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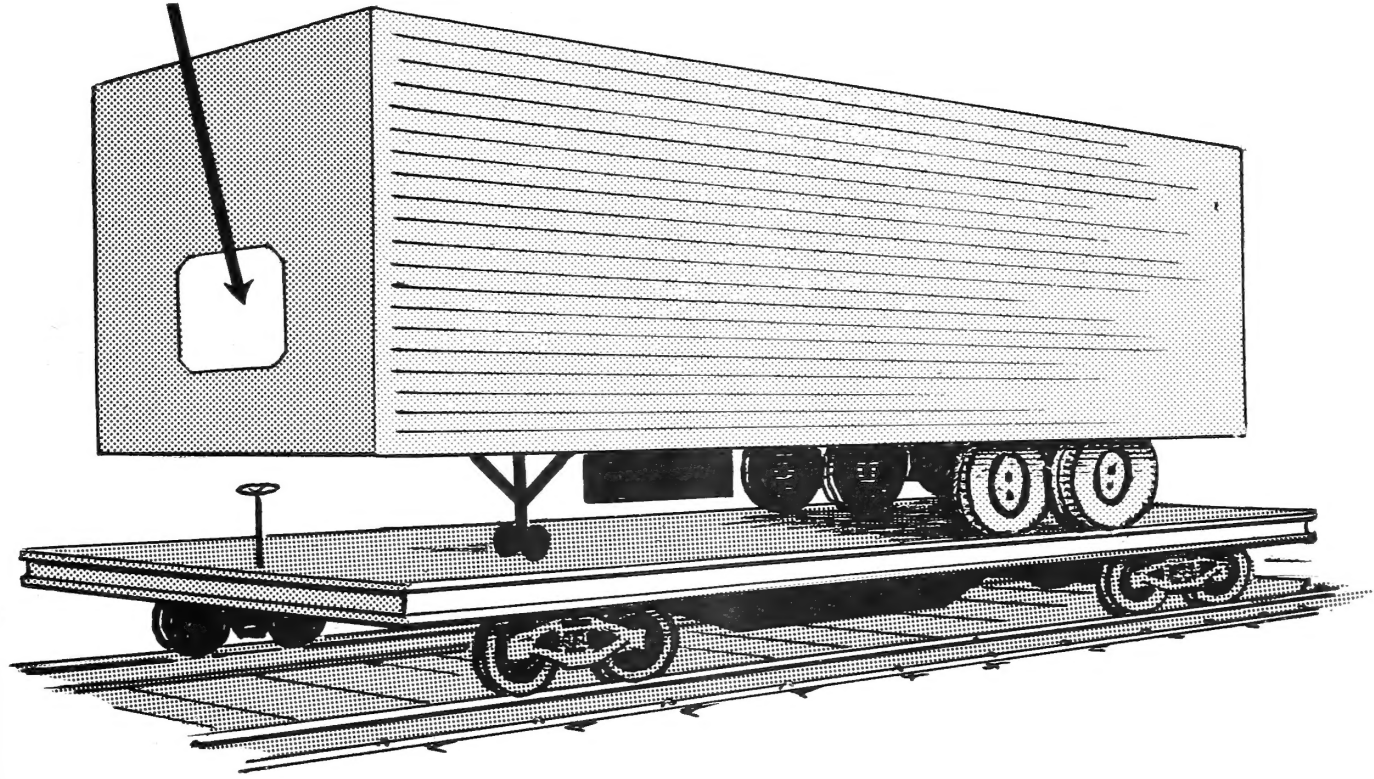
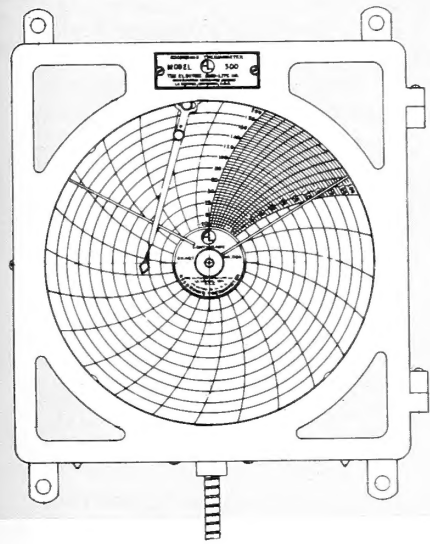
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**Truck-Rail
and Sea-Land
SHIPPING TESTS
with Texas Fruits
and Vegetables**



PREFACE

Much information is available on transportation of fresh fruits and vegetables in railway refrigerator cars. However, less is available on transportation of these commodities in the modern, mechanically refrigerated truck trailer. One reason for the limited source of pertinent information on this fast-growing mode of transport--in addition to its relatively short operational history--has been the difficulty in making repeated test shipments in similar types of refrigerated trailers.

This difficulty was corrected with the start of the truck-rail (trailer-on-flatcar or "piggyback") service in 1957 and the sea-land (trailer-on-ship) service in 1959 from the Rio Grande Valley of Texas. Both services utilize mechanically refrigerated trailers with similar insulation, construction, and refrigeration units. The trailers are loaded in the producing area and, with the thermostatically controlled refrigeration units operating, sent over the highway to either a rail or a ship loading point for transport to market. Increased minimum-weight loads are featured by both services.

The results obtained in 13 test shipments of fresh fruits and vegetables in mechanically refrigerated truck-rail and sea-land trailers are given in this report. Particular emphasis is placed on the rate of cooling the commodity and the factors involved. This study to evaluate the truck-rail and sea-land equipment for maintaining the quality of fruits and vegetables in transit is part of a broad program of research of the Agricultural Marketing Service, U. S. Department of Agriculture, designed to maintain quality and reduce spoilage losses in marketing farm products.

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TRUCK-RAIL AND SEA-LAND SHIPPING TESTS WITH TEXAS FRUITS AND VEGETABLES

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SUMMARY

The loading pattern is the most important single factor in determining rate of cooling in truck-rail (trailer-on-flatcar) and sea-land (trailer-on-ship) trailers. Solid loading results in slow, uneven cooling. The single source of refrigeration and lack of space beneath the bottom layer of lading in a trailer load are indicative that a horizontal airflow is needed to obtain uniform cooling. Such an airflow pattern is established with a loading pattern described in this report.

Other factors responsible for the disparity between temperatures obtained and temperatures desired, as indicated by the thermostat setting, were: (1) Outside air temperatures, (2) load weight, (3) commodity temperatures at loading, and (4) packaging and type of container.

Continuous temperature records were obtained in selected test locations in 10 truck-rail and 3 sea-land shipments of citrus fruits and vegetables from south Texas. Solid and channeled loading patterns were used.

Eleven of the 13 test loads qualified for "incentive rates" for heavy loading, with billing weights ranging from 30,000 to 42,000 pounds.

Temperature reductions during transit varied between test locations in the same load and between the same location in different loads.

The middle layer of the halfway stack is one of the most difficult spots in the load to cool. If little or no cooling can be accomplished in this part of a particular shipment, it is probable that commodity temperatures in many other load locations have not been significantly reduced. Temperatures in this part of the load were reduced to the desired range in only 1 of the 13 test shipments.

For maintaining highest product quality in transit, the refrigeration requirements of the lading should be given primary consideration in determining "incentive rate" load weights.

The truck-rail and sea-land trailers are equipped with mechanical units capable of delivering ample refrigeration. Setting the thermostat to the desired temperature means little by itself; satisfactory cooling of lading may be obtained only if conditions conducive to good air circulation through the load and effective operation of the unit are provided by the carrier and shipper.

BACKGROUND

Truck-rail and sea-land services for shipping perishable commodities are relatively new developments in the field of transportation. The first truck-rail service from points in the Rio Grande Valley of Texas was made available in September 1957. The sea-land service was inaugurated from Texas points approximately 2 years later and was temporarily suspended after 1 year of operation.

Truck-rail and sea-land services involve the use of mechanically refrigerated trailers which are loaded in the producing areas and then sent over the highway to rail or ship loading points for final transport to market. Truck-rail and sea-land services are sometimes referred to as "piggyback" and "fishyback" services, respectively.

Truck-rail service, with daily departures, provided regular rail schedule delivery to many cities in the mid-central States. Sea-land service, with one weekly departure from Houston, Tex., was limited to the Port Newark, N. J., area, with delivery on the seventh, or eighth day after loading at Valley points.

Heavier minimum-weight loads than usual, or "incentive rate" loads, were featured by both services from the start. For example, the truck-rail rate from lower Rio Grande Valley points to St. Louis, Mo., on a 30,000-pound minimum tomato load was \$107.59 less than the combined freight and refrigeration charge (Rule 247 with one re-icing) on a similar all-rail shipment. (5)¹

The "incentive rate" was even more attractive in the sea-land service. The charges from Valley points to the New York City area were \$650 per load not to exceed 35,999 pounds. For an additional charge of \$25, the load weight could be increased to a maximum of 42,000 pounds.

Heavier loading of refrigerator rail cars has been accomplished by adding an extra one or two layers of containers to already established loading patterns, leaving the air channels intact. This was not true in loading truck-rail and sea-land trailers. These trailers have approximately 25 percent less cubic capacity than the average refrigerator car, so it was necessary to use a solid loading pattern to reach the weights required for the "incentive rates." The sea-land service maximum 42,000-pound load was impossible to make unless the fresh commodity lading was place-packed in large master containers and loaded solid.

A series of 10 truck-rail and 3 sea-land shipping tests was conducted to determine the actual cooling obtained during transit with different loading patterns, many of which disregarded the basic principles of good rail-car or truck-van loading. (4)

BASIC PRINCIPLES IN COOLING FRUITS AND VEGETABLES

The cooling of any commodity necessitates the transfer of heat from the lading and inside surfaces of the load chamber to the refrigeration source. In ice-refrigerated rail cars, the heat is transferred to the ice in the bunkers; with mechanically refrigerated truck-rail and sea-land trailers, the heat-absorbing surface is the finned evaporator coil of the unit. With either ice or mechanical refrigeration, the medium of heat exchange is the air circulating to, through, and around the warm commodity and then over the refrigerating surface, a condition impossible with solid loads.

There are three main sources of heat which must be considered in shipments of fresh fruits and vegetables, (1) field heat, (2) heat leakage, and (3) vital heat, or heat of respiration.

Field heat is that which must be removed from the commodity to lower its temperature to that desired for shipment. The heat load of the wood and metal in the interior of the vehicle, as well as that of the containers and car strips, is included in this category. Field heat is the first and usually the heaviest load on the refrigeration source, but, once removed or absorbed, it does not recur in ordinary handling practice.

¹ Underlined numbers in parenthesis refer to items in Literature cited, p. 25.

Heat leakage is the heat conducted into the car or trailer through the insulated structure and also that entering the vehicle through air leaks at cracks around the doorway and other openings. The greater the differential between the inside and outside air temperatures, the greater is the rate of heat leakage. Thus heat leakage into the vehicle is of more importance in spring and summer shipments than in those moving during winter.

Vital heat, or heat of respiration, is the result of a continuous process which goes on in every living cell of which fresh fruits and vegetables are composed. In the process, oxygen is consumed, carbon dioxide released, and heat produced.

The rates of respiration of most fresh fruits and vegetables have been determined. (6) They vary considerably between different commodities, and, within the limits of usual temperature exposure, the rate increases as the temperature rises and decreases as the temperature falls. The more highly perishable commodities, such as the leafy vegetables, have a much higher rate of respiration than the less perishable, such as potatoes.

EQUIPMENT

The truck-rail and sea-land trailers used in the tests were similar in many respects. All trailers had 6 inches of insulation in the roof, floor, and all four sides. The same types of insulation were used. The 1,500-cubic-foot capacity of the sea-land trailer was slightly more than that of the truck-rail RF series and 177 cubic feet less than the RC series. The designations RF and RC used in connection with the truck-rail service denote a specific-sized series of trailers, with the RC slightly larger in all dimensions.

Each refrigerated trailer of both services had a bulkhead at the nose end, which made a duct for the return airflow from the floor level to the evaporator-blower mounted near the ceiling. The bulkhead provided a 6- to 10 -inch vertical channel the full width of the trailer. In a sea-land trailer, the solid bulkhead extends from the ceiling down to 6 inches above the channeled, extruded floor surface. In the truck-rail trailer, the bulkhead is solid down to approximately 36 inches above the channeled, extruded floor, after which 3-inch full-width openings are alternated with 4-inch solid strips.

Forced air circulation systems differed in the two services. In truck-rail trailers, there was no circulation during the "off" cycle of the refrigeration unit. In sea-land trailers, air circulation was continuous, regardless of the unit's cycling. In the truck-rail trailers, the air supply, or refrigerated airblast, was carried toward the rear by adjustable, overhead canvas air ducts suspended from the ceiling. The sea-land trailers had no overhead duct system.

Trailers of both services were equipped with the same make and type of thermostatically controlled mechanical refrigeration unit, described in one brochure as the "largest compressor available - -." The rated refrigeration capacity of the unit at two operating temperatures, as given by the manufacturer, is as follows:

1 00 ^o F. ambient,	0 ^o F. trailer temp. - -	13,000 B. t. u. /hr.
1 00 ^o F. " "	35 ^o F. " " - -	19,000 B. t. u. /hr.

The unit provided heating when such protection was desired. The truck-rail refrigeration units were powered by propane engines mounted on the outside nose end. The sea-land trailers, with the same engine mountings, used propane on the highway but electrical power was used in terminal parking areas and aboard ships.

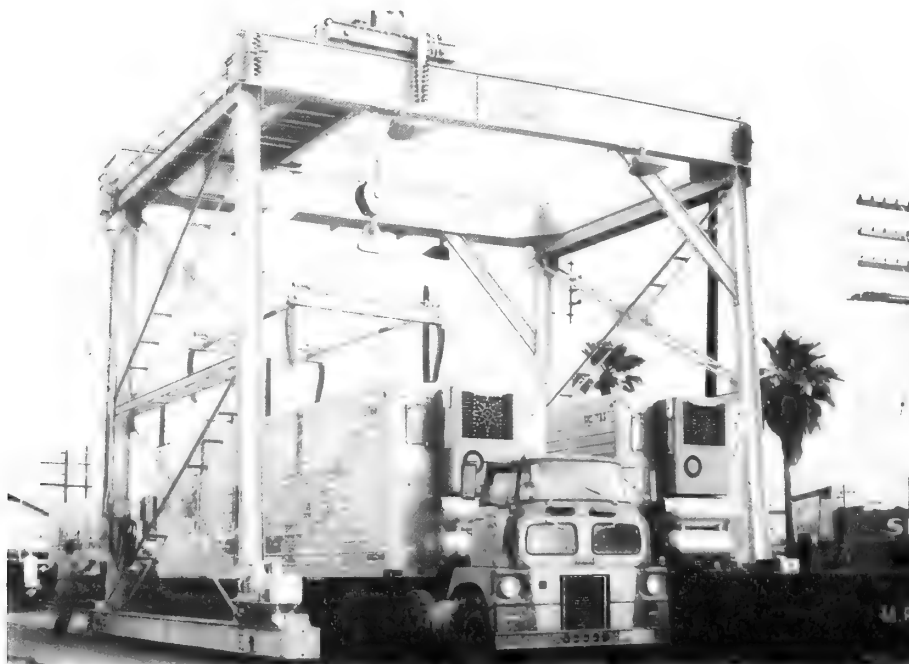
The thermostat sensing element and the thermometer bulb were mounted jointly in the left side air return vent of the evaporator-blower housing. This location was near the top of the cargo-free air-return duct in the nose end of the trailer.

The two types of truck-rail trailers used in the tests and the method of handling one type are shown in figures 1, 2, and 3.



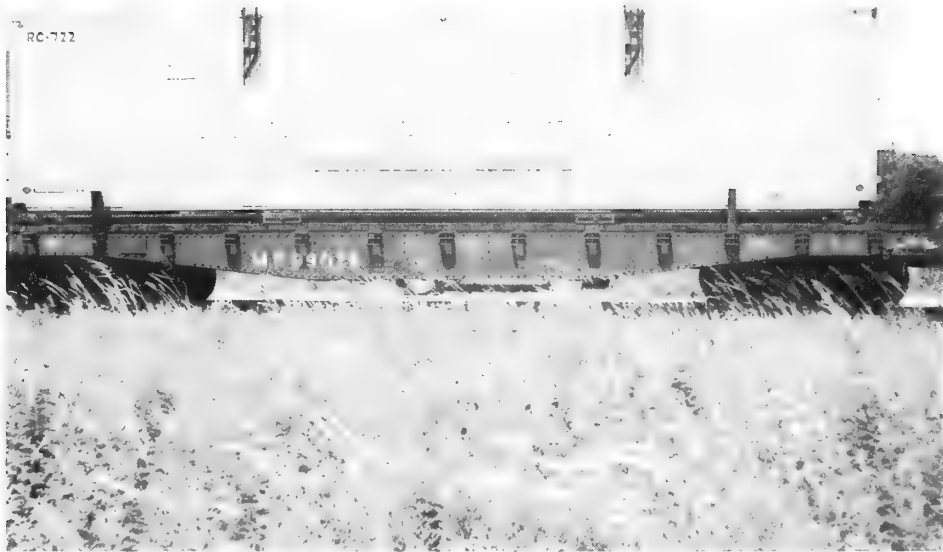
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Figure 1. --Truck-rail series R or RF trailer loaded on flatcar. Single gangway at diagonal ends of car in raised position for transit.



BN-18189

Figure 2. --Truck-rail series RC trailer (removable chassis) in position under gantry crane.



BN-18190

Figure 3. --Truck-rail series RC trailer on flatcar after removal from wheels. The sea-land trailers are similar to these units.

METHODS

Truck-rail tests were conducted during the 1957-58 and 1958-59 shipping seasons. The sea-land tests followed one season later. Single tests were made under a variety of conditions with respect to lading, loading pattern, container, produce and outside air temperatures, and load weight.

All test loads originated from points in the lower Rio Grande Valley in Texas. Destinations of the truck-rail shipments were cities in the mid-central States. The three sea-land tests went to the New York area.

Temperatures were obtained in three to five test locations in each load by burying recording thermometers in containers in the bottom, middle, and top layers at the centerline. Temperatures were obtained in the middle and top layers of the center or halfway stack in all tests. Temperatures in the bottom layer were recorded either in the center or halfway stack or the second stack from the doorway. Temperatures were also obtained in the middle layer in the first complete stack at the nose of the trailer in several tests. The air temperatures recorded within the packages of the commodity under test are referred to as "commodity temperatures" in this report. The average of these "commodity temperatures" for each individual load is referred to under Results as "average load temperature." This is a comparative term and not an exact measure of the entire load temperature.

"Zero time" on the temperature chart of each individual test shipment is the first midnight after loading (figs. 4 through 16). After completion of loading, the trailer doors were closed and the refrigeration unit started. This initial cooling time varied from 1/2 to 12 hours before the first midnight and is expressed on each chart as "plus ___ hours cooling." This explains the apparent differences between the stated temperatures of the pulp at loading under Results, and those shown for the first midnight (zero time) on the charts.

Also under Results for each test, the temperatures recorded 72 hours after trailer doors were closed are given. The 72-hour time interval affords a basis of uniformity in the comparison of the rates of cooling between tests, regardless of the total elapsed time either in transit or to unloading.

Outside air temperatures, referred to in the text and shown in figures 4 through 16, are the maximum and minimum temperatures for transit-point cities as reported by the U. S. Weather Bureau. These outside air temperatures approximate those experienced by the individual test load. They are given to show whether or not the outside air temperatures were generally above or below those of the thermostat settings.

TEST LOADS AND RESULTS

Truck-Rail Test A. --One-pound polyethylene bags of carrots packed in 50-pound multiwall paper bags. Loaded Feb. 7, 1958, in Harlingen, Tex.; shipped in RF-180 to East St. Louis, Ill. 600-bag, solid, through load (33,600 lb.). Lengthwise on sides, 5 wide x 9 high x 13 long; last 3 stacks 10 high (in contact with ceiling). Doorway bulkhead not used. Pulp loading temperature 45° F. (hydrocooled). Thermostat set at 40°. Doors closed 10:00 p.m. The load moved during a cold period with below-freezing temperatures prevailing the second day and on to destination.

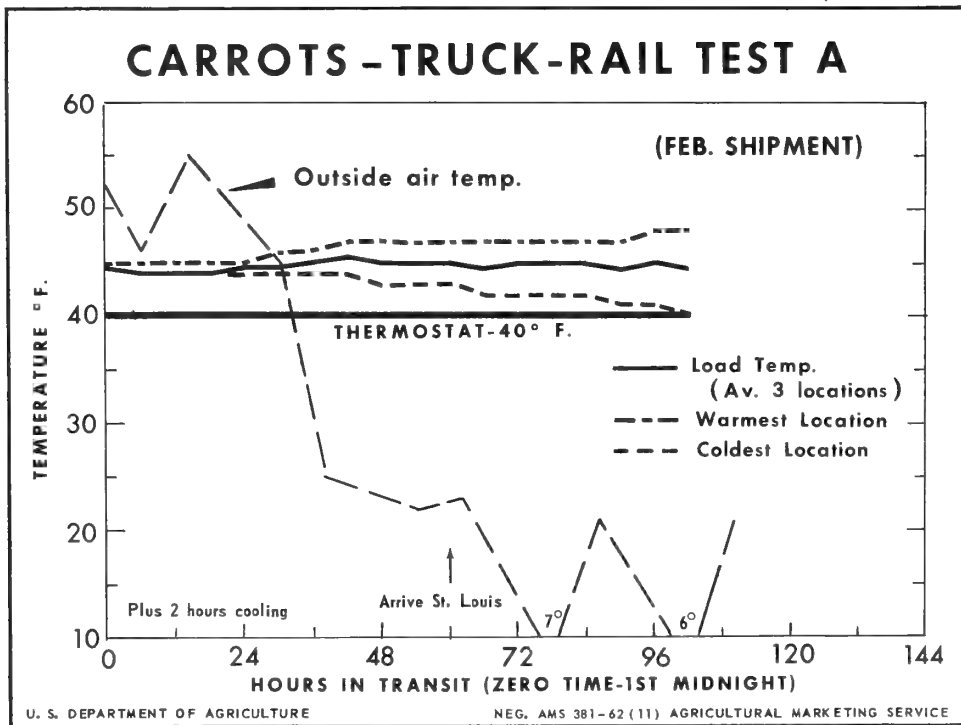


Figure 4

At 72 hours after loading (70 hours as shown in fig. 4), the average load temperature was 45° F., the same as when loaded. However, a spread of 5 degrees had developed among the three test locations. Carrots in the top and middle layers warmed slightly during transit while the bottom layer cooled. Cooling in the bottom layer started in 36 hours and reflected the low outside air temperatures.

Truck-Rail Test B. --Grapefruit in 1/2-box cartons. Loaded Feb. 14, 1958, in Mission, Tex.; shipped in RF-202 to East St. Louis, Ill. 834-carton, channeled load (30,024 lb.). Lengthwise on bottoms, 6 wide x 6 high x 21 long; 22 cartons lengthwise

along each wall in seventh layer; plus 34 cartons in two incomplete stacks in nose end. Doorway bulkhead in place. Pulp loading temperature 62° F. Thermostat set at 40°. Doors closed 4:30 p.m. Outside temperatures were cool the first day and were below freezing the second day and on to destination.

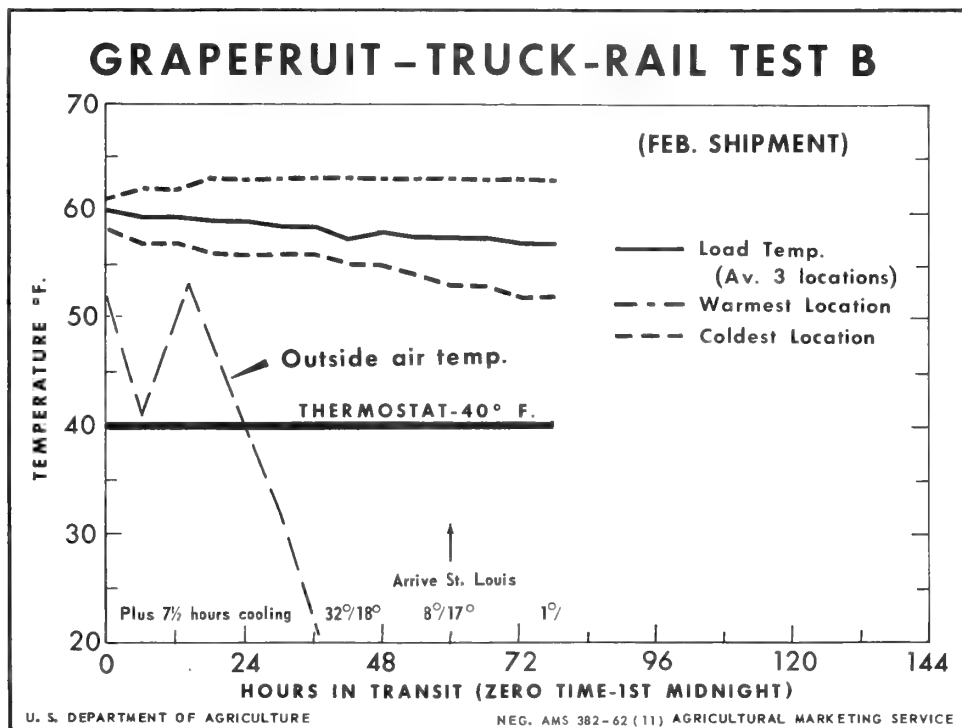


Figure 5

At 72 hours after loading (65 hours as shown in fig. 5), the average load temperature was 57° F., a reduction of only 5 degrees. The spread among the three test locations was 10 degrees, ranging from about 63° to 53°. The middle-layer fruit had warmed 2 degrees to 63°. The top-layer fruit cooled to 56° in 24 hours and remained at that temperature for the rest of the test period. This was the coldest test location until noon of the second day; after then, the bottom layer was the coldest. The additional cooling in the bottom layer reflected low outside air temperatures as the refrigeration unit apparently cycled off after 24 hours of operation. This probably explains the lack of further cooling of the top layer.

Truck-Rail Test C, --Grapefruit in 1/2-box cartons. Loaded Feb. 21, 1958, in Pharr, Tex.; shipped in RF-181 to East St. Louis, Ill. 838-carton, channeled load (30,168 lb.). Lengthwise on bottoms, 5 wide x 2 high x 22 long; 6 wide (5 lengthwise, 1 crosswise) in third, fourth, and fifth layers; 7 wide on sides in sixth layer; two rows lengthwise along each wall in seventh layer; plus three incomplete stacks in nose. Spaced with through channels between all rows in first two layers; rest of load solid. Doorway bulkhead in place. Pulp loading temperature 80° F. Thermostat set at 40°. Doors closed 4:30 p.m. Outside temperatures were moderately cool the first 3 days, but on the fourth day the minimum was below the thermostat setting.

At 72 hours after loading (65 hours as shown in fig. 6), the average load temperature was 50° F., a reduction of 30 degrees. The spread among the three test locations was 18 degrees, ranging from 61° to 43°. The refrigeration unit operated only during the first 36 hours, after which the top layer started to warm. This location had been the coldest during the period the unit operated. After the unit cycled off, fruit in the bottom layer continued to cool because of low outside temperatures. The air temperature within the trailer was reduced to the thermostat setting after 36 hours of unit operation. During this time, the top layer and the two channeled lower layers had cooled satisfactorily.

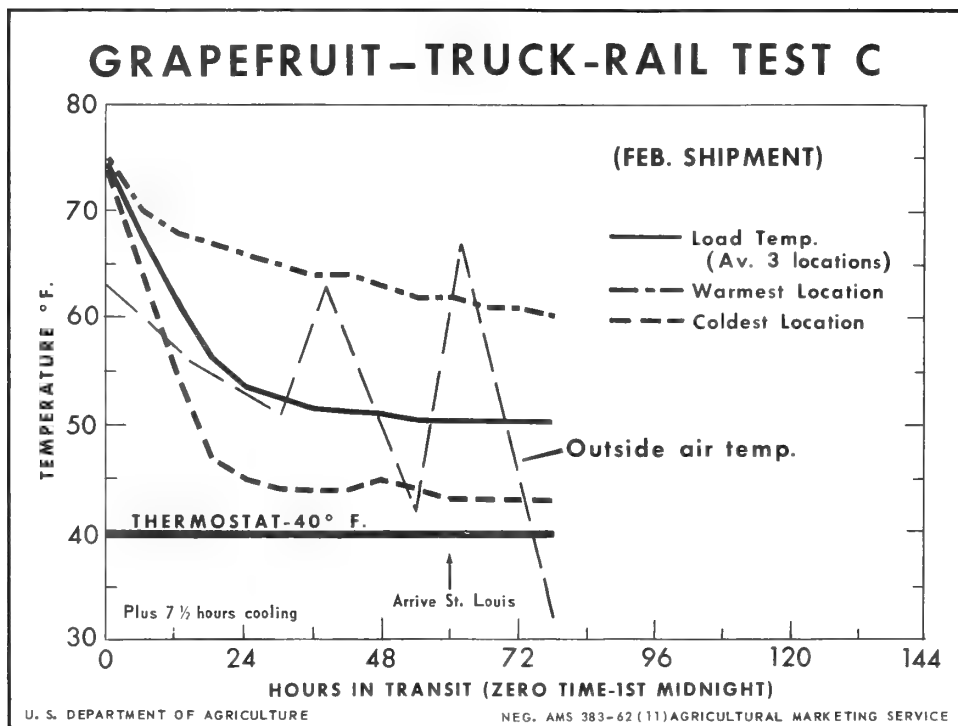


Figure 6

Solid third, fourth, fifth, and sixth layers were responsible for the slow cooling in the middle of the load. The lack of continuous air circulation, plus low outside air temperatures the last day, kept the refrigeration unit in an "off" cycle.

Truck-Rail Test D. --Onions in 50-pound mesh bags. Loaded April 22, 1958, in Raymondville, Tex.; shipped in RF-163 to East St. Louis, Ill. 600-bag, solid, through load (30,300 lb.). Lengthwise on sides, 6 wide x 7 high x 14 long; plus 12 bags in eighth layer. Doorway bulkhead not used. Pulp loading temperature 80° F. Thermostat set at 60°. Doors closed 6:00 p. m. Outside air temperatures the first 2 days were moderately warm but on the third day temperatures fell below the thermostat setting.

At 72 hours after loading (66 hours as shown in fig. 7), the average load temperature was 68° F., a reduction of only 12 degrees. The spread among the three test locations was 4 degrees. The lowest temperature was in the top layer. The temperature curve for this location clearly reflects the operational record of the refrigeration unit. The curve leveled off twice for periods of 6 and 18 hours, during which times the unit was off.

Truck-Rail Test E. --Tomatoes in 60-pound wirebound crates. Loaded May 2, 1958, in La Feria, Tex.; shipped in RF-191 to Memphis, Tenn. 500-crate, solid load (32,500 lb.). Lengthwise on bottoms, 6 wide x 5 high x 16 long; plus 2 incomplete stacks in nose end; each layer slightly offset. Doorway bulkhead in place. Pulp loading temperature 84° F. Thermostat set at 60°. Doors closed 5:00 p. m. Outside air temperatures the first 2 days in transit were moderately warm but the minimum temperatures on the third and fourth days were below the thermostat setting.

At 72 hours after loading (65 hours as shown in fig. 8), the average load temperature was 66° F., a reduction of 18 degrees. The spread among the three test locations was 9 degrees, ranging from 70° to 61°. Tomatoes in the top layer cooled to 61° in 36 hours. Temperature in this location remained constant until the third midnight, when a slight rise occurred. Apparently the refrigeration unit operated in normal cycle until the

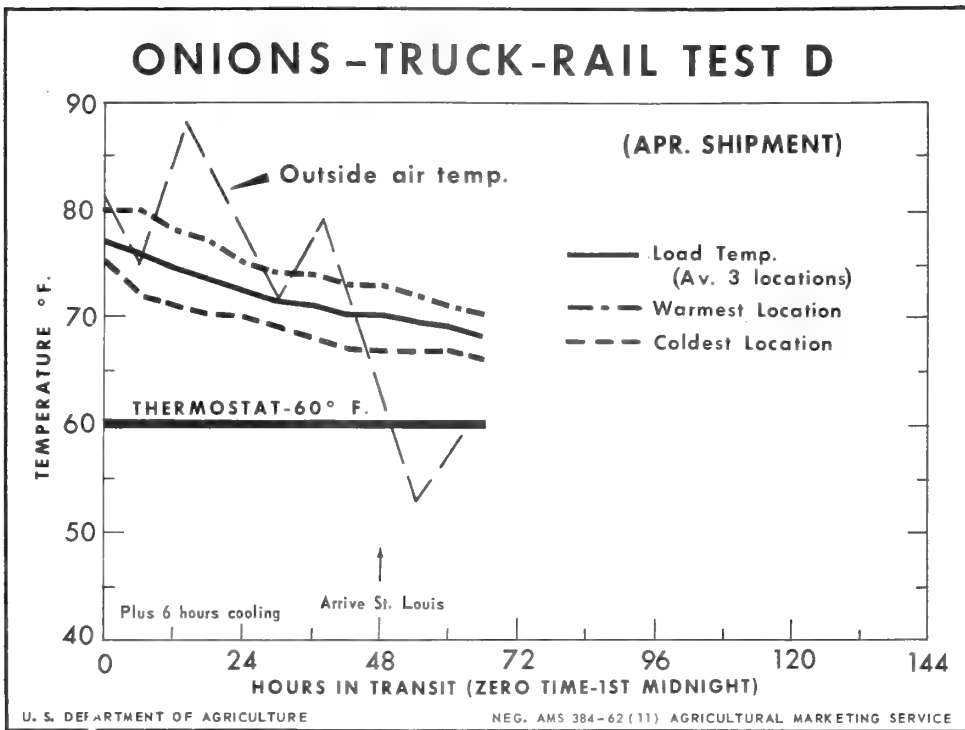


Figure 7

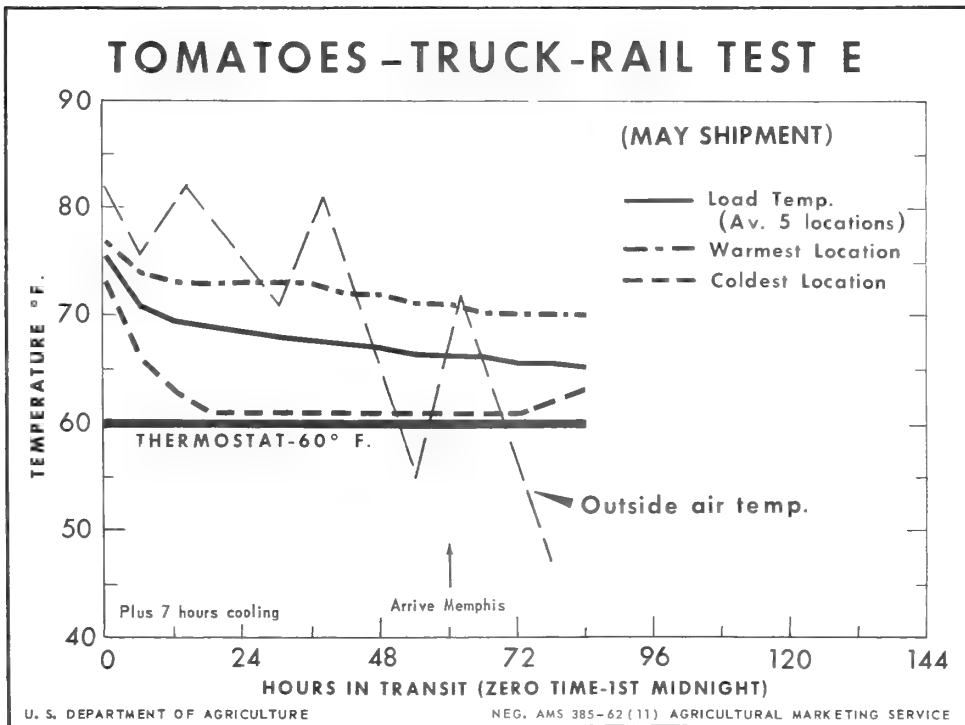


Figure 8

third midnight, when the thermostat was affected by low outside air temperatures. Tomatoes in the bottom and middle layers cooled to 67° and 70° during the 72-hour period.

Truck-Rail Test F. --Tomatoes in 60-pound wirebound crates. Loaded May 16 and 17, 1958, in La Feria, Tex.; shipped in RF-190 to East St. Louis, Ill. 468-crate, channeled load (30,420 lb.). Lengthwise on bottoms, 5 wide x 3 high x 15 long; 6 wide in fourth and fifth layers; plus 36 crates in 2 incomplete stacks in nose end. Spaced, with through lengthwise channels between all rows in first three layers. Doorway bulkhead in place. Loading completed at noon of second day. Pulp temperature 80° F. Thermostat set at 60°. Doors closed at noon, the second day of loading. Outside air temperatures were moderately warm during transit with only the third morning minimum falling slightly below the thermostat setting.

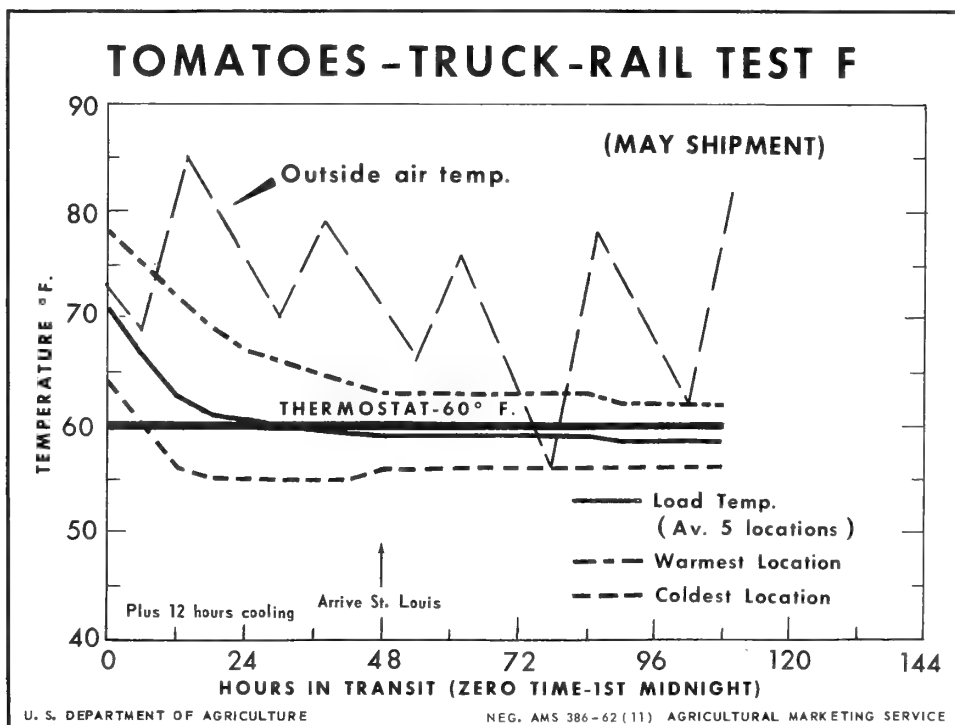


Figure 9

The average load temperature was 77° F. when loading was completed the second day. Seventy-two hours later (60 hours as shown in fig. 9), the load had cooled to 59°, 1 degree below the thermostat setting, a reduction of 18 degrees. The temperature spread among the five test locations was 7 degrees, ranging from 63° to 56°. The rates of cooling in all test locations were very uniform, with the greatest spread of 16 degrees occurring at noon the first day. The refrigeration unit operated continuously the first 30 hours and then intermittently in normal cycle until the trailer was unloaded on the fifth day.

Truck-Rail Test G. --Five-pound polyethylene bags of oranges packed in master cartons (rail container carton #4785). Loaded Nov. 25, 1958, in Mission, Tex.; shipped in RF-200 to Cincinnati, Ohio. 464-master-carton, solid load (27,500 lb.). Lengthwise on bottoms, 5 wide x 5 high x 17 long; plus 2 incomplete stacks in nose end. Doorway bulkhead in place. Pulp loading temperature 87° F. Thermostat set at 45°. Doors closed 3:30 p.m. The test load moved during a cold period with outside temperatures the second day below 50°, and below freezing the third day and on to destination.

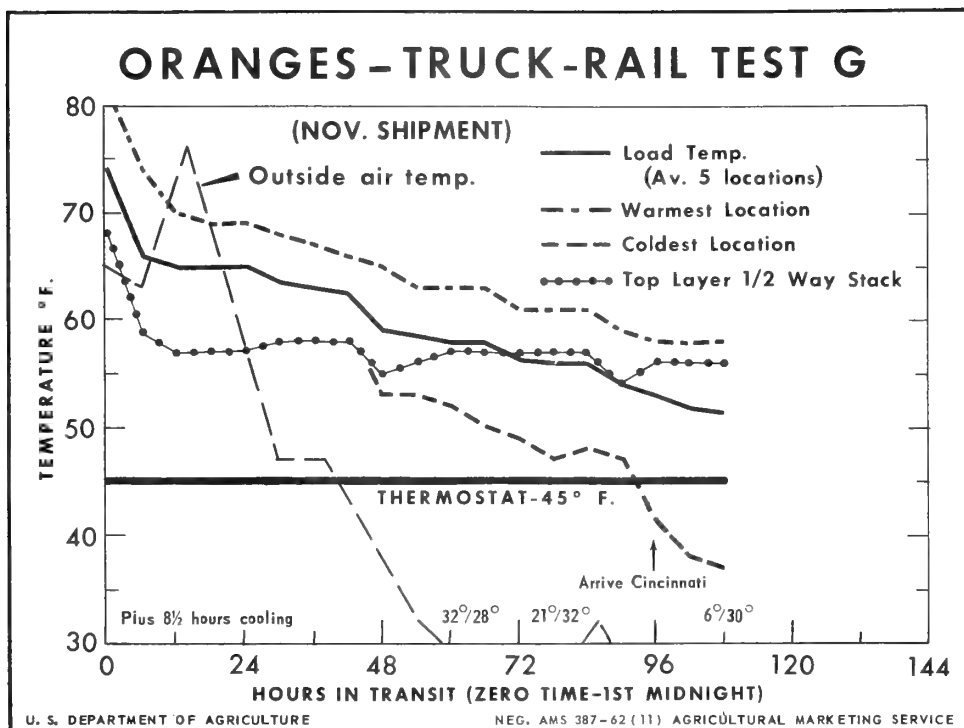


Figure 10

At 72 hours after loading (64 hours as shown in fig. 10), the average load temperature was 58° F., a reduction of 29 degrees but still 13 degrees above the thermostat setting. The spread between the warmest and coldest of five test locations was 12 degrees, ranging from 63° to 51°. Rapid cooling occurred the first 20 hours, with the average load temperature reduced 22 degrees. The refrigeration unit operated continuously during this period but very erratically for the remainder of the transit period. At the start, the top layer, halfway stack, was the coldest. Late on the second day, after the unit had been off for 30 hours, the bottom layer, doorway location, was the coldest. The erratic operation of the unit is reflected in the temperature curve for the top layer location. The curve shows the unit operated three times for a total of 32 hours and was off for a total of 84 hours even though the average load temperature ranged from 20 to 11 degrees above the thermostat setting. The bottom-layer test location, reflecting low outside air temperatures, cooled to below 45° the fourth midnight.

Truck-Rail Test H. --Grapefruit in 1/2-box cartons. Loaded Dec. 22, 1958, in Mission, Tex.; shipped in RF-200 to Louisville, Ky. 490-carton, channeled load (22,500 lb.). Crosswise on bottoms, 4 wide x 4 high x 27 long; plus 27 cartons crosswise along each wall in fifth layer; also 60 rail master containers in 3 incomplete stacks in nose end. Doorway bulkhead in place. Pulp loading temperature 65° F. Thermostat set at 45°. Doors closed 5:00 p. m. Outside temperatures below 50° were encountered the second day and below-freezing minimums the third day and on to destination. These outside temperatures were similar to those experienced by test load G.

The average load temperature 72 hours after loading (65 hours as shown in fig. 11) was 53° F., a reduction of 12 degrees, but 8 degrees above the thermostat setting. The spread between the warmest and coldest of five test locations was 6 degrees. The refrigeration unit operated the first 12 hours. During this short period, the load cooled 8 degrees with only a 1-degree spread between test locations. After this initial period of cooling, the load temperature showed a slight rise and then started to cool again on the third day. Fruit in the top layer was the coldest the first day, but after the unit cycled off the top layer became the warmest for the remainder of the transit period. Fruit in

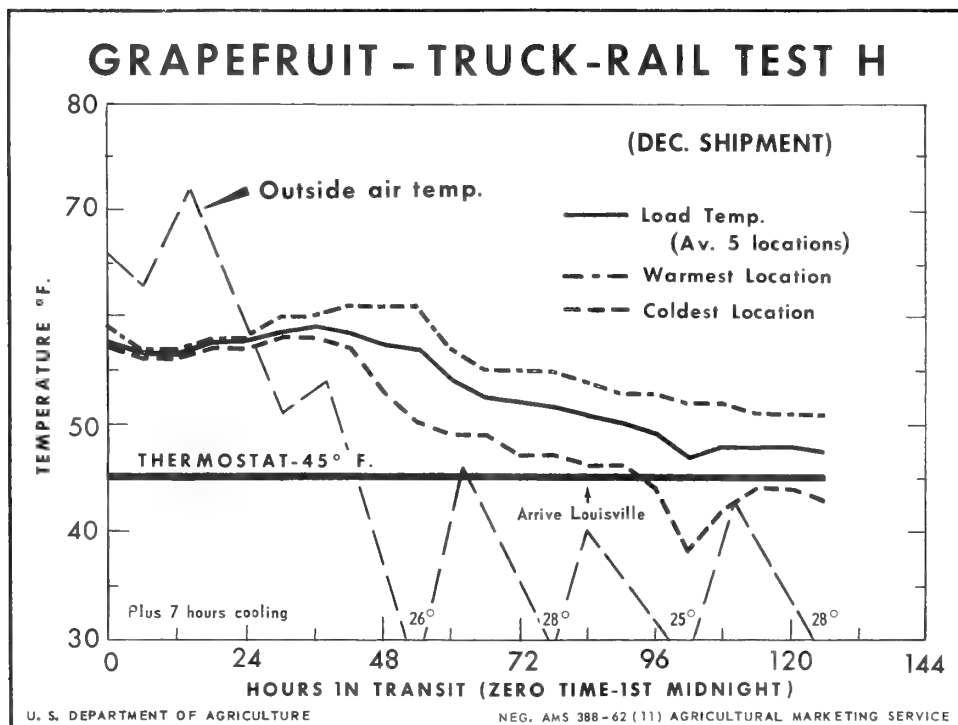


Figure 11

this location cooled 6 degrees in 12 hours on the third day, which indicated the unit operated a second time. All cooling that occurred after the third day probably resulted from low outside air temperatures.

Truck-Rail Test I. --Tomatoes in 50-pound cartons. Loaded May 12, 1959, in Weslaco, Tex.; shipped in RC-575 to East St. Louis, Ill. 623-carton, channeled, chimney load (33,000 lb.). Thirteen chimney stacks along each wall, 4 cartons each layer x 5 high; one row, lengthwise on bottoms, 1 wide x 5 high x 21 long, along centerline. Vertical through lengthwise channel on each side of centerline row. Doorway bulkhead in place. Pulp loading temperature 90° F. Thermostat set at 55°. Doors closed 11:30 p. m. Outside air temperatures were moderately warm until the third morning, when the minimum was 46°, 9 degrees below the setting of the thermostat.

The average load temperature 72 hours after loading (72 hours as shown also in fig. 12) was 66° F., a reduction of 24 degrees but still 11 degrees above the thermostat setting. The spread among the five test locations was 13 degrees, ranging from 75° to 62°. The average load temperature had reached 68° 24 hours earlier. The refrigeration unit operated the first 36 hours. During this period the nose stack test location was the coldest. This indicated that a limited air-circulation pattern had been established within the trailer. Air-circulation patterns are described later under Loading Pattern, page 19.

Truck-Rail Test J. --Tomatoes in 60-pound wirebound crates. Loaded May 22, 1959, in La Feria, Tex.; shipped in RC-769 to Kansas City, Mo. 500-crate, channeled load (32,500 lb.). Lengthwise on bottoms, 5 wide x 3 high x 20 long; 6 wide in fourth layer, tight against each wall; plus two rows along each wall in fifth layer. Nose stack, 1 wide along each wall in incomplete fifth and sixth layers. Spaced with through lengthwise channel between all rows in first three layers; lengthwise centerline channels, 6 inches wide in fourth layer, 30 inches wide in fifth layer. Doorway bulkhead in place. Pulp loading temperature 88° F. Thermostat set at 60°. Doors closed 6:00 p. m. Outside air temperatures were moderately warm, never falling below the thermostat setting during transit.

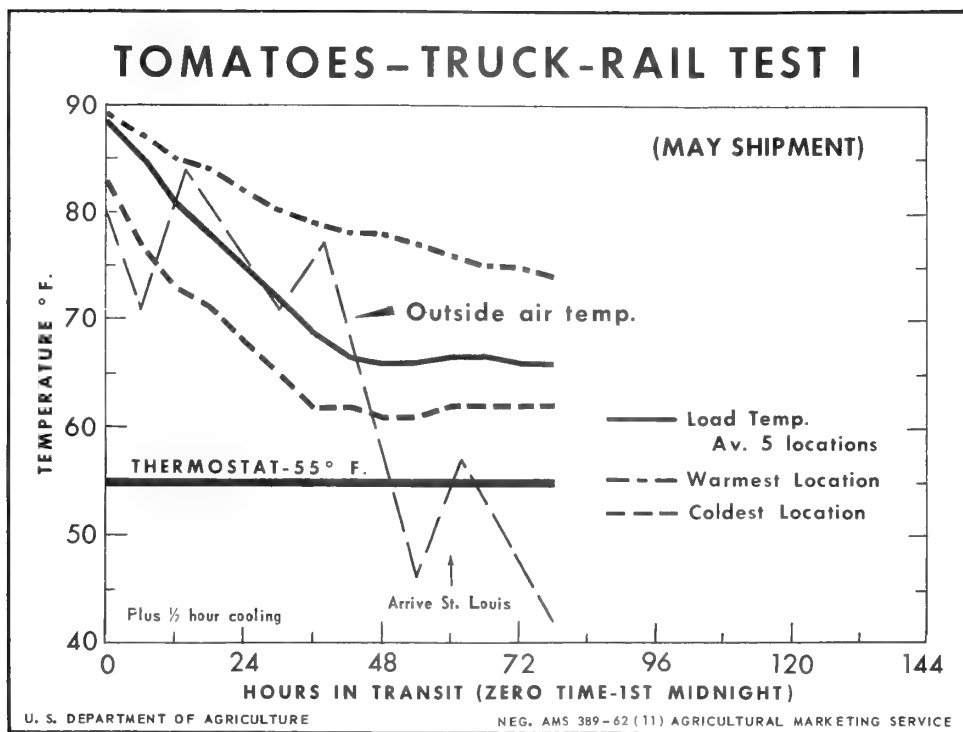


Figure 12

The average load temperature 72 hours after loading (66 hours as shown in fig. 13) was 65° F., a reduction of 23 degrees. The spread among five test locations was 9 degrees, ranging from 70° to 61°. Actually, the lowest average load temperature was reached after the first 48 hours when the unit cycled off. The load had cooled to 63° F., 3 degrees above the thermostat setting. Tomatoes in two test locations, including the middle layer, nose stack, had cooled to 58°. Tomatoes in the other locations had not cooled to the desired range.

Sea-Land Test K. --Grapefruit in rail container carton #4785; place-packed to gross 80 pounds. Loaded Feb. 23, 1960, in Edinburg, Tex.; shipped in trailer No. 4372 to Port Newark, N. J. 458-carton, stripped, solid load (41,000 lb.). Lengthwise on bottoms, 5 wide x 5 high x 15 long; in doorway, crosswise on bottoms, 4 wide x 5 high x 2 long; plus 2 incomplete stacks in nose end. Also, 900 5-pound polyethylene bags of fruit distributed over top of cartons. Pulp loading temperature 70° F. Thermostat set at 34°. Doors closed 3:30 p.m. The load encountered a low of 34° outside air temperature the first morning enroute to Houston.

No appreciable cooling occurred the first 30 hours. From then on, the load cooled gradually until unloaded. The average load temperature 72 hours after loading (64 hours as shown in fig. 14) was 57° F., a reduction of 13 degrees, but 23 degrees above the thermostat setting. The spread among the five test locations was 12 degrees, ranging from 60° to 48°. At time of delivery on the eighth day, the load had cooled to 37° F. with a spread of 12 degrees. Two days earlier, the spread had been 18 degrees, with a minimum temperature of 28° F. This temperature caused some freezing of fruit in top-layer cartons and polyethylene bags near the refrigeration unit. The top-layer location remained the coldest during the entire transit period. Two bottom-layer locations in the doorway and halfway stack showed the least cooling.

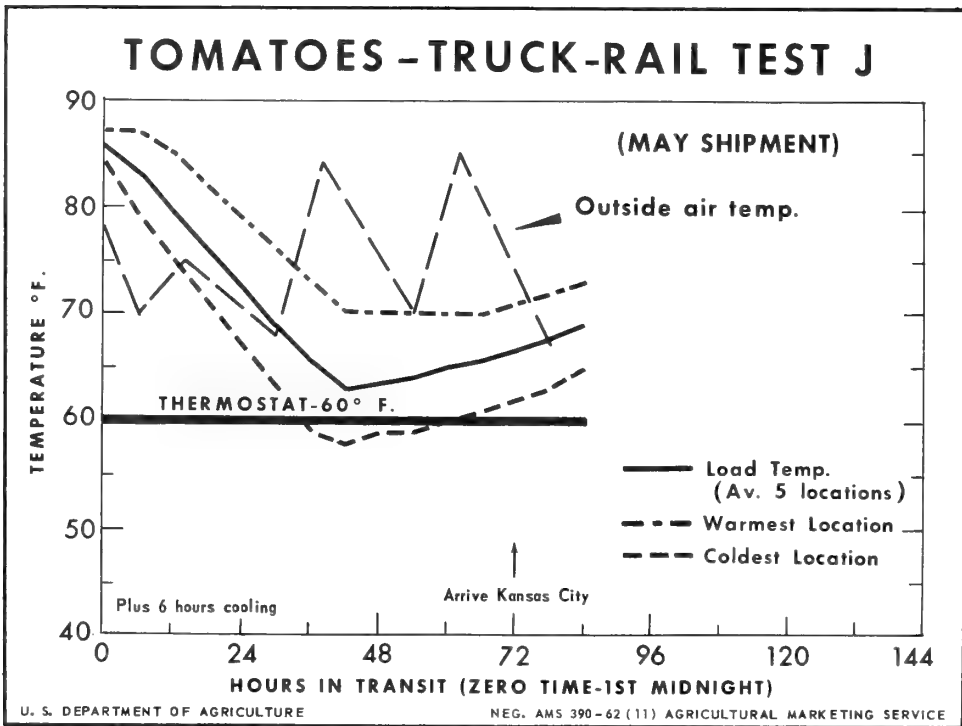


Figure 13

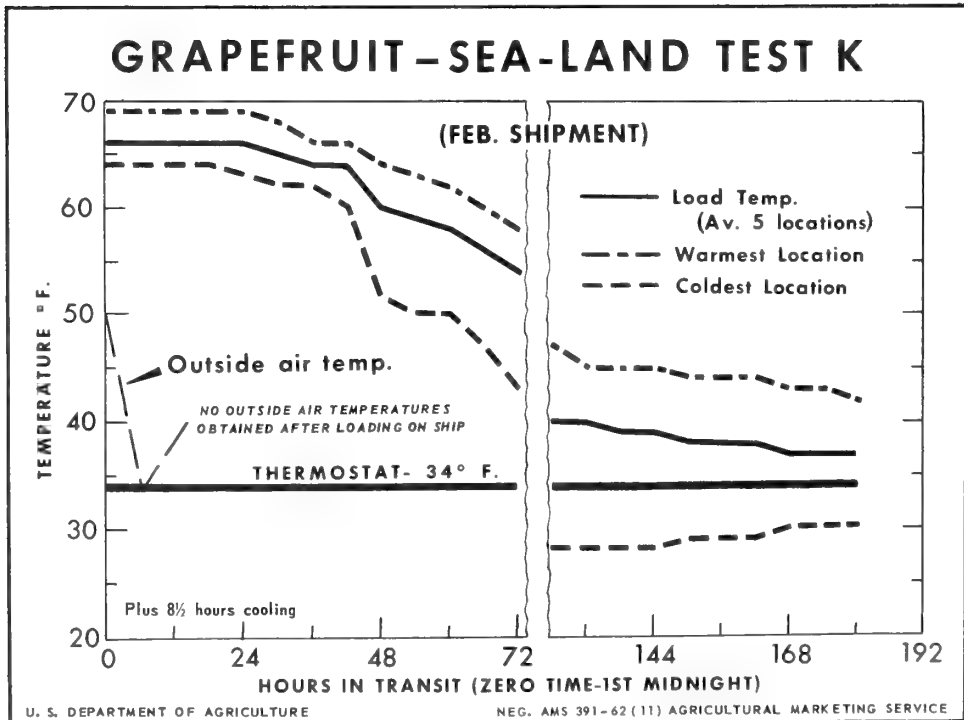


Figure 14

Sea-Land Test L. --Grapefruit in rail container carton #4785; place-packed to gross 80 pounds. Loaded Feb. 23, 1960, in Mission, Tex.; shipped in trailer No. 4424 to Port Newark, N. J. 512-carton, stripped, solid load (42,000 lb.). Crosswise on bottoms, 4 wide x 5 high x 23 long; in doorway, lengthwise on bottoms, 5 wide x 5 high x 1 long; plus 27 cartons in 2 incomplete stacks in front end. Also, 396 5-pound polyethylene bags of fruit laid over top of carton load. Pulp loading temperature 70° F. Thermostat set at 34°. Doors closed 5:15 p.m. Outside minimum air temperature of 34° was reported the first morning enroute to Houston.

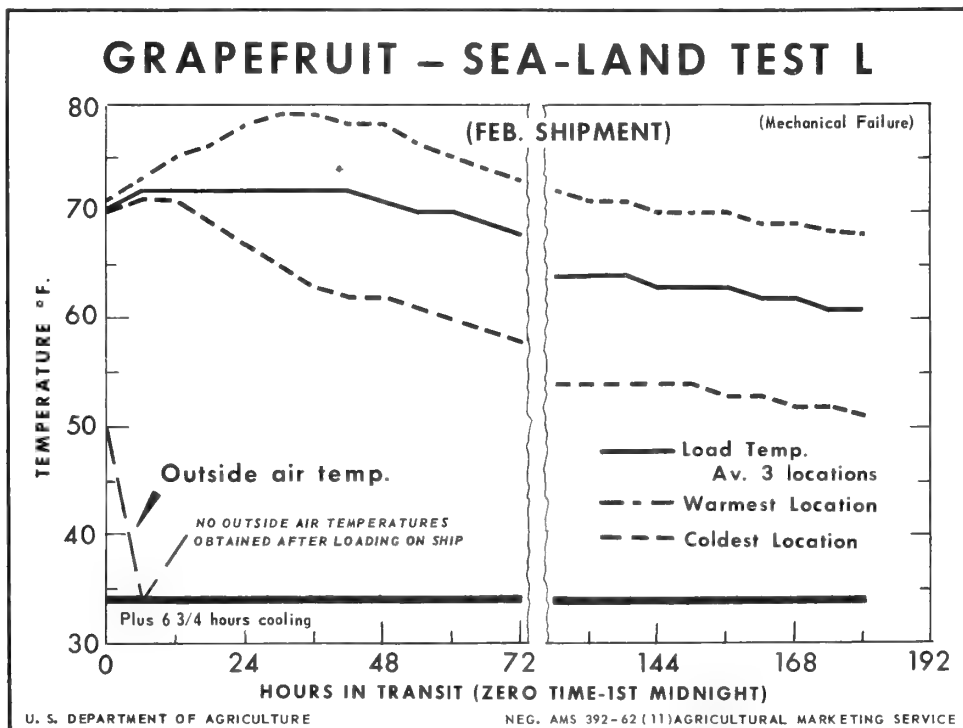


Figure 15

The fan and refrigeration unit failed to operate after the first several hours of the test period. The recorded temperatures are shown in figure 15. They show clearly the effect of respiration on load temperature if no source of refrigeration is available to absorb the heat. Low outside air temperatures cooled the load 9 degrees during the 8-day transit period. When unloaded, approximately 7 percent of the cartons were leaking because of penicillium green mold decay of the fruit.

Sea-Land Test M. --Grapefruit in rail container carton #4785; place-packed to gross 80 pounds. Loaded March 22, 1960, in Mission, Tex.; shipped in trailer No. 4376 to Port Newark, N. J. 514-carton, stripped, solid load (42,000 lb.). Crosswise on bottoms, 4 wide x 5 high x 24 long; plus 34 cartons in 2 incomplete stacks in nose end. Also, 40 50-pound mesh bags of fruit over top of carton load. Pulp loading temperature 70° F. Thermostat set at 36°. Doors closed 3:00 p.m. Moderately warm outside temperatures prevailed the first day enroute to Houston.

At 72 hours after loading (63 hours as shown in fig. 16), the load had cooled to 59° F., a reduction of 11 degrees, but 23 degrees above the thermostat setting. The spread among four test locations was 19 degrees, ranging from 65° to 46°. The load temperature at noon on the eighth day was 48° F., a reduction of 22 degrees, but still 12 degrees above the thermostat setting. The spread among test locations was 24 degrees, ranging from 58° to 34°. Fruit in the test cartons had 2 percent decay at destination (penicillium green mold).

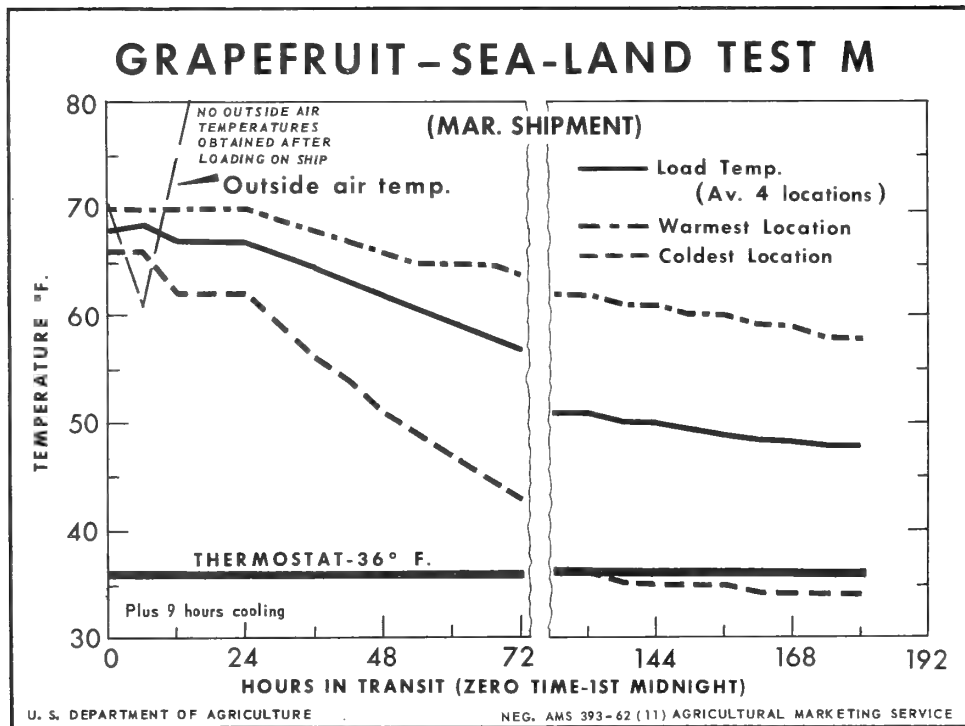


Figure 16

DISCUSSION

Temperatures were obtained in 10 truck-rail and 3 sea-land shipments consisting of fresh carrots, citrus fruits, tomatoes, and dry onions. Pulp loading temperatures varied with the commodity and season. Temperature reductions during transit varied between loads, between test locations in the same load, and between the same location in different loads.

The temperature in the middle layer at the halfway stack is representative of the effectiveness of cooling of any trailer load. The rates of cooling obtained in this location and the desired temperature, as indicated by the thermostat setting, are given in figure 17 for all truck-rail tests. The temperatures in the middle layer at the halfway stack in sea-land tests K and M were the warmest the first 3 days, as shown in figures 14 and 16.

Factors responsible for the disparity between temperatures obtained and temperatures desired were: (1) Loading pattern, (2) outside air temperatures, (3) load weight, (4) pulp loading temperature, and (5) packaging and type of container. The influence of these factors, acting either alone or in combination, determines the degree of cooling available to the lading.

The truck-rail and sea-land trailers are equipped with mechanical units capable of delivering ample refrigeration. Setting the thermostat to the desired temperature means little by itself, however; satisfactory cooling of lading may be obtained only if conditions conducive to good air circulation through the load and effective operation of the units are provided by the carrier and shipper.

Loading Pattern

The loading pattern is the most important single factor affecting the cooling of the lading. Shippers of fresh fruits and vegetables too often overlook the importance of air circulation through the load in a mistaken belief that "an envelope of refrigerated air" around the load is sufficient protection. This belief applies when frozen commodities are involved but not when the lading is living, respiring, fresh produce with considerable field heat to be removed. To cool such loads, the air must circulate through and around the entire load. If the air returning to the refrigeration unit is allowed to bypass or short circuit any part of the load, cooling will be ineffective.

Solid loading patterns were used in tests A, D, E, G, K, L, and M. Slow and uneven cooling of the commodity in most test locations was the rule, with the exception of test A. This shipment of prepackaged carrots had been hydrocooled to 45° F. before loading (fig. 4). Transit temperatures were fairly satisfactory, but most of the load did not reach the thermostat setting during transit. The middle and top layers warmed slightly in transit. On the sixth day in test K, the commodity in the top layer had cooled to 28° F. (with subsequent freezing damage) while that in the warmest location was 45° (fig. 14). Similar situations have been reported for vacuum-cooled lettuce shipped by truck-rail.

The loading pattern used in test C was semisolid, with four solid layers over two channeled lower layers. Satisfactory cooling was not obtained in the middle layers because of the solid loading (fig. 6). Satisfactory cooling of the entire load would have been accomplished had the four lower layers been channeled, leaving the solid fifth and sixth layers to be cooled by the air blast and return airflow.

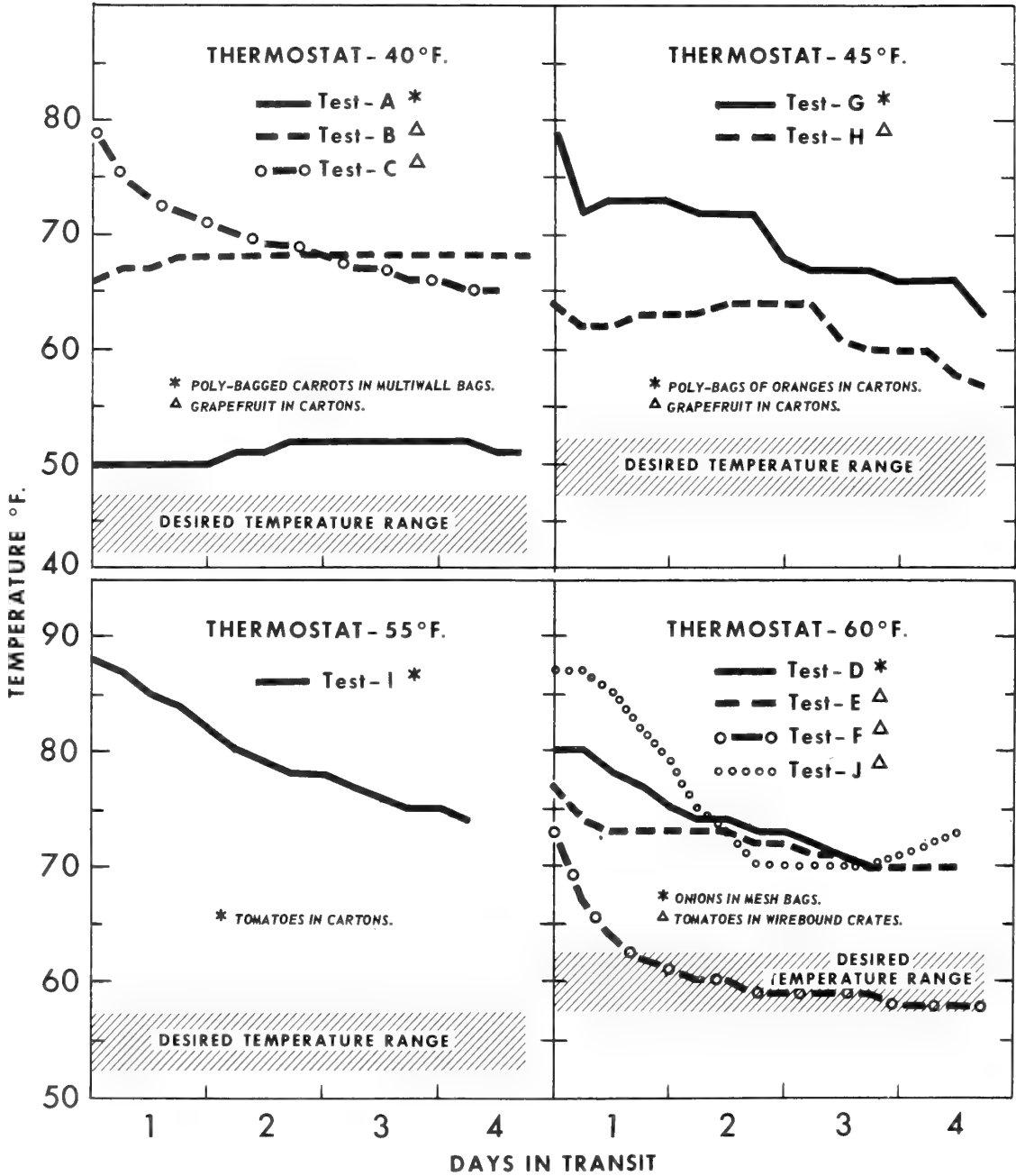
Channel and chimney loading patterns did not necessarily provide better cooling of lading than solid loading. Two loading patterns that are in common usage in rail-car shipments did not prove satisfactory in trailer loads. In test H, a spaced, crosswise carton load, cooling was fast and uniform the first 12 hours. However, cooling of the air within the trailer was considerably faster than that of the lading. The result was that air temperature was reduced to the thermostat setting in 12 hours, after which the unit was inactivated for the next 48 hours (fig. 11). Location of the thermostat and lack of positive air circulation were contributory factors to the unsatisfactory cooling. In test I, warm tomatoes in cartons were loaded in a chimney pattern. Cooling was not satisfactory (fig. 12). Each of these two loading patterns is designed for vertical movement of air through the load. Such an airflow requires ample space beneath the floor rack and close proximity to a source of refrigeration, conditions present in two-bunker iced refrigerator cars but not in trailers. When either of these two loading patterns is used in a trailer, the return airflow short circuits that part of the load most distant from the source of refrigeration (the doorway end of the trailer).

The source of refrigeration in trailers is limited to one location versus two in rail cars with two bunkers. This single source of refrigeration at one end of the loading space indicates that a horizontal airflow is needed to obtain uniform cooling in trailer loads. Test F is an example of a loading pattern which permits a horizontal airflow.

In test F, a spaced, 60-pound wirebound crate load, the through lengthwise channels in the lower layers provided adequate air return to the refrigeration unit. The solid fourth and fifth layers prevented any short circuiting of the return airflow. The important function of these two layers is to act, in conjunction with the ceiling, as a duct in conveying the air blast the full length of the load to the doorway bulkhead before its return through the channeled lower layers. Cooling in test F was rapid and uniform (fig. 9). The commodity temperature in the middle layer at the halfway stack was reduced to the desired range, an accomplishment not attained in the other 12 tests (fig. 17). The warmest location during the entire transit period was the middle layer in the nose stack near the refrigeration unit. This is most desirable, as it shows there is little or no short circuiting back over the load, and the air return flow is absorbing heat from the lading, which means a full air-circulation pattern is established.

TRUCK-RAIL TESTS

Rate of Cooling in Middle Layer-Halfway Stack-Centerline



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Figure 17

The opposite of this condition occurred in test J (fig. 13), which was similar to test F except that the loading pattern differed slightly. In test J, the solid fourth and incomplete fifth layers were loaded tight against each wall (in a 3-inch wider trailer than was used in test F). The resultant lengthwise, centerline channel, 6 inches wide in the fourth layer and 30 inches wide in the fifth layer, afforded a direct route for much of the return airflow to the refrigeration unit (via the top opening in the nose bulkhead), and thus allowed it to bypass the channeled lower layers. The absence of duct-forming, solid, complete fourth and fifth layers to properly direct the airflow resulted in slower cooling and inactivation of the unit before the entire load had cooled to the desired temperature. In test J, one of the two coldest locations was the middle layer in the nose stack. This was contrary to that in test F and showed an inadequate pattern of air circulation, with considerable air short circuiting the load. Short circuiting of the air return in test J would have been prevented if the fourth layer had been loaded six wide, tight against one wall, and the fifth layer four wide, tight against the opposite wall.

Horizontal airflow would be improved by placing the batten strips on both sidewalls in a parallel, horizontal pattern instead of the vertical arrangement used in the truck-rail trailers and the diagonal arrangement used in sea-land trailers. With a horizontal pattern, provision would have to be made for some vertical movement of air immediately adjacent to the attachment of the forward bulkhead with the sidewalls. Such an arrangement would allow the air flowing forward along the walls between the horizontal strips to pass under the forward bulkhead for return to the evaporator-blower unit.

In truck-rail service, portable 5-inch doorway bulkheads were available to be used at the option of the shipper. Their use might well be required as an adjunct to approved loading patterns. Making the bulkhead a permanent part of the rear doors would insure its use by the shipper. The trailers in the sea-land service have 2-inch batten strips attached vertically to the rear doors. Double strips (to allow a 4-inch space) are needed here, because the warmest location during part of the transit period in tests K and M was in the bottom layer of the second doorway stack. This was in contrast to the results in the truck-rail tests in which the doorway bulkhead was used. Here the bottom layer in the second doorway stack was one of the coldest locations in the load and indicated satisfactory air circulation to this point.

Outside Air Temperatures

The outside air temperature is nearly as important as the loading pattern in truck-rail service. It is a minor factor in sea-land service. This apparent paradox is explained by the differences in the air circulation systems used by the two services. Forced air circulation in truck-rail trailers is provided only when the refrigeration unit is operating; in sea-land trailers, forced air circulation is continuous.

Only in tests E and F did the refrigeration units operate continuously until the air temperature within each trailer was reduced to the thermostat setting, and then continue to operate in normal cycle. Warm outside air temperatures were responsible for the positive operation of the refrigeration units (figs. 8 and 9).

Erratic operation of refrigeration units was experienced in all other truck-rail tests. The initial operating period varied from 12 to 48 hours, during which time the air temperatures within the trailers were reduced to the thermostat settings. Low outside air temperatures kept the units inactivated after the initial operating periods. In test B, the unit operated only during the first 24 hours (fig. 5). In this connection, attention is called to the operating performance of the units in tests G and H. In test G, the unit operated a total of 32 hours and was off a total of 84 hours; in test H, the unit operated 24 hours and was off 108 hours (figs. 10 and 11). After 4 days, the bottom location in each test cooled to the thermostat setting. Cooling in this location reflects low outside air temperatures.

Static test on an empty trailer showed a 10-degree differential between the outside air temperature and that inside the trailer. Thus, outside air temperatures 10 degrees lower than the thermostat setting may keep the unit (and fan) inactivated after its initial operating period, even in a loaded trailer in which the load temperature may be considerably higher than that of the thermostat setting. The apparent reason for this seemingly contradictory condition is that the thermostat bulb is located in the unit behind the return air bulkhead where it is somewhat isolated from the load when no air is circulating. Also, its temperature may be affected by conductance of heat through the refrigerating unit structure to the low outside air and by possible leakage of the cold outside air into the return air duct through loose-fitting or damaged vent doors in the trailer nose. This condition could prevail as long as outside air temperatures remained well below the thermostat setting and the air circulation was stopped. Continuous fan operation, independent of the thermostatically controlled refrigeration system, would substantially improve product cooling and temperature distribution.

Heat leakage into the trailers did not appear to constitute a problem in either winter or summer shipments.

Load Weight

The influence of load weight on the rate of cooling of the lading is dependent upon a satisfactory combination of loading pattern and positive operation of the refrigeration unit.

In truck-rail test H, well-channeled and the lightest of the loads, cooling was not satisfactory because low outside air temperatures kept the unit inactive, even though the temperature of the lading was above the desired range (fig. 11). In sea-land tests K and M, two of the heavier loads, the refrigeration units operated continuously, but cooling was slow and uneven because of the solid loading patterns used (figs. 14 and 16).



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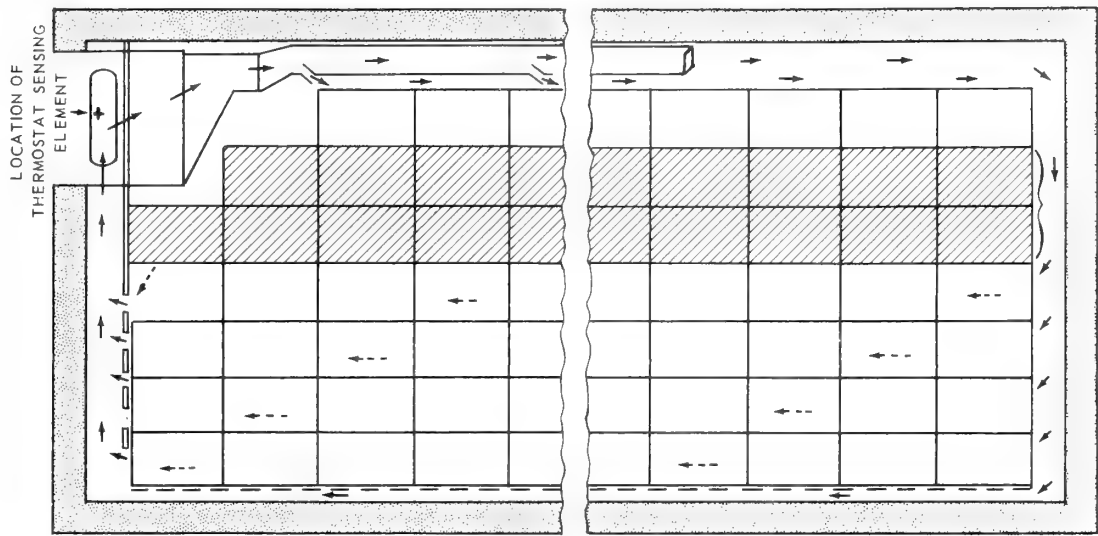
Figure 18.--Sea-land trailer load test L. Note solid loading pattern and ineffectiveness of car strips to make channels between layers.

Although cooling was slow in the sea-land tests, some cooling had occurred by the time the loads reached their destination. The solid loads had no channels other than those in the extruded floor surface and the space over the load (fig. 18). The latter became larger as the load settled. The settling was mainly at the expense of the horizontal channels between layers, which were originally provided by two car strips placed lengthwise over each container during loading.

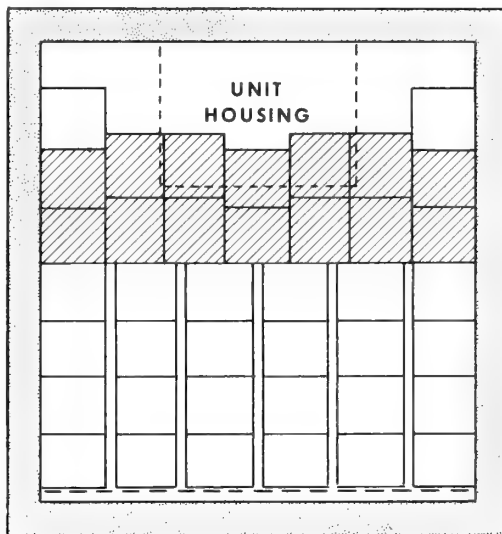
In determining "incentive rate" load weights, the refrigeration requirements of the lading should be the primary consideration in arriving at the weight limit. The requirements vary somewhat between commodities. Approved loading patterns, such as those described in test F or shown in figure 19, which provide proper air circulation, should be specified.

SUGGESTED CITRUS CARTON LOAD

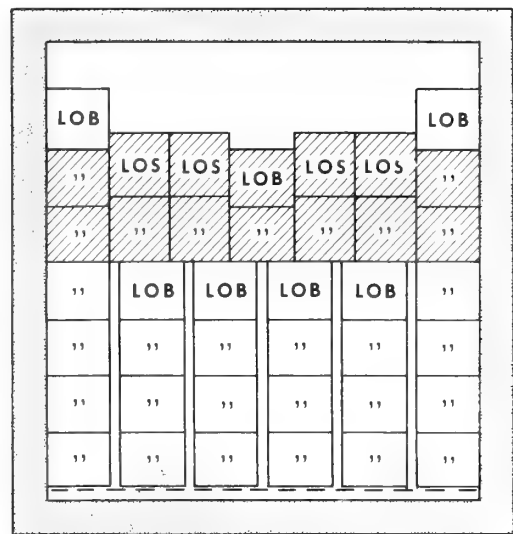
RC Truck-Rail Trailer Loading Pattern, Air Circulation



CUTAWAY SIDE VIEW



FIRST COMPLETE NOSE STACK



DOORWAY STACK

LOB- Lengthwise on bottoms
 LOS- Lengthwise on sides

Figure 19

Pulp Loading Temperature

Pulp loading temperature, as would be expected, influences transit temperatures. High loading temperatures of pulp require rapid cooling after loading, and the cooling rate is dependent upon a satisfactory combination of loading pattern and efficient unit operation. With low pulp temperatures at loading, rapid cooling is not as essential, hence loading pattern is less important. For example, in test A, in which the lading consisted of carrots hydrocooled to 45° F. before loading, transit temperatures were fairly satisfactory notwithstanding the solid loading and early inactivation of the unit by low outside air temperatures (fig. 4). Test D also had a solid loading pattern similar to that in test A, but the lading consisted of warm onions instead of precooled carrots. Load temperature was not satisfactorily reduced during transit, even though the unit operated continuously (fig. 7).

Packaging and Type of Container

The factor of packaging and type of container was the least important of the five factors mentioned as affecting the degree of cooling.

It is generally accepted that commodity cooling is hastened with increased ventilation of the container. Therefore, certain wooden containers, because of their open construction, are more easily cooled than the average vented carton; likewise, a nonbagged item cools faster than the same item in polyethylene bags when both are packed in the same type of container.

In no test could either success or failure in cooling the load be charged against packaging and type of container. In test E, tomatoes in the commonly accepted easy-to-cool wirebound crate did not cool satisfactorily, because of the solid load (fig. 8). In test G, oranges in polyethylene bags in master cartons, a combination difficult to cool, were cooled surprisingly well in spite of solid loading and erratic operation of the refrigeration unit (fig. 10).

Recommended Loading Pattern

A suggested pattern for loading refrigerated trailers equipped with a bulkhead at the nose end is shown in figure 19. The figure shows 1/2-box citrus cartons loaded in the larger RC-type trailer. However, the pattern is adaptable to any size of carton, nailed box, or wirebound container for loading in a refrigerated trailer with a bulkhead. This pattern was used in the load of tomatoes in wirebound boxes in test F, in which cooling was effective.

Figure 19 is self-explanatory as to details of loading and air circulation pattern. The importance of capping the channeled lower layers with one or two solid layers is emphasized. In this case, solid fifth and sixth layers are obtained by placing three cartons lengthwise on bottoms and four cartons lengthwise on sides in these layers in each stack. The evaporator-blower housing restricts the cap to one solid layer (the fifth) in the first nose stack. In the smaller RF-type trailer, the housing is lower than in the RC type, so that the fourth layer in the nose stack would be solid, with one-layer steps up until the housing is cleared. The sea-land trailers are similar to the truck-rail RC type in height of housing. In all cases, the loads should be laid out tight against the forward bulkhead and carried in this manner to the rear doors, allowing for at least 6 inches of free space for the doorway bulkhead. The pattern shown in figure 19 loads out 913 cartons, a 36,000-pound orange load.

The cap formed by the solid fifth and sixth layers increases the stability of the load and conducts the refrigerated air blast the full length of the trailer to the doorway bulkhead before its return through the lengthwise-channeled lower layers. This type of air circulation pattern insures effective cooling of the load.

The importance of proper air circulation and of the means to accomplish it in truck shipments of fresh produce has been recognized and described. Johnson, in a preliminary report on the results of shipping tests in truck-rail units, described the loading pattern mentioned here, using the 60-pound wirebound box. (5) Hinds, working with the 1/2-box citrus carton, introduced a pattern which uses a solid top layer over vertical channels in the first nose stack and alternate layers, channeled, in the balance of the load. (3) Hinds and Breakiron, in tests with Florida avocados and limes, recommended a pattern similar to the pattern under discussion. (2) Atrops, in tests with citrus in 1/2-box cartons shipped in mechanically refrigerated trailers lacking forward bulkheads, devised a pattern using a solid top layer, lengthwise channels, and a special baffle to direct the airflow. (1)

The several patterns described are similar in that all use a solid one- or two-layer cap over channeled lower layers. The end result, regardless of the specific pattern used, is effective cooling. Selection of the pattern to be used by the individual shipper will be governed by the type of equipment available and by ease of loading.

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