPE
Recorded by Two Ships Carrying California Citrus Fruit, May and August 1955
°F.
80
60
40
Sea water
TEST NO. 3 SHIP C
South of Tropic of Cancer
Air
Panama
Mona-Passage
Pauillac
Antwerp
10
15
20
25
30
1
5
Sailing Date
MAY
JUNE
°F.
80
60
40
Sea water
TEST NO. 6 SHIP F
South of Tropic of Cancer
Air
Panama
Mona-Passage
Antwerp
6
10
15
20
25
30
1
Sailing Date
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Figure 3

were moderate, and the fruit temperatures at loading varied from 65° to 71° F. (average 66.4°). Inspections of test fruit at shipside showed it to be in excellent condition as to general appearance, color, and firmness, and with few skin blemishes and no decay.

On the day of sailing, the temperatures in test cartons at top and bottom positions in No. 4 lower hold, forward, were about the same as when loaded, but those in middle positions showed an average rise of 2 degrees. On the 19th, 5 days after sailing, the range of temperatures was 44° to 59° F. (average 50.4°). The range was 40° to 50° (average 44.0°) on the 10th day. The temperatures varied from 40° to 45° after 15 days at sea. Temperatures in No. 4 lower hold, forward, and No. 3 'tween deck, the two general locations selected for stowing the test fruit, were essentially the same. The maximum, minimum, and average transit temperatures in these areas are presented in figure 4. The temperatures after mid-voyage were very satisfactory, but it would have been better had these temperatures been reached earlier.

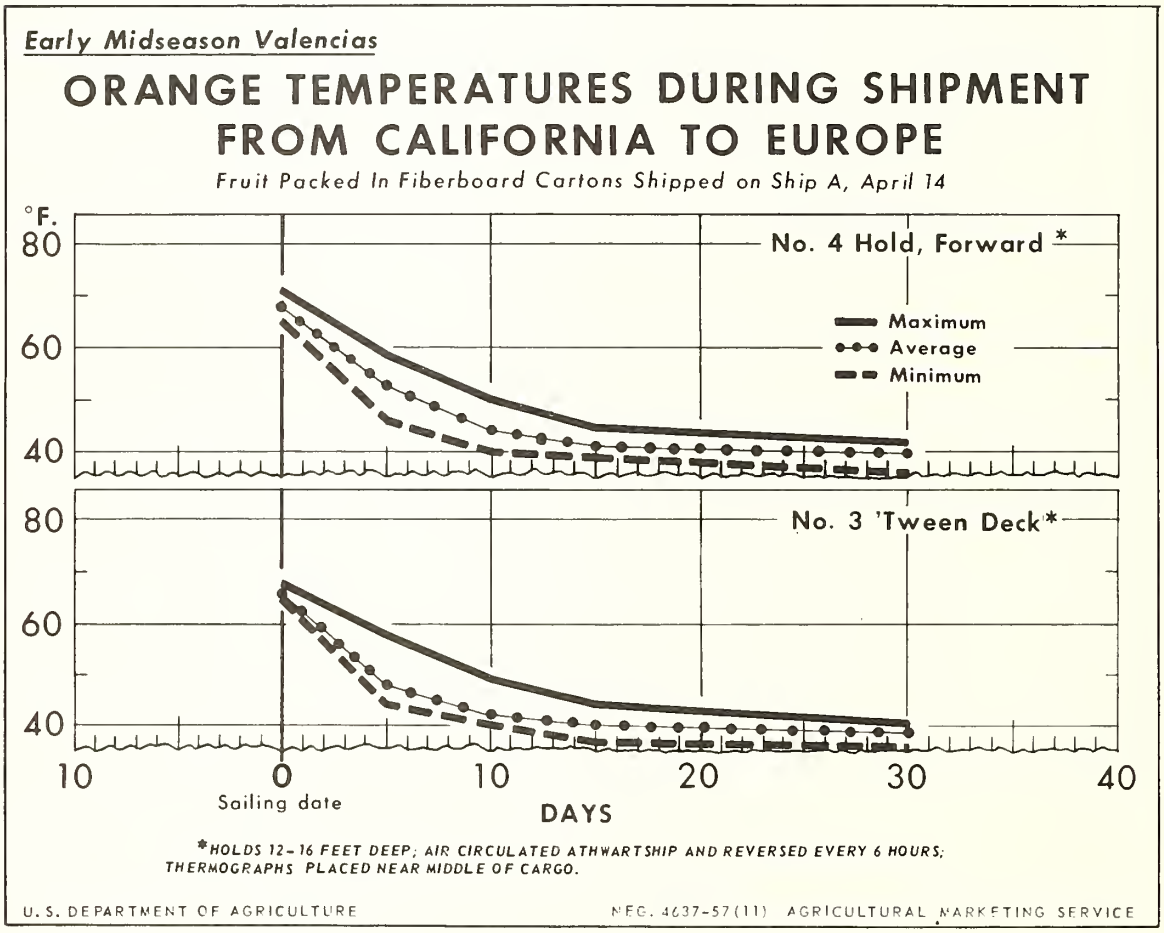

Figure 4

On arrival the test fruit still retained much of its original excellent appearance, being firm and bright. It showed an average of 0.2 percent severe pitting, 0.5 percent aging, and 0.5 percent decay (table 1). Almost all the severe pitting and aging were confined to 2 of the 5 test lots. The other 3 test lots retained very good quality to the end of the holding period.

Test No. 2.--Test 2 was made on Ship B, April 21 to May 24. The date of departure was April 24.

The test fruit and commercial cargo were again early midseason Valencia oranges from central California citrus districts. Most of the cargo arrived on the pier about 4 days before sailing. At shipside the appearance of test fruit was excellent, being firm and bright, with good color, few skin blemishes, and no decay.

Test cartons in No. 3 lower hold showed a temperature range of 60° to 67° F. (average 63.5°) at loading, and 55° to 65° F. (average 60.6°) by sailing time. The temperature ranges were 47° to 56° F. (average 51.0°) on May 30, after 5 days at sea, and 39° to 47° (average 42.5°) after 10 days. Temperatures in the test cartons in No. 2 upper 'tween-deck space were practically the same as in No. 3 lower hold at the start, but they dropped faster and after 5 and 10 days they averaged 41° and 38°, respectively. This is a good transport temperature record and leaves little to be desired. The maximum, minimum, and average transit temperatures in the 2 areas containing oranges are presented in figure 5.

On arrival the test fruit still had an excellent general appearance, being firm, bright, and well colored. The greatest amount of severe pitting in any lot was 0.8 percent. Severe aging appeared in only 1 test lot, where it was 3 percent. The greatest amount of decay in any lot was 0.35 percent. After 2 weeks' storage at 50° F. plus 1 week at room temperature, the most severe pitting was 1.5 percent in 1 lot, none in 2 lots, and the general average was 0.7 percent. Severe aging was confined mostly to 1 lot, where it was 5.5 percent. No severe aging developed in 2 of the lots. The most accumulative decay in any test lot was 1.7 percent, the least 0.2 percent, and the average for all was 1 percent as shown in table 1.

The excellent general appearance and condition of the test fruit at the end of the holding period indicates that this is an example of very satisfactory transport of oranges.

Results of tests 1 and 2 show how well oranges that are above the general average in quality can withstand the stress of overseas shipment if they are transported under conditions somewhat above the average of those presently available from California. The handling of the oranges could be improved considerably. The need for better handling between packinghouse and loading may be somewhat obscure in these cases, but it would likely have been clear if the oranges had been lower than average in quality, or if they had been loaded on less efficient ships.

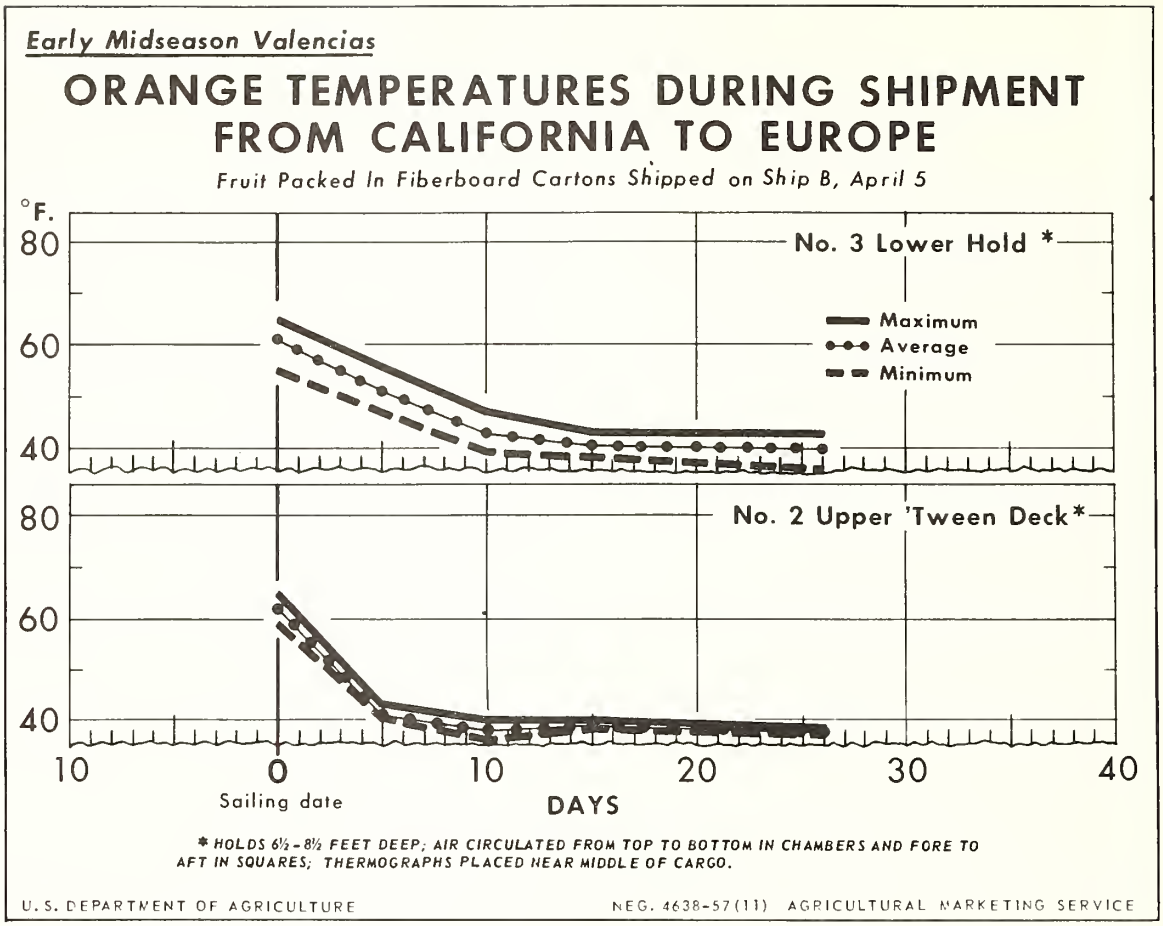

Figure 5

Test No. 3.--This test was made on Ship C, May 6 to June 9. The date of departure was May 10. A research worker accompanied this test.

The test lots of oranges were from central California citrus districts, as was most of the citrus fruit in the cargo. The fruit was later than midseason for that area. The 5 large commercial lots from which the test fruit was selected were on the pier 4 to 5 days before loading. The inspection record indicates that the test fruit was of excellent general appearance, firm, well colored, and free of decay and serious skin blemishes.

The temperature was 65° to 68° F. (average 66.5°) at loading and 55° to 65° (average 61.0°) at departure. After 5 days at sea the temperature was reduced to 40° to 47° (average 43.7°). On the 10th day it was 39° to 42° (average 40.7°), which was within 1 to 2 degrees of the temperatures on arrival.

The temperature data for tests 1 and 2 were from thermographs, which were in test cartons of oranges located mostly near the middle of the cargo. Additional temperature data were collected in the third shipment, which was accompanied by a research worker, from 36 electric resistance thermometers (3 cables, each with 12 thermometers) and 33 thermocouples (3 sets, each with 11 thermocouples). Forty-five of these thermometers were placed in the orange cargo and 24 in the lemon and grapefruit cargo. The data gathered may be summarized as follows:

In the lower half, aft, of chamber No. 1 the temperatures were: immediately after loading, 65° to 75° F. (average 69.4°); at departure, 50° to 67° (average 57.4°); after 5 days at sea, 41° to 48° (average 43.2°); and after 10 days at sea, 41° to 44° (average 41.4°).

In the lower half, forward, of chamber No. 2, the temperatures were: at loading, 60° to 69° F. (average 65.0°); at departure, 50° to 73° (average 58.6°); after 5 days, 39° to 55° (average 44.2°); and after 10 days, 39° to 48° (average 41.6°).

In chamber No. 3, which was divided by a false floor, the temperatures were: at loading, 66° to 71° F. (average 68.6°); at departure, 51° to 67° (average 59.2°); after 5 days, 39° to 52° (average 44.9°); and after 10 days, 39° to 46° (average 42.1°). Top and bottom temperatures were similar, which indicated that the false floor had improved the circulation of air.

The maximum, minimum, and average transit temperatures in the 3 different chambers are presented in figure 6.

After only 5 days in transit the temperatures at 60 percent of the positions in the load were down to 45° or lower, and several had already stabilized at about 40°. The general refrigeration performance of the Ship C was very good, and in some positions, all that could be desired.

Temperatures had stabilized at 39° to 43° F. in 90 percent of the recorded locations in the orange chambers after 10 days in transit. The thermometers showing higher temperatures than these were near the middle of the load, but the most divergent temperature was only 5 degrees higher. The records show that middle layers tended to be the warmest at both center and side positions in the load. In fact the middle side positions were usually higher than those of the middle centerline. This seems odd since in this ship the path of the refrigerating air was athwartship, and its direction was reversed every 6 hours.

Inspection of the oranges on arrival at Rotterdam showed the general appearance to be excellent as to brightness, color, and firmness. Severe pitting was negligible; one lot showed 0.2 percent, the others less than 0.1 percent. Severe aging was confined almost entirely to 2 of the 5 test lots, where it amounted to 3.8 percent and 4.5 percent. In 1 lot there was no severe aging, and in 2 lots less than 0.1 percent. The average decay on arrival was 0.8 percent, and this amount

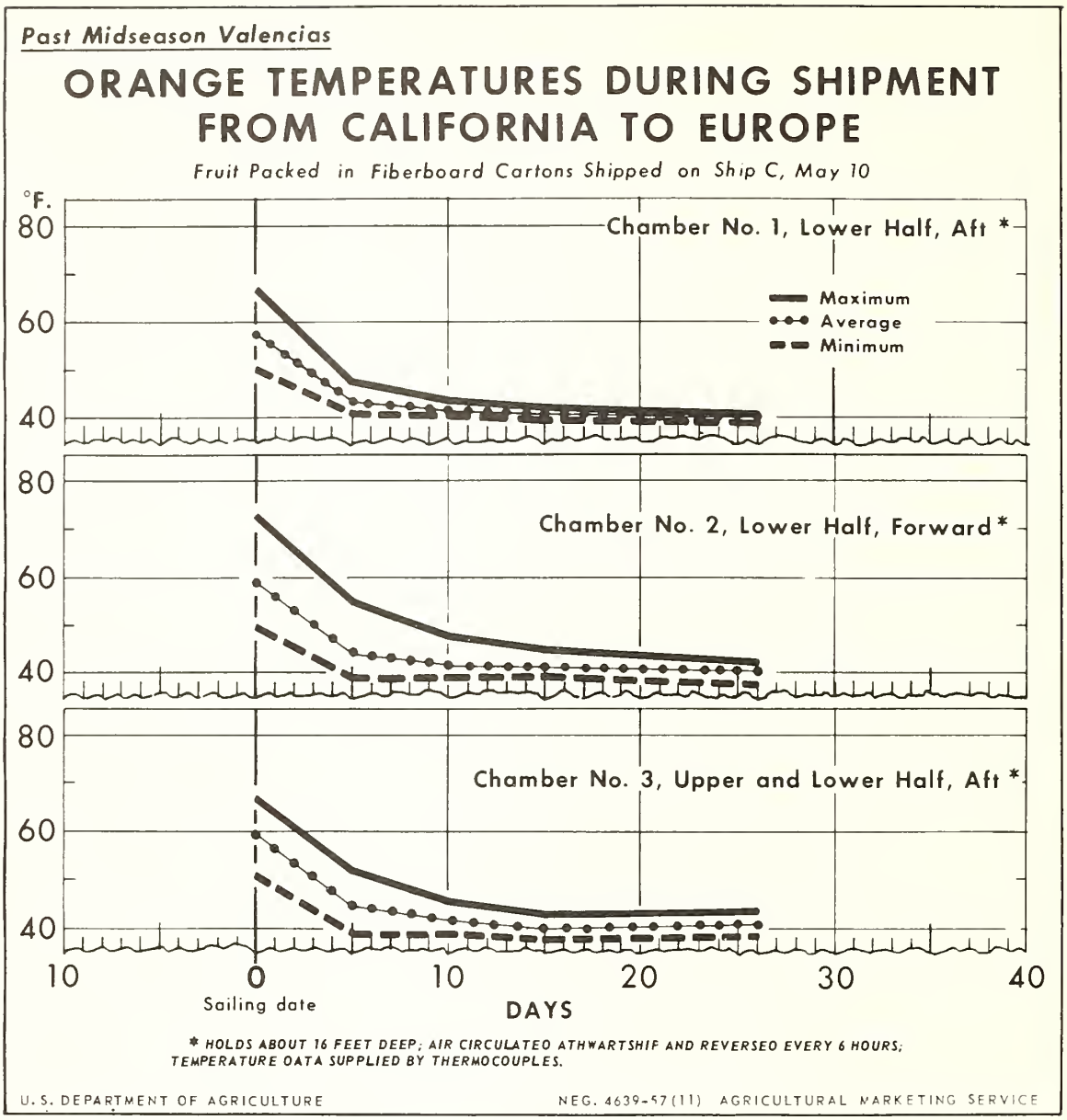

Figure 6

was contributed mainly by the same 2 lots that showed considerable severe aging on arrival. Decay in the 5 lots varied from 0.3 to 1.4 percent. The average aging, pitting, and decay of these 5 test lots are shown in table 1.

After 3 weeks at room temperature, severe pitting averaged only 0.3 percent. The most in any lot was 0.8 percent. Severe aging had increased in the 2 poorest

Table 1.--Averages of severe aging, pitting, and decay of test Valencia oranges observed on arrival and after holding 2 and 3 weeks [1]

Test number, ship, number of thermometers and number of fruit	Inspection on arrival					Inspection after 2 weeks					Inspection after 3 weeks					Total decay (Accumulative)					
			Decay					Decay					Decay			After 2 weeks			After 3 weeks		
	Aging	Pitting	Pen.[2]	Misc.	Total	Aging	Pitting	Pen.[2]	Misc.	Total	Aging	Pitting	Pen.[2]	Misc.	Total	Pen.[2]	Misc.	Total	Pen.[2]	Misc.	Total
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
1. Ship A..... 13 thermographs 7,230 fruit	0.5	0.2	0.3	0.2	0.5	1.5	0.8	0.3	([3])	0.3	2.1	1.4	0.7	0.5	1.2	0.6	0.2	0.8	1.3	0.7	2.0
2. Ship B..... 18 thermagraphs 6,672 fruit	.7	.3	.2	.1	.3	1.1	.5	.3	0.2	.5	1.5	.7	.2	([3])	.2	.5	.3	.8	.7	.3	1.0
3. Ship C [4]..... 8 thermagraphs 33 thermacouples 36 electric resistance bulbs 6,925 fruit	1.8	.1	.7	.1	.8	3.7	.1	1.9	.6	2.5	9.2	.3	1.1	.3	1.4	2.6	.7	3.3	3.7	1.0	4.7
4. Ship D ..... 19 thermographs 8,055 fruit	2.8	.1	5.3	1.9	7.2	6.9	.2	4.9	1.7	6.6	7.7	.5	4.1	1.7	5.8	10.2	3.6	13.8	14.3	5.3	19.6
5. Ship E..... 18 thermagraphs 7,192 fruit	2.2	.1	2.1	1.1	3.2	4.2	.1	5.0	1.0	6.0	6.6	.3	2.1	1.2	3.3	7.1	2.1	9.2	9.2	3.3	12.5
6. Ship F [4]..... 8 thermographs 22 thermocouples 48 electric resistance bulbs 5,687 fruit	4.7	.8	8.1	1.9	10.0	6.4	.8	8.2	1.5	9.7	4.6	.6	5.3	1.1	6.4	16.3	3.4	19.7	21.6	4.5	26.1

[1] All test fruit was packed in ½-box size cartons, treated with biphenyl, and shipped in refrigerated halds. All fruit was held at destination at 60° to 65° F. (room temperature), except in tests 1 and 2 where they were held at first at 50°.

[2] Penicillium.

[3] Less than 0.05 percent.

[4] This test was accompanied by a research worker.

lots to 17.7 and 20.6 percent, respectively. Accumulated decay averaged 3.3 percent after 2 weeks, and 4.8 percent after 3 weeks. By this time the 2 worst lots had developed 5.8 and 7.4 percent decay, but the best lot had only 2.1 percent. The general appearance of 3 of the test lots remained very good, whereas that of 2 was rather poor. The differences in behavior of these 5 test lots, as regards loss of quality after arrival in Europe, illustrates not only the importance of careful selection for export but also the risk assumed if sales are delayed for any reason.

Test No. 4.-- Test 4 was made on Ship D, June 19 to July 28. The date of departure was June 24.

Most if not all the orange cargo was from southern California. Therefore it may be considered as early season and, perhaps, potentially somewhat "stronger" than that of test 3. The carrying distances from packinghouses to shipside were considerably less, but some of the lots were delivered at the pier 6 to 7 days before loading.

Temperatures in the orange cargo were recorded by 18 thermographs, and the maximum, minimum, and average transit temperatures are presented in figure 7. The loading temperatures of the cartons of the 5 test lots were 63° to 74° F. (average 67.6°). On the day of sailing the range was 53° to 73° (average 61.2°); 5 days later it was 43° to 68° (average 53.4°); and after 10 days it was 39° to 61° (average 48.8°). Five days after departure all recorded temperatures in middle positions were 50° or above. Of 10 positions which were above 50° at this time, 5 were still 50° or above 10 days after departure, and 4 after 15 days. At 5 locations test lots of fruit did not reach the minimum temperature during the 34 days in transit. The slow rate of cooling in the more central locations may be partly attributed to the size of the cargo (approximately 350,000 cartons of citrus fruit).

Inspection of the test oranges on arrival at destination disclosed poor to very bad general appearance from aging, shrinkage, and decay. Severe aging in the 5 test lots ranged from 1 to 5 percent, with an average of about 2.8 percent. However, it was mainly decay that ruined their appearance. Decay ranged from 5 to 9 percent on arrival, and after 3 weeks at destination the accumulated decay ranged from 14 to 24 percent (average 19.7 percent). Even the oranges which had not decayed were unsightly with mold spores. Severe pitting after 3 weeks did not exceed 1 percent, but some pitting may have been hidden by the mold spores which covered the surfaces of apparently sound oranges. Decay in many commercial lots was quite serious and some lots required repacking. Average values of the 5 lots at each inspection are given in table 1.

Failure of the oranges to carry as well in test 4 as they did in the preceding shipping tests may be attributed to the 8-day period between the first delivery to the pier and completion of loading, the longer transit period (34 days), the slow cooling in portions of the cargo, and possibly to some poor selections of export fruit.

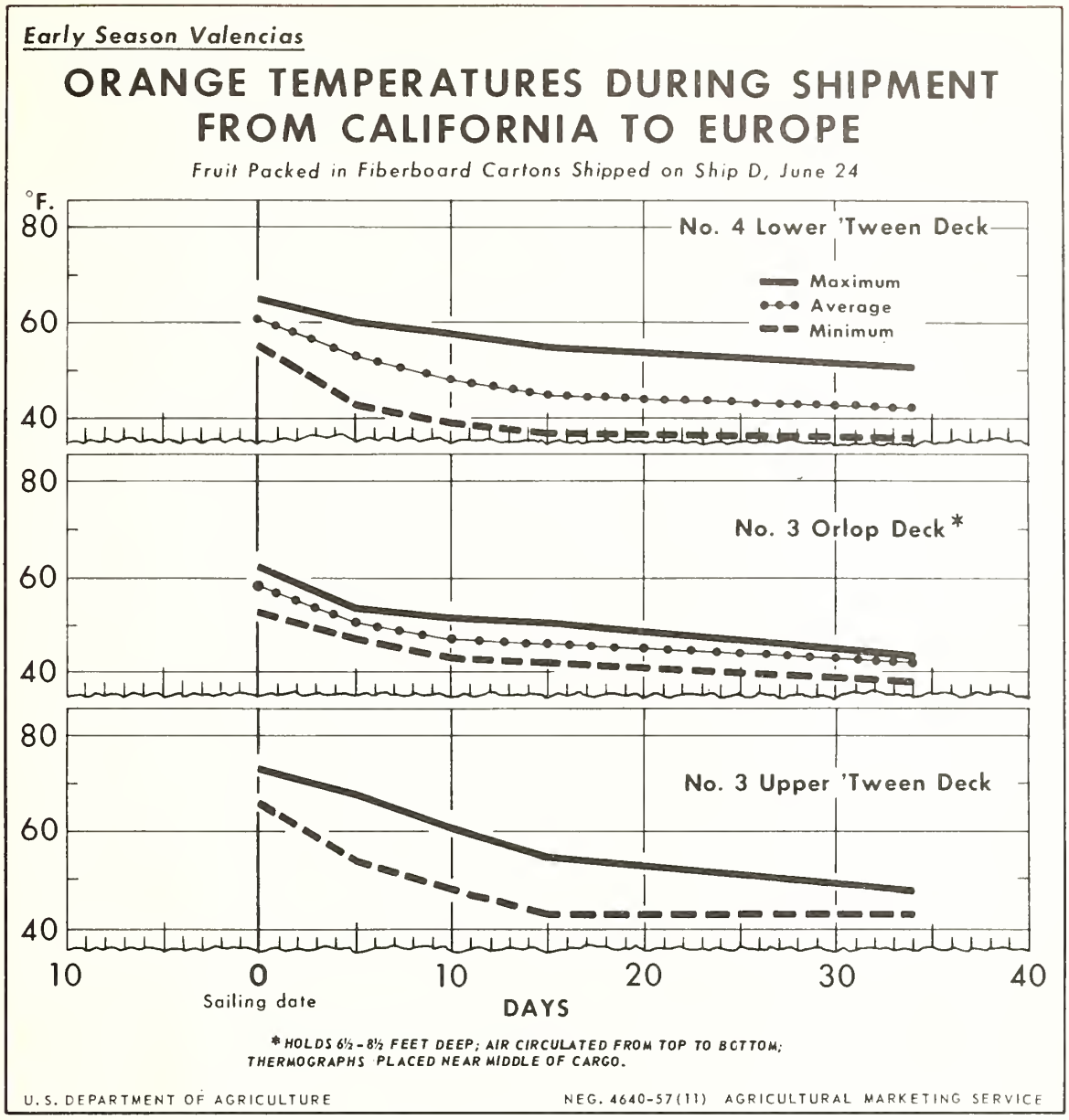

Figure 7

Test No. 5.--Test 5 was made on Ship E, June 24 to August 6. The date of departure was July 4.

The test oranges were from 5 large commercial export lots, and all were grown in southern California. The fruit had about the same potential shipping quality as that of test 4, but was from different shippers.

Test 5 supplied information on the amount of cooling accomplished by transporting oranges from packinghouse to shipside in preiced cars as well as by shipping overseas in refrigerated ships. Thermographs were placed in the test cartons at the packinghouses. Each car was held at the pier until time for loading the fruit into the ship. Unfortunately, most of the cars ran short of ice during the 5 to 9 days from packinghouse to loading into the ship.

Temperatures within the test cartons when they were loaded into the cars ranged from 72° to 81° F. (average 76.6°), and when they were removed from the cars at shipside the temperature range was 51° to 74° (average 61.4°). The amount of cooling in the cars was 6° to 22° (average 15.2°). During the transfer of the cartons from car to ship's hold, temperatures of some fruit rose as much as 11°. Temperatures on the day of departure ranged from 43° to 63° (average 51.9°). On the 5th day at sea the range was 42° to 53° (average 48.0°). After 10 days the range had become 41° to 49° (average 45.6°). Temperatures stabilized at about 42° in 2 to 3 days in starboard and port chambers of No. 3 lower hold, except at 1 bottom location in the former and a middle location in the latter. The slowest rates of cooling recorded were in the squares of No. 3 shelter and orlop decks, where the air circulation was fore and aft instead of vertical as generally maintained in this ship. The maximum and minimum transit temperatures in 4 areas of the orange cargo are presented in figure 8.

The general appearance of most of the test oranges on arrival was fair to good. The rinds of fruit in one lot showed considerable roughing and scarring, and all lots except one showed severe aging, some softness, dark buttons, and 1.2 to 5.0 percent decay. The average decay was 3.2 percent (table 1). Some of the decay was associated with breaks in the weakened rind of creased oranges.

Pitting was negligible in all lots; the most recorded was less than 1 percent after 3 weeks' holding. Table 1 gives the average amount of pitting for all lots. There was far too much severe aging in 3 of the 5 test lots, but 1 was practically free of aging on arrival and remained so to the end of the holding period. This latter lot also showed the least decay and the best color and firmness. The accumulated decay by the end of the 3d week ranged from 3.9 to 19.8 percent (average 12.5 percent).

Although this shipment lost a great deal in quality during transportation it seems likely that even greater loss was prevented by conveying it to shipside in preiced cars.

Test No. 6.--This test was made on Ship F, August 2 to September 2. The date of departure was August 6. A research worker accompanied the shipment.

Oranges of this shipment were from southern California and should be classified as being from the past midseason crop and as lacking in best carrying qualities. To offset this weakness to some extent most of the orange lots were

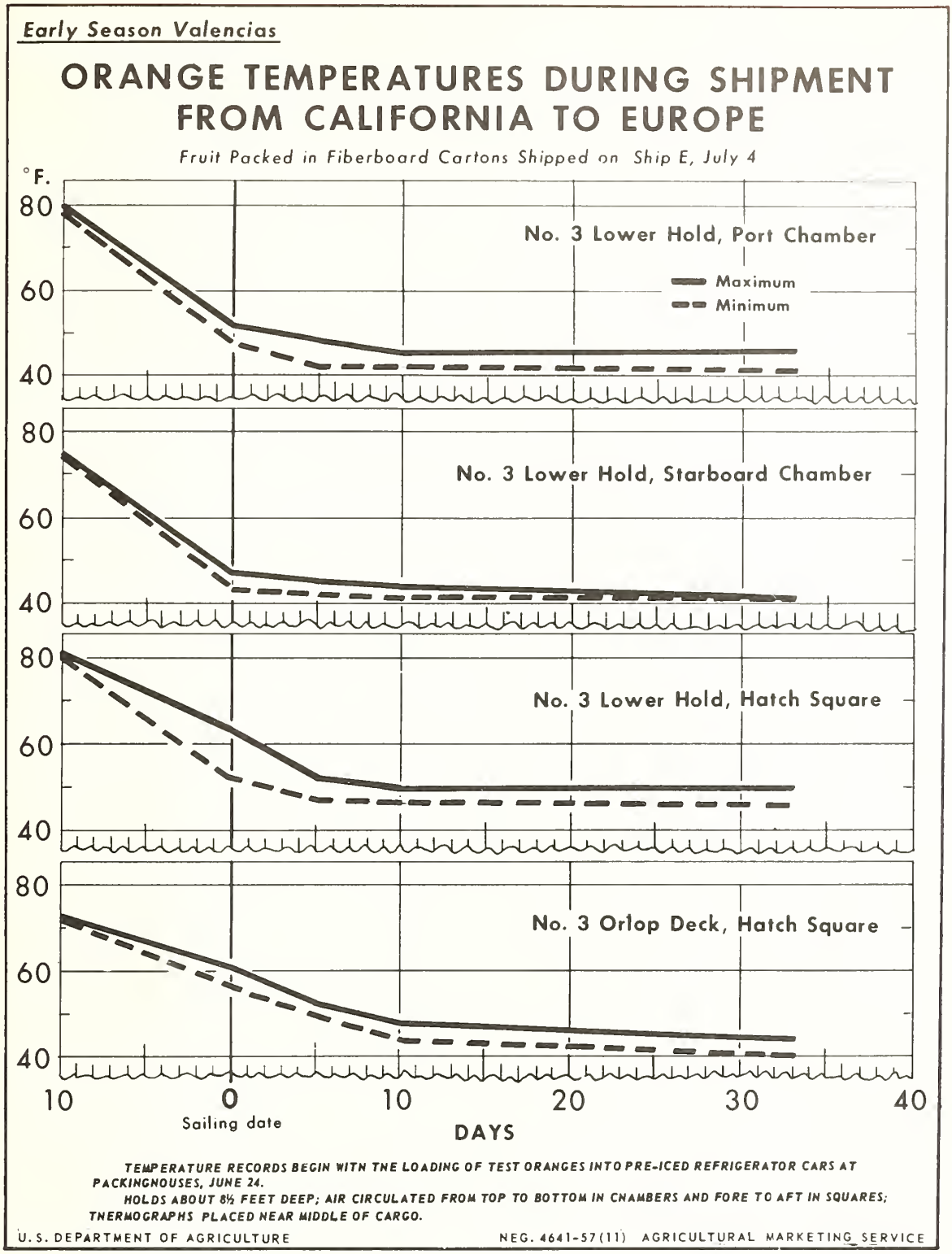
Early Season Valencias
ORANGE TEMPERATURES DURING SHIPMENT FROM CALIFORNIA TO EUROPE
Fruit Packed in Fiberboard Cartons Shipped on Ship E, July 4
°F.
80
60
40
No. 3 Lower Hold, Port Chamber
Maximum
Minimum
No. 3 Lower Hold, Starboard Chamber
No. 3 Lower Hold, Hatch Square
No. 3 Orlop Deck, Hatch Square
10
0
10
20
30
40
Sailing date
DAYS
TEMPERATURE RECORDS BEGIN WITN TNE LOADING OF TEST ORANGES INTO PRE-ICED REFRIGERATOR CARS AT PACKINGNOUSES, JUNE 24.
HOLDS ABOUT 8½ FEET DEEP; AIR CIRCULATED FROM TOP TO BOTTOM IN CNAMBERS AND FORE TO AFT IN SQUARES; TNERMOGRAPHS PLACED NEAR MIDDLE OF CARGO.
U.S. DEPARTMENT OF AGRICULTURE
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Figure 8

transported to shipside in preiced cars; nevertheless some test fruit had temperatures of 72° and 74° F. at loading time. Thermographs were placed in the test cartons at shipside instead of at the packinghouses as in test 5.

The thermometric equipment installed in the orange cargo consisted of 5 thermographs; 2 cables, each having 12 electric resistance thermometers; and 2 thermocouple sets, each with 11 thermocouples. A cable and a thermocouple set were installed near the center and the side lines in the upper and lower halves (i.e., above and below the false floor) of No. 4 lower hold.

The thermograph records showed that loading temperatures in the test cartons stored in No. 4 lower hold ranged from 66° to 75° F. (average 71.0°). At departure they were 59° to 69° (average 65.0°), 5 days after departure 52° to 66° (average 60.5°), 10 days after departure 51° to 62° (average 57.8°), and on arrival at Antwerp 51° to 61° (average 56.0°).

These temperatures are not at all satisfactory for orange shipments, especially those of midseason or later maturity. The middle of the upper half of No. 4 lower hold was probably the warmest location in the orange cargo. The false floor in this hold apparently was not adequate to provide good circulation.

In the 'tween-deck space of No. 4 hold the single thermograph in middle position recorded a gradual reduction in temperature from 72° to 45° F. in 15 days; this temperature was maintained to Antwerp.

The fruit temperature in the centerline of the upper half of No. 4 lower hold remained too high throughout the voyage. Only in 2 of 10 locations had the temperature dropped to 45° F. at destination. The 5 middle locations still ranged from 54° to 61° (average 57.5°).

The cooling performance was very much better on the starboard side than along the centerline. In 10 days after departure 10 of 11 thermometers read 50° F. or lower. The remaining thermometer, at a bottom location, read 57.5°. The average temperature at this position for the first 10 days in transit was 66.6°.

On the port side of the lower half of No. 4 lower hold the 2 middle and 1 top locations rose in temperature after loading, and the top one did not return to its initial temperature of 62° F. until 16 days after sailing. The temperatures were widely spread throughout the voyage and most were too high. On the 5th day after sailing the range was from 42° to 70° on the 10th day, 40° to 65°, and at destination 40° to 59°.

The range in the temperatures in the centerline of the lower half of No. 4 hold also was too wide and the temperatures too high throughout the voyage. Average temperatures at the 10 recorded positions ranged from 61° to 73° F. at loading and from 43° to 58° on arrival. The maximum, minimum, and average transit temperatures in the 4 areas of the orange cargo are presented in figure 9. The undesirable wide spread of temperatures is clearly indicated.

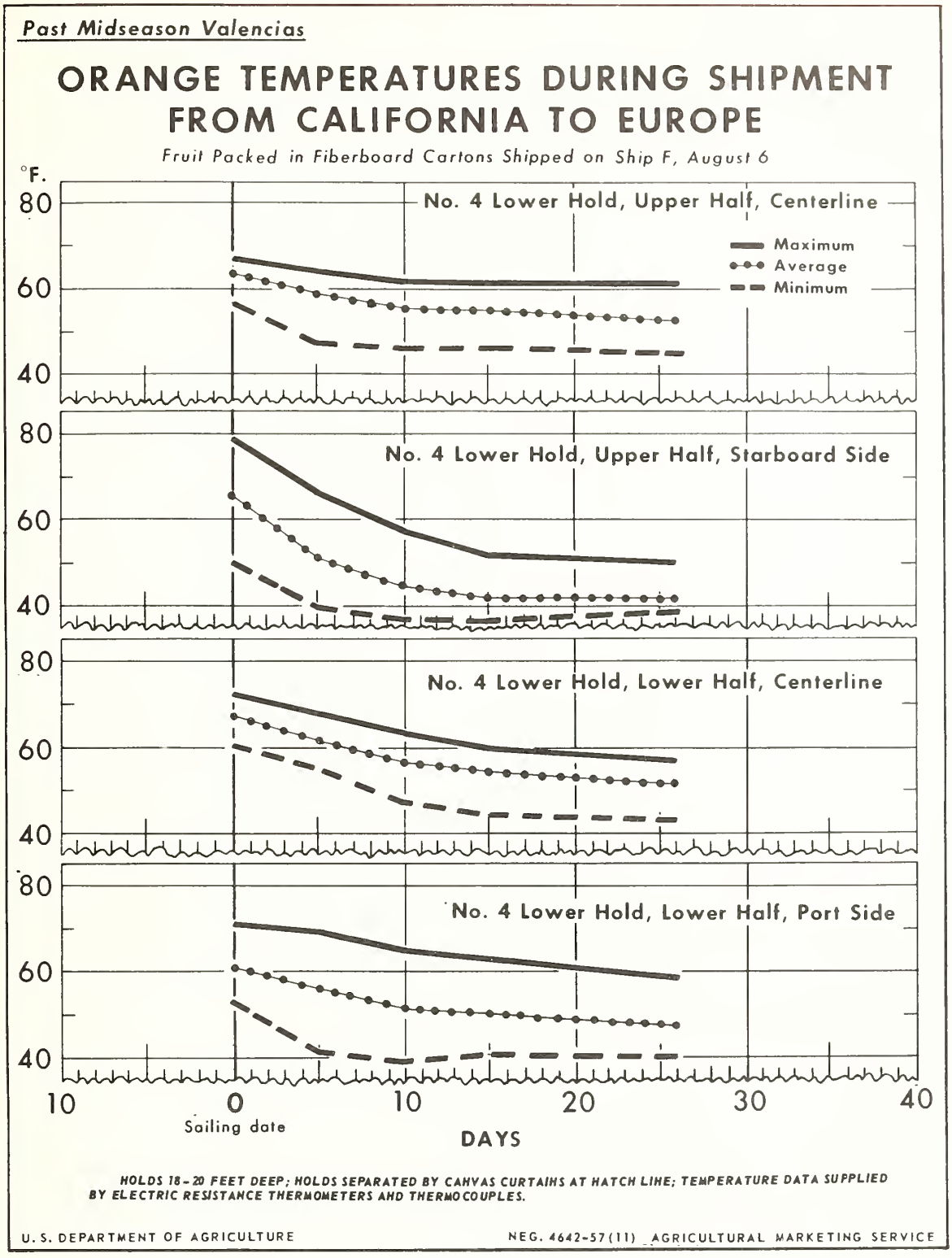
Past Midseason Valencias
ORANGE TEMPERATURES DURING SHIPMENT FROM CALIFORNIA TO EUROPE
Fruit Packed in Fiberboard Cartons Shipped on Ship F, August 6
°F.
80
60
40
No. 4 Lower Hold, Upper Half, Centerline
Maximum
Average
Minimum
No. 4 Lower Hold, Upper Half, Starboard Side
No. 4 Lower Hold, Lower Half, Centerline
No. 4 Lower Hold, Lower Half, Port Side
10
0
10
20
30
40
Sailing date
DAYS
HOLDS 18-20 FEET DEEP; HOLDS SEPARATED BY CANVAS CURTAINS AT HATCH LINE; TEMPERATURE DATA SUPPLIED BY ELECTRIC RESISTANCE THERMOMETERS AND THERMOCOUPLES.
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Figure 9

The general appearance of the test fruit varied greatly. The lot stowed in the upper half of No. 4 hold was dull and fairly firm to soft, and the buttons were mostly brown. Serious decay in every carton on arrival (average 10.0 percent) caused the overall appearance to be very bad. In one lot the decay on arrival was 15.2 percent. After 2 weeks' holding the decay in that lot had accumulated to 28.4 percent and 1 week later to 35.9 percent.

The general appearance of 2 of the 3 test lots from No. 4 'tween deck was fair, but some oranges showed considerable softness and the buttons were mostly brown. Decay on arrival was 5.0 and 7.0 percent; after 2 weeks, accumulated decay was 10.0 and 13.0 percent; and after 3 weeks, 15.0 and 17.0 percent. The remaining test fruit from this location in the ship presented a general appearance similar to that of the fruit stowed in No. 4 lower hold. In addition this fruit showed a great amount of severe aging (10.6 percent) and pitting (1.4 percent), about twice as much as in the 5 previous tests. Decay on arrival was 12.5 percent; after 2 weeks, accumulated decay was 26.3 percent, and a week later 35.2 percent. Table 1 presents the averages of severe pitting, aging, and decay but does not show the above differences in behavior of individual lots.

The total average accumulative decay at the end of the holding period for the 4 test lots was 26.1 percent.

In all characteristics observed, the oranges in this test were the worst of the 6 overseas shipments.

This test is an example of the effects of shipping late season, non-precooled oranges in cartons in a ship with below-average refrigerating equipment. The potential danger from poor-quality fruit and inadequate transit refrigeration apparently cannot be offset by using the best methods in handling export oranges from packinghouse to loading into ship.

Lemons and Grapefruit

During the tests attention was directed chiefly to oranges because non-precooled oranges in cartons were assumed to present the main problem in exporting citrus fruits, but small test lots of lemons and grapefruit were included in 5 of the 6 shipping tests. Observations of these and commercial lots in Europe disclosed that oranges are not alone in suffering loss of quality during transport overseas. Transport conditions which are favorable for lemons also should be favorable for grapefruit. Therefore in all shipments observed, lemons and grapefruit were stowed together in holds or chambers with specifications for temperatures 10 to 15 degrees higher than for oranges.

Test No. 2 included 2 test lots of lemons in chamber E No. 2 orlop deck of Ship B. Thermograph records for middle centerline positions indicated a loading temperature of 60° F., which was gradually lowered to 54° at destination (fig. 10). The carrying temperature was therefore very good.

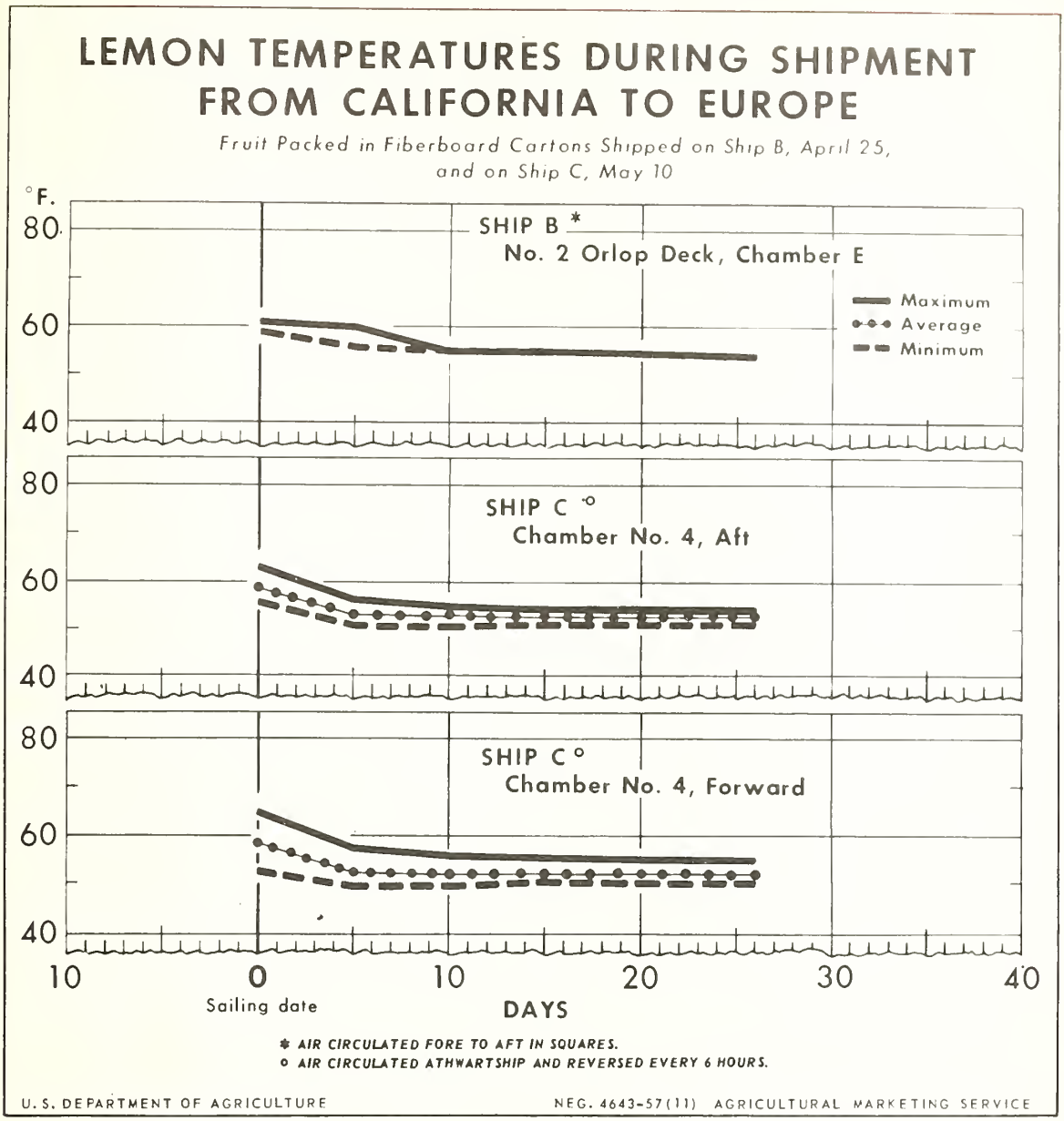

Figure 10

The lemons of both lots were firm, bright, and of good color on arrival, and the general appearance was excellent. One lot showed less than 0.1 percent decay on arrival and only 0.2 percent after being held 3 weeks. The other lot showed 0.4 and 0.6 percent decay, respectively. Table 2 shows decay found in individual lots at each of 3 inspections.

Test No. 3 included test lots of lemons and grapefruit which were stowed aft in chamber No. 4 of Ship C.

Twenty-four electric resistance thermometers were located in the commercial lemon and grapefruit cargo both forward and aft in chamber No. 4. The records show a range in loading temperatures of 56° to 72° F. and an average arrival temperature of 52.4° (fig. 10). Such carrying temperatures are satisfactory so far as is known.

The test grapefruit was fairly firm and of good color on arrival, and the general appearance was very good. Decay was 0.7 percent on arrival, and total accumulated decay after 3 weeks was 1.5 percent (table 2). The fruit showed some aging in the last inspection.

General appearance of the lemons in test No. 3 was excellent in all characteristics observed. There was 0.3 percent decay on arrival, but no more decay appeared during the next 3 weeks at room temperature.

Test No. 4 included 1 lot of test lemons in No. 1 upper 'tween-deck of Ship D.

Thermograph records indicated that temperatures in the central positions of the lemon cargo were 70° F. or higher for 9 of the first 10 days after loading and 60° or higher for the next 6 days (fig. 11). These temperatures were higher than desirable and favorable for decay.

General appearance of the lemons in test No. 4 was good. They were firm, with buttons mostly green but fruit color definitely too high (reddish). Decay was 3.5 percent on arrival and it accumulated to 6.0 percent during the holding period (table 2).

All decay found on arrival was caused by Penicillium, but that which appeared during holding was mostly brown rot. Some membranous staining was noted.

Test No. 5 included 1 test lot of lemons in No. 4 'tween-deck of Ship E.

The thermographs recorded rather good carrying temperatures, which dropped from an average of 63° F. at loading to 54° on arrival. They were mostly between 54° and 57°, which is about optimum for lemons (fig. 11).

General appearance of the lemons in test No. 5 was good but marred by too high color and stain from mold spores and brown rot. Decay on arrival was 1.3 percent from Penicillium and 2.8 percent from brown rot. After 3 weeks, penicillium decay amounted to 3.8 percent and brown rot 5.2 percent. Although the temperatures were optimum for lemons, they were not sufficiently low to prevent decay in lemons infected with brown rot.

Test No. 6 included 1 test lot of lemons stowed on the false floor of lower No. 3 hold of Ship F. Temperatures were obtained from 2 cables, each with 12 electric resistance thermometers, installed in the commercial lemon and grapefruit cargo in this hold. Both cables were in the lower half, one along the centerline,

Table 2.--Summary of decay in lemons and 1 lot of grapefruit in 5 test shipments, on arrival and after holding 2 weeks and 3 weeks

Test number, ship, kind of fruit, and test lot	Decay on arrival		Decay after 2 weeks		Decay after 3 weeks		Total decay (Cumulative)	
	Penicillium	Miscellaneous	Penicillium	Miscellaneous	Penicillium	Miscellaneous	After 2 weeks	After 3 weeks
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
2. Ship B:								
Lemons A	0.1	0	0	0	0.1	0.1	0.1	0.3
Lemons B	.3	.1	0	0	0	.2	.4	.6
3. Ship C:								
Grapefruit	.7	0	.7	0	0	0	1.4	1.4
Lemons	.3	0	0	0	0	0	.3	.3
4. Ship D:								
Lemons	3.5	0	.6	1/ 1.2	.5	1/ .4	5.3	6.2
5. Ship E:								
Lemons	1.3	1/ 2.8	1.9	1/ 2.1	.7	1/ .3	8.1	9.1
6. Ship F:								
Lemons	0	1/ .8	.9	1/ 2.6	.6	1/1.4	4.3	6.3

1/ Decay caused by brown rot.

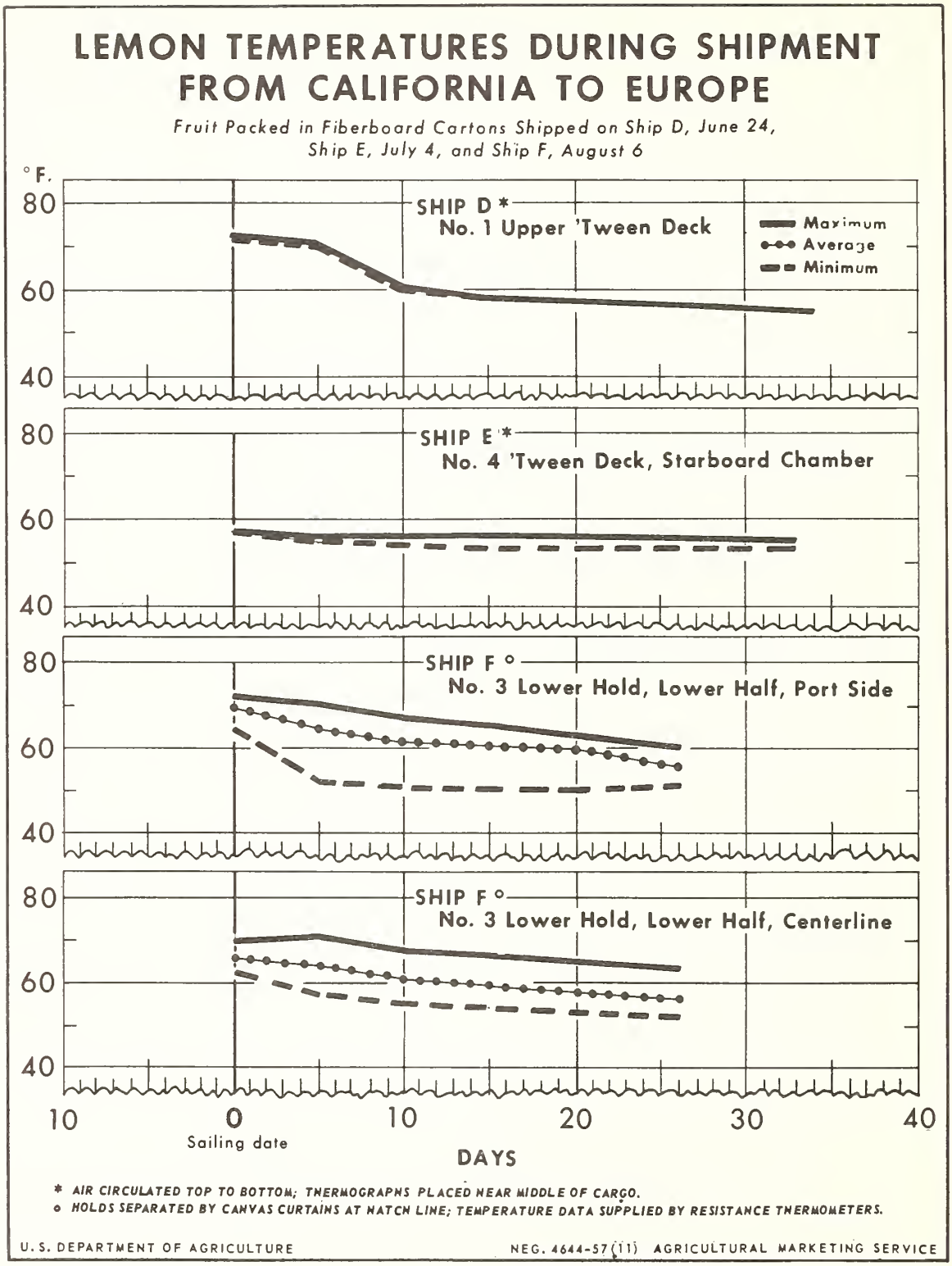
LEMON TEMPERATURES DURING SHIPMENT FROM CALIFORNIA TO EUROPE
Fruit Packed in Fiberboard Cartons Shipped on Ship D, June 24, Ship E, July 4, and Ship F, August 6
°F.
80
60
40
SHIP D *
No. 1 Upper 'Tween Deck
Maximum
Average
Minimum
SHIP E *
No. 4 'Tween Deck, Starboard Chamber
SHIP F °
No. 3 Lower Hold, Lower Half, Port Side
SHIP F °
No. 3 Lower Hold, Lower Half, Centerline
10
0
10
20
30
40
Sailing date
DAYS
* AIR CIRCULATED TOP TO BOTTOM; THERMOGRAPHS PLACED NEAR MIDDLE OF CARGO.
° HOLDS SEPARATED BY CANVAS CURTAINS AT HATCH LINE; TEMPERATURE DATA SUPPLIED BY RESISTANCE THERMOMETERS.
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Figure 11

the other along the port side. Some of the low or intermediate temperatures were satisfactory, but mostly the temperatures were too high for safety (fig. 11). The wide range in temperatures indicates poor distribution of the refrigerating air. The thermometers nearest the test lemons showed that the transit temperatures at that position were near the average of the lemon and grapefruit cargo as a whole.

On arrival the test lemons were firm, fresh, and bright, although the color of some was too high. There was no aging or pitting and no penicillium decay, but nearly 0.8 percent of brown rot (table 2.). During the holding period total decay, which was mostly brown rot, increased to 6.3 percent. No pitting or aging developed, and the buttons remained mostly green.

DISCUSSION

The fine general appearance and high quality of California oranges and lemons arriving in Europe may be a matter of much satisfaction, perhaps mixed with amazement that citrus fruit can endure so well the long series of handlings and the different environments imposed upon it during 5 or more weeks from the packing-houses. In fact, a large percentage of California citrus fruit survives transport to Europe remarkably well. Yet too much export fruit does not arrive there in good condition. This must be remedied if citrus fruit exports are to be expanded. When so large a proportion of California citrus fruit reaches Europe in good to excellent condition, why do some costly failures occur?

During the observation of test and commercial lots of oranges and lemons shipped to Europe, 3 general patterns or situations seemed to be repeated, namely:

The most common and desirable situation is that in which the fruit arrives with excellent appearance and negligible decay and maintains its high quality through a reasonably long holding or marketing period. This situation may be expected when lots have been carefully selected and handled and have been shipped under good transport conditions. The oranges in tests 1, 2, and 3 and the lemons in tests 2 and 3 were good examples of the result of careful selecting, handling, and shipping. But even these tests showed evidence of differences in the original quality of individual lots. Of the 5 lots of oranges in each of these 3 shipping tests, 1 lot in test 1 and 2 lots in test 3 were somewhat inferior to the other lots, which were excellent throughout.

The second situation is that in which the fruit arrives with poor appearance and considerable decay. This is bad, but the appearance of the fruit warns the receiver that the fruit will not keep well. Poor selection of fruit, poor handling, or poor transport conditions may be largely responsible for the appearance of the fruit. The test lots of oranges of tests 4 and 6 were examples. Some of the commercial lots on the same ships required repacking on account of decay.

The third situation can be even worse than the second. The fruit arrives with good, fresh appearance and negligible decay, but its quality deteriorates rapidly, perhaps after the receiver has put it aside for later sale. This behavior of export lots is frequent and is plainly fraught with serious consequences for both receiver and exporter. Examples were noted in test lots of oranges in test 5 and lemons in tests 4 and 5, in which aging and decay developed rapidly during the holding periods. The cause of the rapid loss of quality is not clear. However, this rapid loss suggests that good export lots were shipped but adverse shipside and transport conditions weakened the fruit enough so that deterioration of quality became apparent soon after storage at destination. Experience derived from domestic transportation of citrus fruit does not seem adequate to solve this problem completely. However, qualified persons in the citrus fruit industry believe that through more careful application of presently known improved methods of handling a substantial portion of these failures can be avoided.

RECOMMENDATIONS

1. Citrus fruits for export should be selected more carefully. Selection of good oranges becomes more and more difficult as the season advances, but the need for a good selection becomes greater. That poor selections often are made is indicated by the poor condition of some lots of early season oranges that arrive in Europe on the same ship with lots in excellent condition from the same district. Warm pockets that may occur in refrigerated cargoes of citrus fruit in any ship cannot account for the large amount of spoilage observed on the piers and on the auction displays.

Selection of satisfactory lots of lemons for export can be controlled fairly well. The foreman in the warehouse usually knows, often with astonishing accuracy, the potential holding quality of each lot of lemons in his charge.

2. It seems possible that standards might be set up and technical aid extended to help European receivers select lots of citrus fruit which can be safely stored for later sale on more favorable markets.

3. Arrivals of ships and citrus cargoes at the pier could be coordinated better than they are now.

4. Stowage patterns and the use of dunnage for aiding effective and uniform air circulation still need to be improved. Theoretically, at least, it would be desirable to substitute for the present bonded solid and chimney stowage patterns, one in which the top and bottom vents of the cartons coincide and provide a continuous passage for air.

5. Greater strength and more ventilation are needed in containers. The condition of many export shipments of lemons on arrival indicates that lemons, too, need ventilated cartons.

6. Present directions to ships' engineers for refrigeration of citrus fruit in fiberboard containers can be improved. The directions for wooden crates developed from the 1928 to 1932 tests were used until May 1955. Some modifications have been made since then.

7. The best equipped ships probably do not have sufficient refrigerating capacities for rapid cooling of full cargoes of non-precooled oranges; the more poorly equipped ships definitely do not. Therefore, the fruit should be precooled before loading.

(a) Both precooled and non-precooled oranges should be transported from packinghouse to shipside in iced cars, which are kept iced until the fruit is loaded into the ship. This was the procedure in tests 5 and 6, but the benefits were difficult to evaluate, because oranges produced after midseason do not keep as well as oranges from earlier crops.

(b) The more nearly ideal arrangement would be to have shipside precooling plants in which citrus fruit for export could be thoroughly precooled before being loaded on the ship.

* * *

APPENDIX

Information concerning the ships used in the tests

Test number, ship, number of cartons in load, and kind of fruit used in test	Lacation of test lots and number of cartons in hald or size of space involved	Total refrigerated space in ship	Approximate depth of hold	Refrigerant and refrigerating method used	Air circulation
		Cubic feet	*Feet*		
1. Ship A, apprax. 62,000 cartons:					
Oranges	#4 lower forward; 21,800 ctns.	84,405	16	Freon; direct expansion	Athwartship; reversed every 6 haurs
Oranges	#3 'tween deck; 15,050 ctns.		12		
2. Ship B, approx. 71,000 cartons:					
Oranges	#3 lower; 20,000 ctns.	---	6½ to 8½	CO_2 and brine	Tap ta bottom in chambers; fore to aft in squores
Oranges	#2 upper 'tween decks B-chamber; 4,000 ctns.				
Lemons	#2 orlop E-chamber; 9,400 ctns.				
3. Ship C, approx. 50,000 cartans:					
Oranges	Chamber #1; 10,100 ctns.		16	Freon; direct expansion	Athwartship; reversed every 6 hours
Oranges	Chamber #2; 11,500 ctns.				
Oranges	Chamber #3; 11,500 ctns.				
Lemons and grapefruit	Chamber #4; 14,500 ctns.				
4. Ship D, approx. 347,000 cartons:					
Oranges	#4 lower 'tween	516,435	6½ to 8½	CO_2 and brine	Top to bottom an main decks
Oranges	#3 orlop				
Oranges	#3 upper 'tween				
Lemons	#1 upper 'tween				
5. Ship E, apprax. 66,000 cartons:					
Oranges	#3 shelter deck-square	157,500	8½	Ammonio brine	Top to bottom in chambers; fore to aft in squares
Oranges	#3 orlop deck-square				
Oranges	#3 lower hald-port chamber; starbaard chamber				
Oranges	#3 lower hald-square				
Lemons	#4 'tween deck-starboard chamber				
6. Ship F, approx. 70,000 cartans:					
Oranges	#4 lower hold, 28,800 cu. ft.	93,350	Lower holds 18 to 20 feet	Ammonia brine	Holds separated by 2 canvas curtains on port and starboard at hatch lines
Oranges	#4 'tween deck, 18,850 cu. ft.				
Lemons	#3 lawer hold, 33,100 cu. ft.				
	Not used far test:				
	#3 'tween deck 12,600 cu. ft.				

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