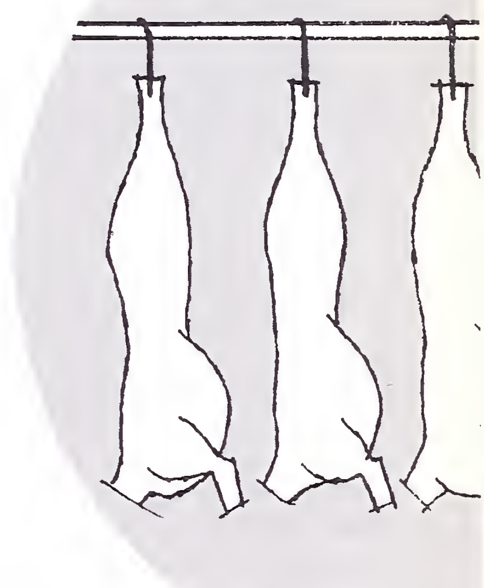
FRESH LAMB transported by REFRIGERATED RAIL CARS and PIGGYBACK TRAILERS



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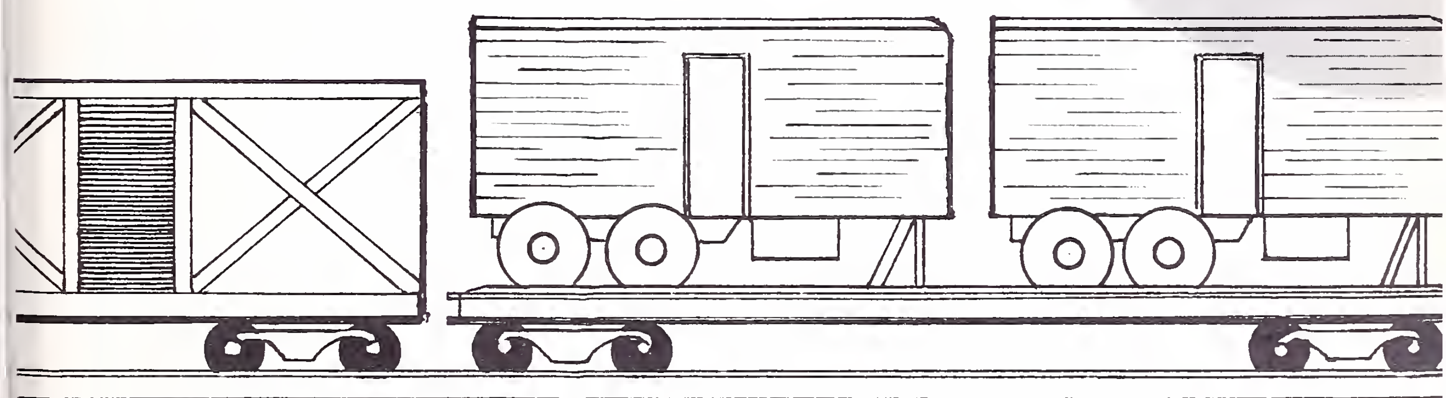

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Transportation and Facilities Research Division
Market Quality Research Division

PREFACE

This study is part of a broad program of research to improve the design and performance of equipment for transporting agricultural products, as a means of improving the efficiency of marketing farm products.

The purpose of this test was to evaluate the ability of refrigerated rail cars and trailers to transport fresh lamb at the recommended temperature of 32° to 34° F.

The following companies cooperated in the test: Burlington Refrigerator Express Company; Chicago, Burlington, and Quincy Railroad Company; Pacific Fruit Express Company; and Pennsylvania Railroad Company.

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Washington, D. C. July 1962

SUMMARY

This report covers a test of two refrigerated rail cars and two refrigerated trailers moving fresh lamb from Pueblo, Colo., to Philadelphia, Pa. One of the cars was mechanically refrigerated, and the other used water ice and a new system of air circulation. Both trailers were mechanically refrigerated; one had overhead air distribution ducts and the other had no air ducts.

Twenty thermocouple wires were installed in each car and trailer before loading, to obtain lamb and air temperatures at various locations every 2 or 3 hours en route. A humidity sensing element was also placed in each vehicle.

The entire shipment of lamb arrived in good condition at destination with temperatures on arrival approximately the same in all vehicles. The lamb in one car, however, had a shrinkage, or weight loss, of 1.25 percent en route, while the shrinkage in the other car was 0.55 percent. The shrinkage was probably more in the first car because the air flowed through the load of hanging meat; in the second car the air flowed around the cargo area through flues formed by false walls, ceiling, and floor. Moving air at high velocity over the meat possibly causes more loss of weight, or shrinkage, than if there is relatively little air movement. Some carcasses from each trailer were weighed for shrinkage, but the number was not enough to give significant results.

This test indicates that the equipment used in the test is capable of transporting and delivering fresh lamb in good condition. Further tests should be made to ascertain the exact effect of various methods of air circulation on weight loss, or shrinkage, en route.

FRESH LAMB TRANSPORTED BY REFRIGERATED RAIL CARS AND PIGGYBACK TRAILERS

By J. J. Dougherty, R. Kulwich and R. W. Penney
Agricultural Marketing Service 1/

INTRODUCTION

Recent years have seen rapid improvements in the equipment used for transportation of perishable foods. New construction methods and better insulating materials have resulted in vehicles in which the refrigeration equipment can more effectively operate. Modifications and improvements in the basic means of refrigeration have resulted in more reliability and better efficiency in the systems installed in the vehicles.

This report concerns a test of refrigerated vehicles, some of which had modified systems or improvements in the installed equipment. The test vehicles were two semitrailers, carried "piggyback" on a flatcar, and two rail cars carrying fresh lamb from Pueblo, Colo., to Philadelphia, Pa. Both trailers were mechanically refrigerated. One of the cars was mechanically refrigerated; the other was a water-ice car with a new system of forced air circulation.

DESCRIPTION OF CARS AND TRAILERS

Figures 1, 2, and 3 show the general arrangement, refrigeration installation, and the air distribution system in the vehicles. Figures 4 and 5 show the trailers and cars used in the test. Tables 1 and 2 show data on the cars and trailers.

Car A was a conventional water-ice car which had been rebuilt with two new features added. One ice bunker had been enlarged to a capacity of 8,200 pounds of crushed ice. The other bunker had been eliminated, thus increasing the internal length of the car by over 3 feet. The other feature was an air circulation system which operated continuously both when the car was in motion and when it stood still. A diesel engine, rated at 3.7 horsepower, was mounted under the car. This engine drove a generator, which supplied the current to operate four fans and the necessary control equipment. One of the

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1/ Mr. Dougherty and Mr. Penney are mechanical engineers in the Transportation and Facilities Research Division. Dr. Kulwich is a biochemist in the Market Quality Research Division.

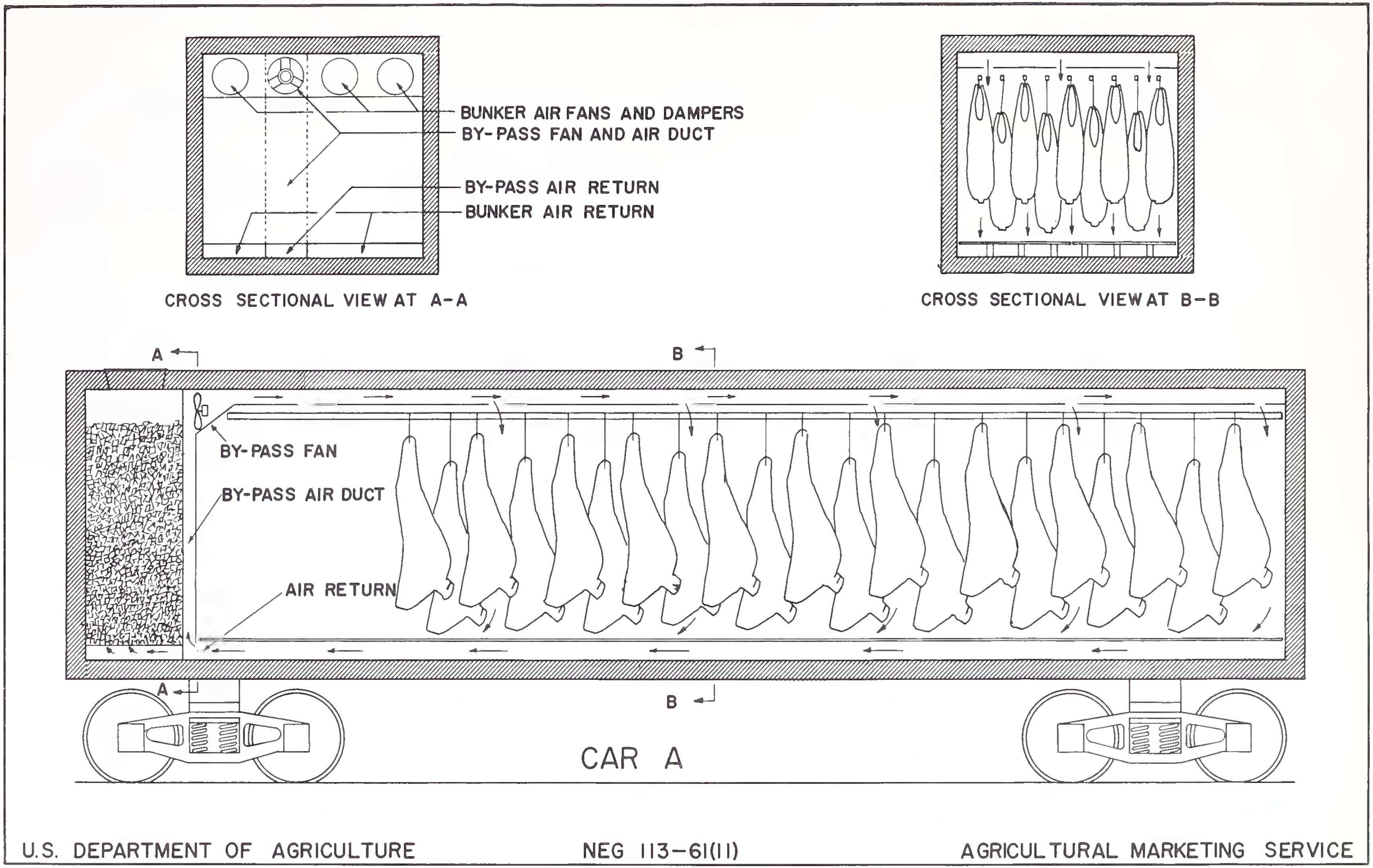

Figure 1.--General arrangement, refrigeration installation, and air distribution system in car A.

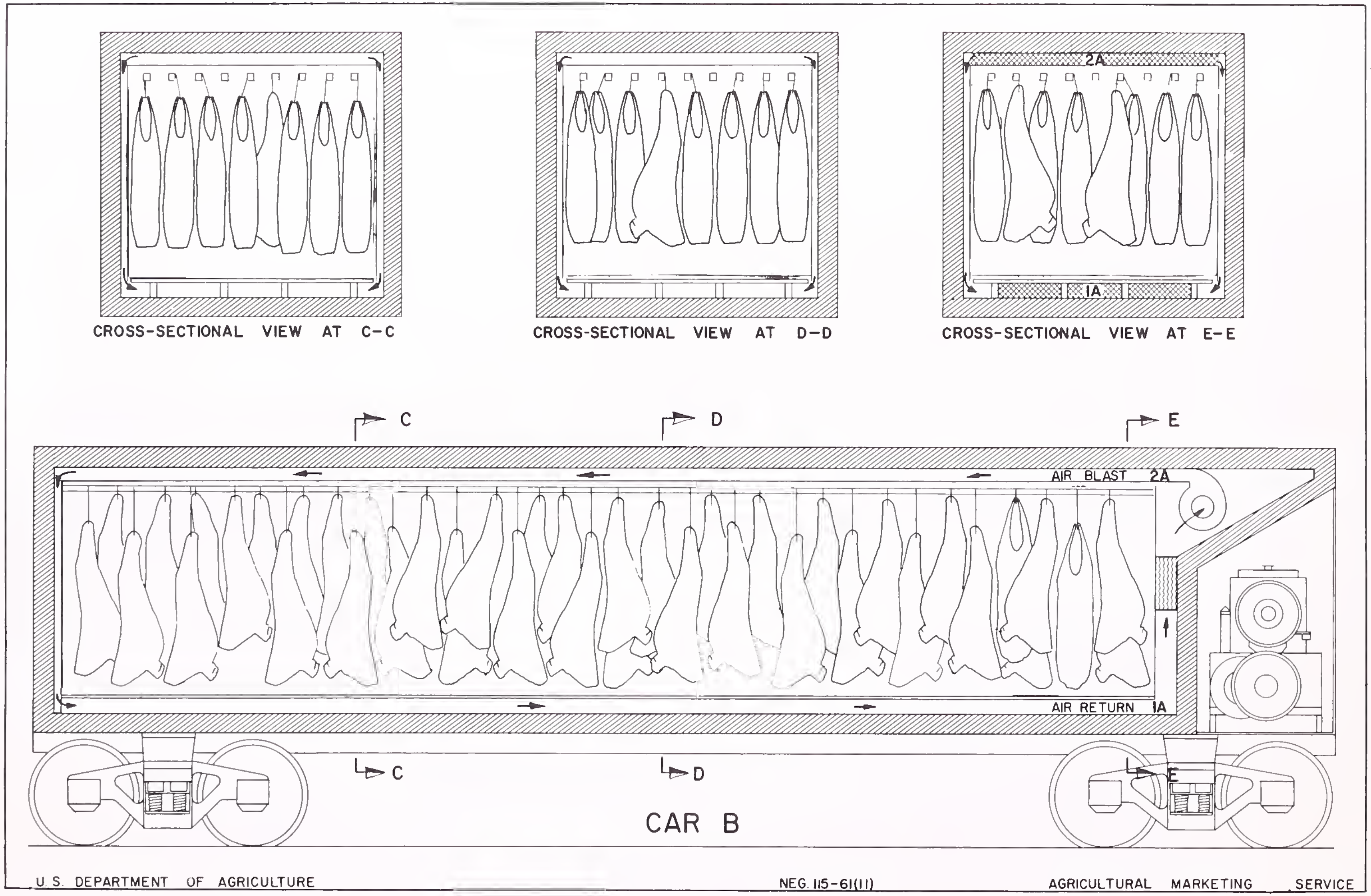

Figure 2.--General arrangement, refrigeration installation, and air distribution system in car B.

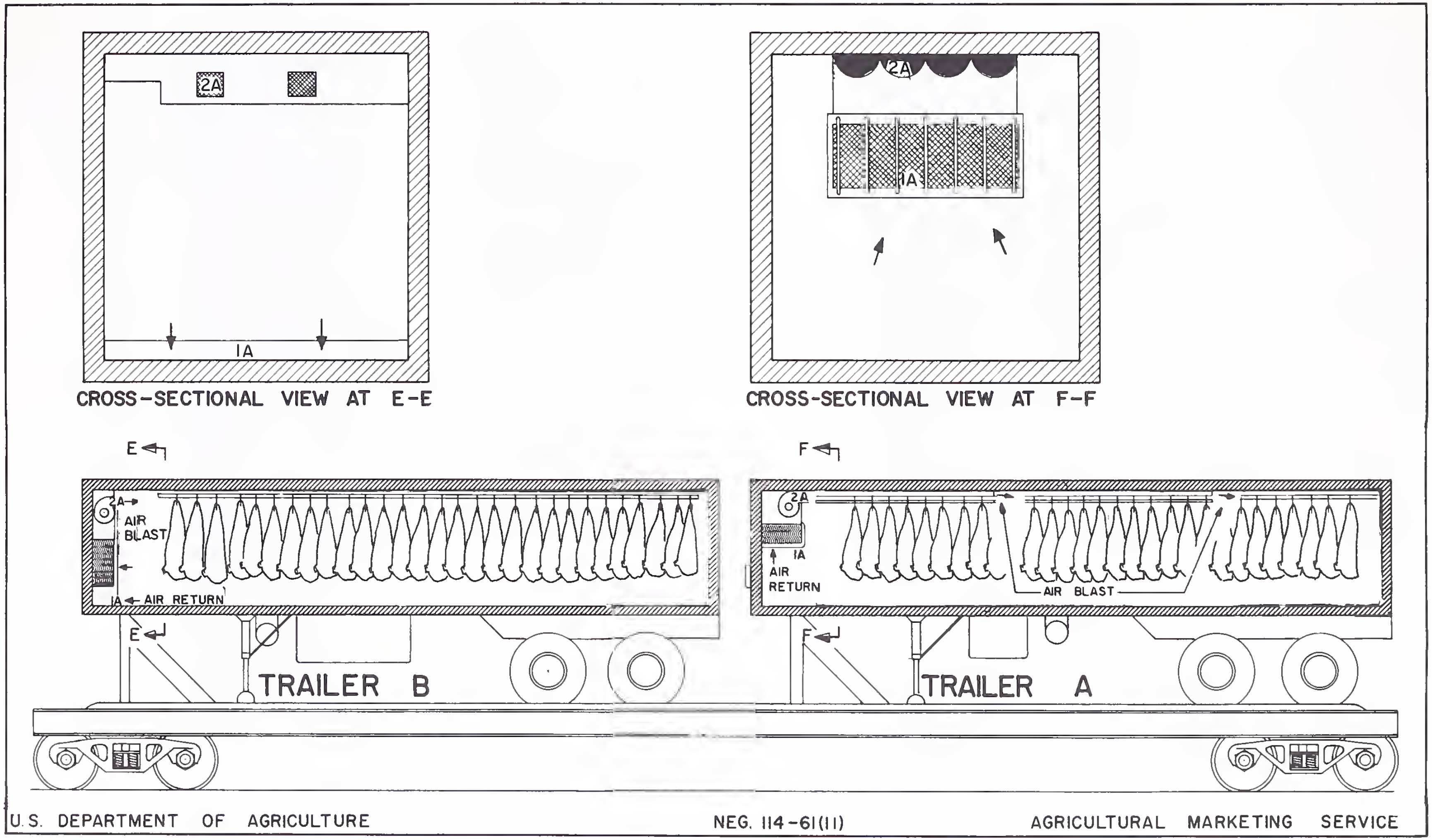

Figure 3.--General arrangement, refrigeration installation, and air distribution systems in trailer A and B.

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Figure 4.--Cars used in this test.

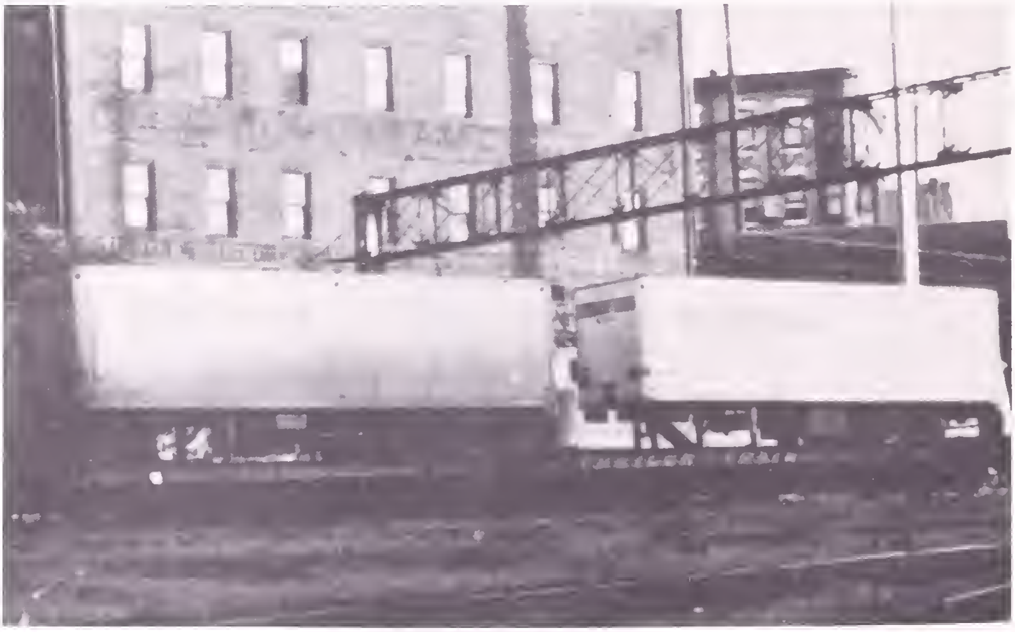

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Figure 5.--Trailers used in this test.

Table 1.--Data on car and trailer bodies

Vehicle	Load limit	Light wt.	Inside lgth.	Inside width	Inside ht.	Inside vol.	Meat rails	Floor racks	Insulation			
									Floor	Walls	End	Roof
	Lb.	Lb.	Ft-in.	Ft-in.	Ft-in.	Cu.ft.	No.					
Car A	60,000	-	36-6	8-2	6-8	2,005	9	Yes	4½" styrofoam panel	2 - 2" blankets of 50% jute and 50% fiber reflective paper.	2 - 2" blankets of 50% jute and 50% fiber reflective paper.	2" blanket glass fiber. 2½" blanket glass fiber reflective paper.
Car B	126,300	83,700	44-2	8-6	7-3	2,737	9	No	3" multilayer panel and 4" glass fiber.	3" multilayer panel and 4" glass fiber.	3" multi layer panel and 4" glass fiber.	7" glass fiber. 3" multilayer and ½" fiber board.
Trailer A	36,000	14,770	33-11	7-3	7-1	1,665	7	No	5" expanded polystyrene.	3" expanded polystyrene, 1" glass fiber.	4" molded styrene.	6" glass fiber.
Trailer B	36,000	14,770	33-11	7-3	7-1	1,570	7	No	5" foamed-in-place polyurethane.	4" foamed-in-place polyurethane.	4" foamed-in-place polyurethane.	6" foamed-in-place polyurethane.

Table 2.--Refrigeration equipment in cars and trailers

Vehicle	Refrigeration unit	Method of cold air distribution
Car A	Ice in the one bunker in the car. Diesel engine drives generator which supplies current to fans. Diesel starts manually and operates continuously. Fuel tank capacity, 60 gallons.	Air blown into plenum chamber above false ceiling in car. Air flows to cargo space through 24 evenly spaced openings in false ceiling. Openings equipped with dampers. Air flows over cargo to space under floor racks and returns to evaporator.
Car B	Mechanical, 2-cylinder diesel, 34 hp., liquid cooled. Two speeds 1,200 r.p.m. and 800 r.p.m. Two separate refrigeration systems, one for low load, both for high load.	Cold air circulated through a semi-envelope system. Air is blown into false ceiling, down end- and side-wall flues and under floor, then returns to evaporator.
Trailer A	Mechanical, 4-cylinder diesel engine mounted underneath trailer with evaporator mounted inside nose of trailer; 12-volt starting system; thermostat range -10° to +70° F. Fuel tank capacity, 40 gallons.	Cold air blown into four plastic cloth air ducts, two delivering air into cargo space one-third distance from front, the other two delivering air two-thirds distance from front; thence free return to cooling coil.
Trailer B	Same as trailer A.	Cold air blown from front toward rear of trailer over top of lading with free return to bottom of bulkhead in front of cooling coil.

fans operated continuously, circulating the air throughout the cargo space but bypassing the ice bunker. Operation of this fan eliminated stratification of warm and cold air in the car. The other three fans, controlled by a thermostat, circulated air through the ice bunker, through the cargo space, and back to the bunker. All four fans in this car discharged into a plenum chamber above the false ceiling. Air flowed into the cargo space through evenly spaced openings in this false ceiling. The air flowed over the cargo and through the floor racks to the air return. No salt was mixed with the ice in this car.

Car B was of semi-envelope construction--false walls, ceiling, and floor inside exterior of car--with a mechanical refrigeration system driven by a diesel engine. The airblast went into a plenum chamber above the false ceiling, down the side- and end-wall flues, and returned under the floor to the evaporator. Openings in the false ceiling allowed some of the air to flow over the cargo.

The two trailers were similar except for the type of insulation and the system of air ducts in trailer A. These air ducts, which provided for a more even distribution of air in the trailer, consisted of four ducts made of plastic. Two of them delivered half the airblast at a point about one-third the distance from the front of the trailer; the other two delivered the rest of the airblast at a point about two-thirds of the distance from the front.

Trailer B had no air duct system. In this trailer the air was blown from the cooling coil over the top of the lading with free return to the opening in the bottom of the bulkhead at the front of the trailer.

TEST PROCEDURE

Each car and trailer had 20 thermocouples installed prior to loading; 14 of these were to obtain lamb temperatures; the other 6 measured air temperatures in various parts of the cargo space. Figure 6 shows the locations of the thermocouples in the vehicles. The thermocouple leads ran to an electronic temperature indicator which, with its necessary switch gear, was located in the instrument car. Humidity sensing elements were placed in each vehicle, wires from the elements leading out through the door seals. At train stops en route relative humidity readings were taken with an electric hygrometer.

Test cars and trailers were adequately precooled before loading. The thermostats in all vehicles were set at 35° F.

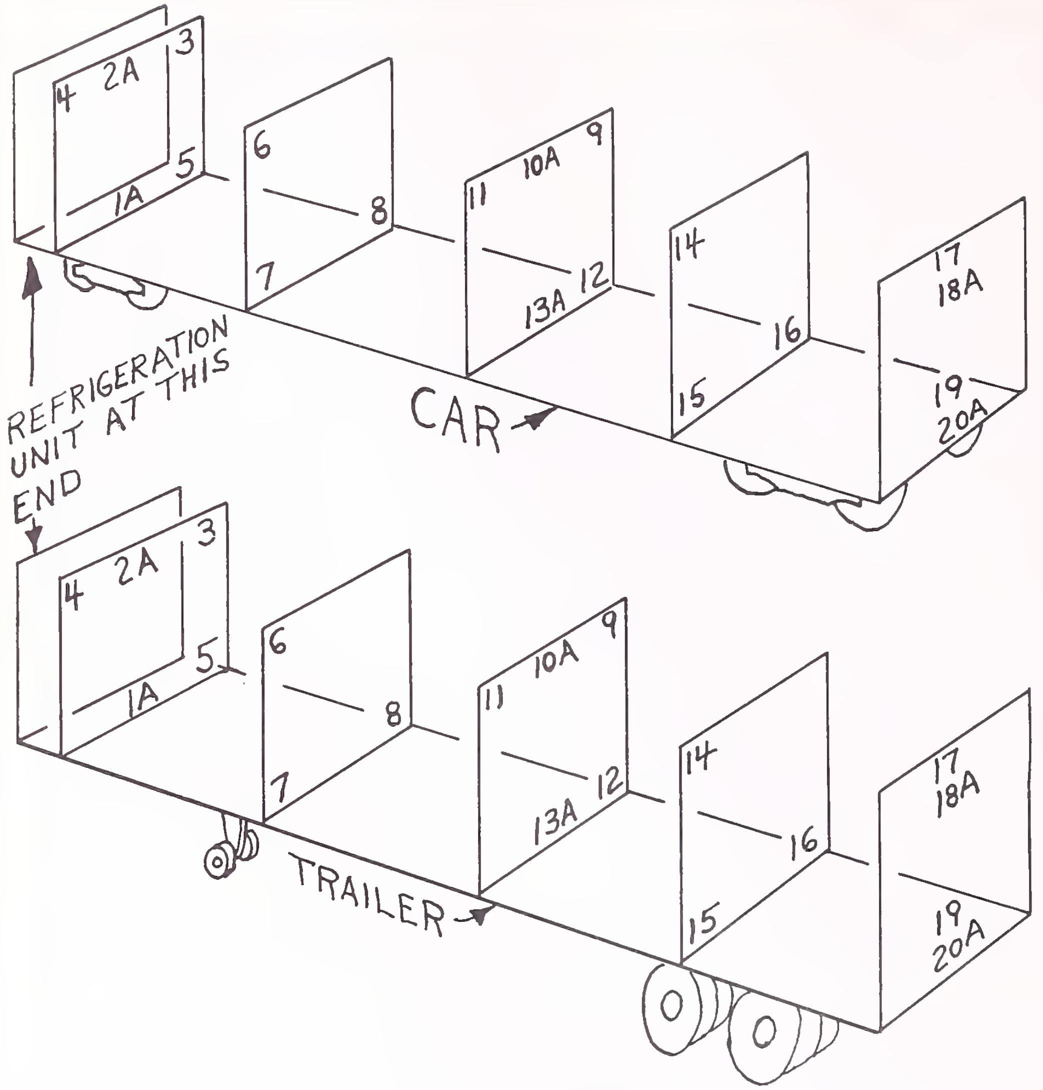
The test cars were loaded on the morning of August 8 with 500 lamb carcasses each. The test trailers were loaded on the morning of August 9, trailer A with 437 lamb carcasses and trailer B with 470; on this date, also, car B was loaded with an additional 70 lamb carcasses, making its total cargo 570. The lamb had been slaughtered the morning before and chilled for 24 hours before loading.

Loading was completed by noon on August 9. The trains left Pueblo about 8 p.m. on August 9 and arrived at Philadelphia at 6:20 a.m. on August 13. Temperatures were taken every 2 or 3 hours throughout the trip.

When the cars were unloaded at Philadelphia, 25 carcasses from each car were weighed to determine the shrinkage en route.

TEST RESULTS

Figures 7 through 10 show temperatures during the trip. The initial readings on these curves were taken immediately after the vehicles were loaded and the doors sealed. These initial temperature readings seem inconsistent with the 24-hour chilling period of the lamb. But the loading dock was not refrigerated, and during the loading both the lamb and the precooled cars and trailers were exposed to the warm ambient air. Although the harm caused to fresh meat by such warming up is not immediately discernible, it is entirely possible that this change in temperature would affect the keeping quality of the meat. The most harmful effect of moving fresh meat at a temperature of about 35° F. from the chilling room to a warm loading dock would probably be the condensation of moisture on the fresh meat, a condition favorable for the slime-forming microorganisms.



No.	Location			No.	Location		
1A	Return air			11	½ length, top, left side		
2A	Blast air			12	½ length, bottom, right side		
3	Front, top, right side			13A	½ length, bottom, center air		
4	Front, top, left side			14	3/4 length, top, left side		
5	Front, bottom, right side			15	3/4 length, bottom, left side		
6	¼ length, top, left side			16	3/4 length, bottom, right side		
7	¼ length, bottom, left side			17	Rear, top, center		
8	¼ length, bottom, right side			18A	Rear, top, center air		
9	½ length, top, right side			19	Rear, bottom, center		
10A	½ length, top, center air			20A	Rear, bottom, center air		

Note: All are commodity temperatures except those designated "A" which are air.

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Figure 6.--Locations in cars and trailers at which temperatures were taken by 20 thermocouples.

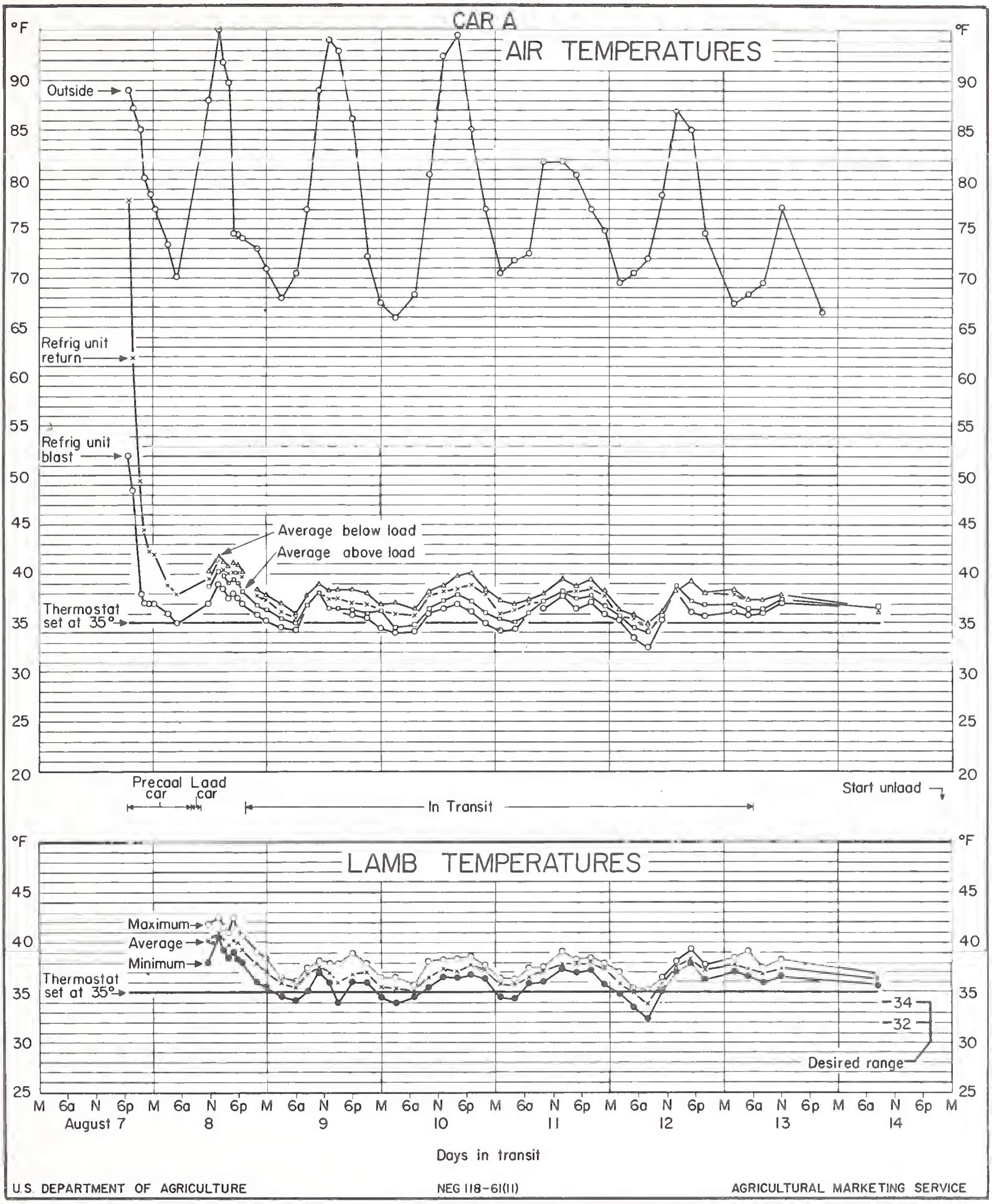

Figure 7.--Temperatures in car A with ice bunker and continuous air circulation through the load.

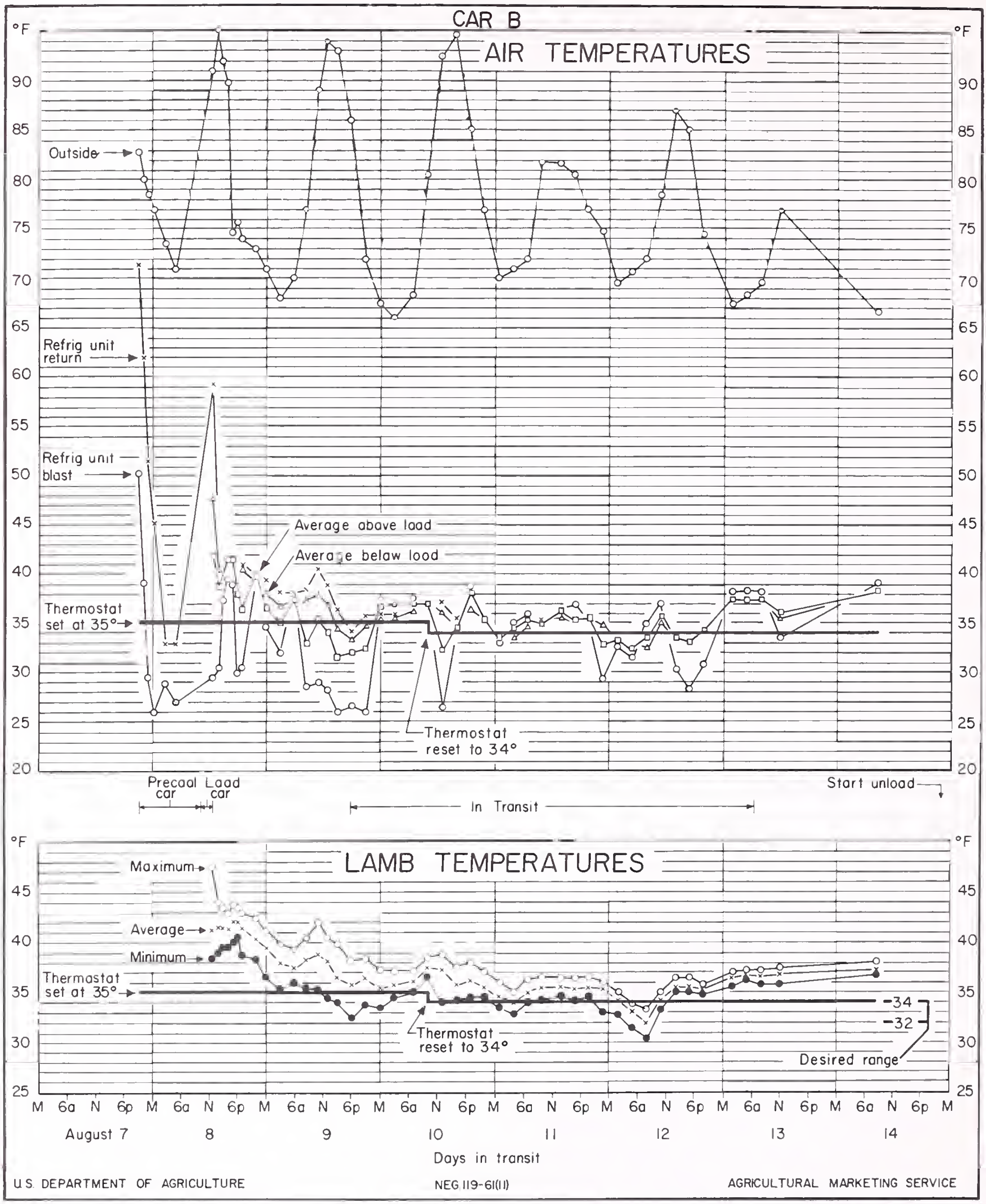

Figure 8.--Temperatures in car B with mechanical refrigeration system. False walls, ceiling and floor inside the car formed an enclosure through which the air could move around the cargo area; some of the air entered the cargo area through openings in the false ceiling.

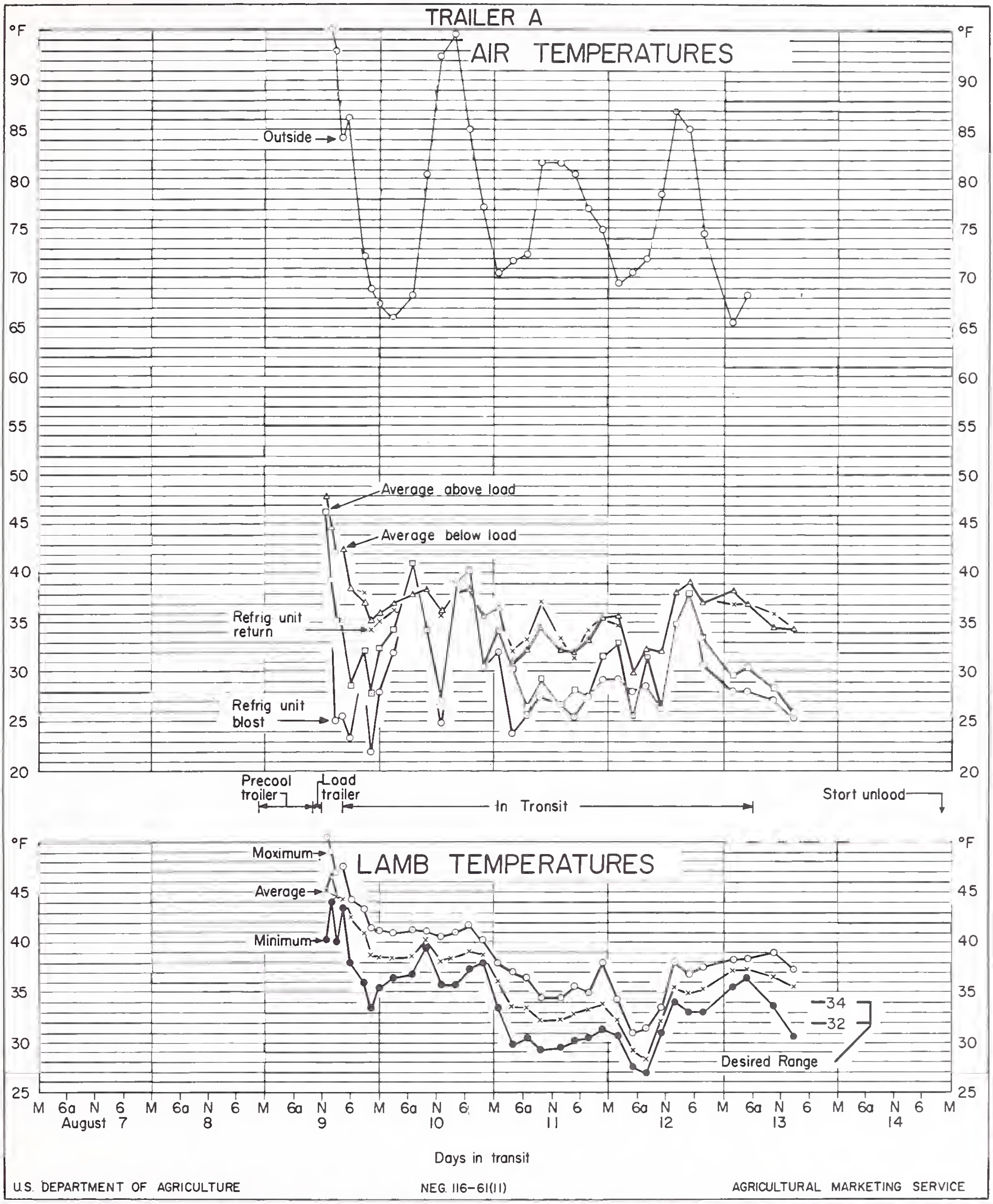

Figure 9.--Temperatures in trailer A with mechanical refrigeration system and four ceiling ducts for air distribution.

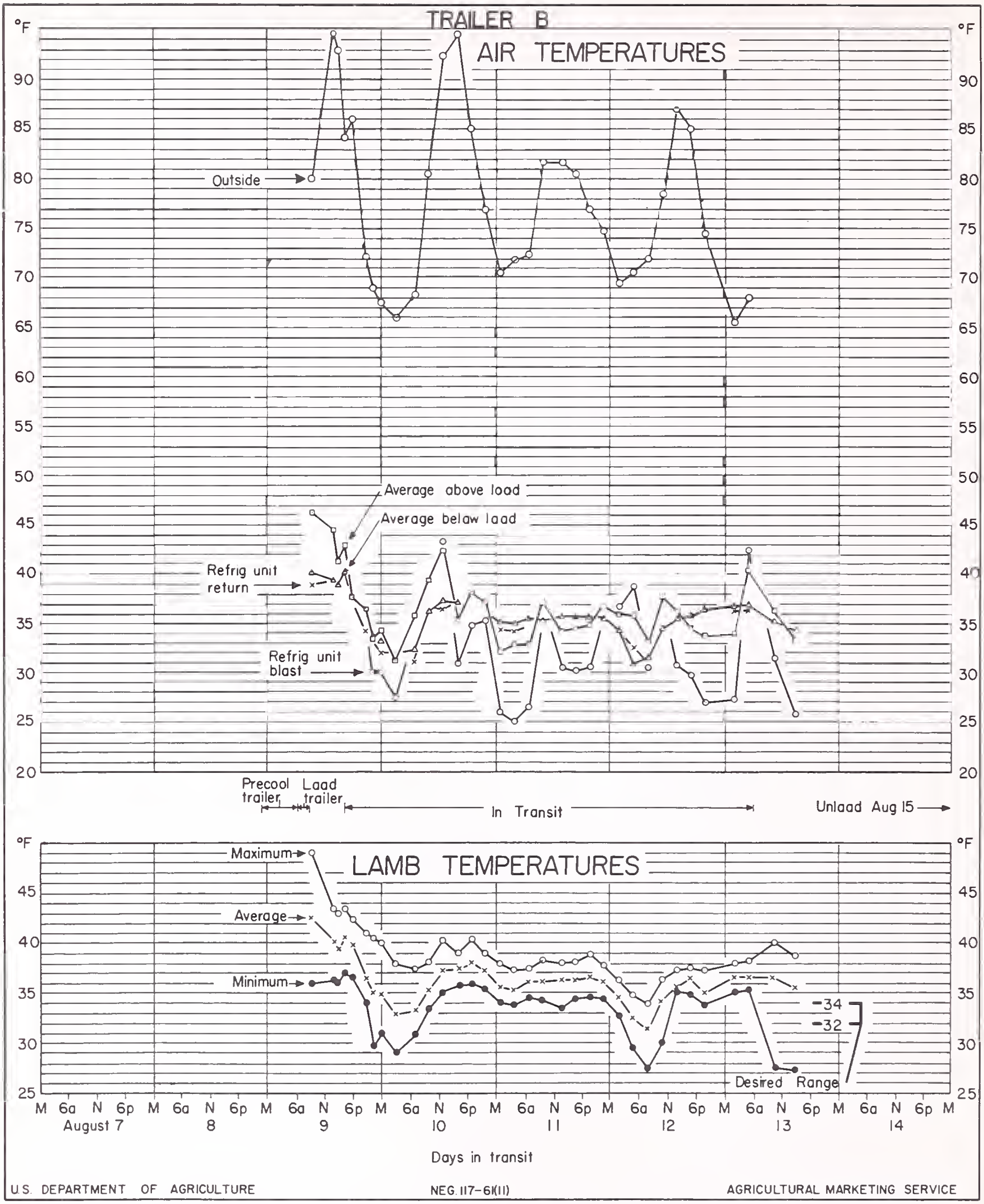

Figure 10.--Temperatures in trailer B with mechanical refrigeration system and air blasted directly into load.

The resume of lamb temperatures during the test is shown in table 3. The temperatures en route are from the time the lamb temperatures had stabilized after loading until arrival of the meat at destination.

Car A.--The thermostat was initially set at 35° F. On the second day, the temperature readings being too high, the thermostat was reset at 34° F. The maximum temperature at any point in the cargo during the trip was 39°, and the minimum temperature was 32.4°. The temperature spread on arrival in Philadelphia was 1.5°. Most of the time the warmest spot was at the bunker end of the car (thermocouple position No. 3, fig. 6) and the coldest spot in the cargo was at the opposite end of the car. However, with a temperature spread as small as this, the location of the hot and cold spots is probably of little, if any, significance. At any rate, one operational test such as this would not be very indicative.

Car B.--The thermostat was initially set at 35° F. and remained there throughout the trip. The maximum temperature in the cargo during the trip was 39° and the minimum was 32.4°. The temperature spread during most of the trip was two degrees or less. The coldest spots in the car were at or near the end of the car containing the refrigerating unit; the warmest spot in the car varied throughout the trip, sometimes near the ceiling, sometimes near the floor. Again, with such a small temperature spread, the location of the hot and cold spots would seem to be of little significance.

Trailer A.--The thermostat was initially set at 35° F. On the third day of the trip the lamb temperature went unduly low; consequently, the thermostat was raised at 7:30 a.m. on August 12. Temperature readings at one point during the trip indicated that the defrost mechanism was not operating properly. After the controls had been manually operated to defrost the coil, the mechanism seemed to operate properly for the rest of the trip. The maximum temperature at any one point during the trip was 41.8°; the minimum was 27°. The average temperature spread was 4.4°. Most of the time the warmest spot was near the ceiling, at the front of the trailer, and the coolest spot was near the rear of the trailer.

Trailer B.--The thermostat was initially set at 35° F. About 8 hours after loading, the thermostat on this trailer also had to be reset to a lower temperature. The maximum temperature at any point during the trip was 40.0°, the minimum 27.4°. The maximum temperature spread at any one reading was 6.4°, the minimum 2.3°. The average spread was 4.8°. During most of the trip the lowest temperatures were near the front, and the highest temperatures were near the rear door.

CONCLUSIONS

Inspection of the lamb upon arrival at destination showed the entire shipment to be in good condition. However, there was enough difference between the performances of the individual cars and trailers to warrant comment.

Table 3.--Lamb temperatures in cars and trailers

Vehicle	Temperature at loading				Temperature at destination				Temperature spread en route*		
	Average top	Average bottom	Spread Min.	Spread Max.	Average top	Average bottom	Spread Min.	Spread Max.	Maximum	Minimum	Average
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
Car A	40.0	40.3	38.0	42.0	37.4	37.4	36.6	39.2	4.0	1.0	2.9
Car B	40.6	40.9	38.5	47.5	36.8	36.6	36.2	37.7	6.7	1.0	2.9
Trailer A	46.7	43.7	40.5	51.0	37.5	37.2	36.4	38.2	7.2	1.7	4.4
Trailer B	42.3	43.1	36.0	49.0	36.6	36.6	35.2	38.2	6.7	2.3	4.1

* These figures do not cover the period immediately following loading; temperatures were allowed to stabilize for a period of about 18 hours before these temperatures were taken from the test data.

As in earlier tests, it was noted that not all thermostats were accurately calibrated.

This test illustrates one of the difficulties of refrigerated transportation. In the meat packing industry the desired conditions of temperature, humidity, and air circulation rate are well understood. Consequently, chilling rooms and holding rooms are designed and constructed to meet these requirements. These requirements are difficult to meet in the construction of refrigerated vehicles, especially in semitrailers, because of space and weight limitations.

If the meat has been properly chilled and loaded into the car or trailer with no temperature rise, then the vehicle is in effect a holding room. Air circulation is necessary in the holding room to prevent sliming; however, too large an airflow will increase drying of the meat and cause shrinkage losses.

In car B much of the airblast circulated above the false ceiling, down the side- and end-wall flues and under the floor; only part of the airblast circulated around the hanging meat. This airflow and a satisfactory relative humidity (84 percent) resulted in a meat shrinkage of 0.55 percent during the trip.

Car A, in which all of the airblast flowed over the cargo, had a shrinkage more than twice that of car B, 1.25 percent, even with a satisfactory relative humidity (87 percent).

While some carcasses were taken from both trailers to determine shrinkage, the number available for this purpose was not great enough to give reliable shrinkage figures. In trailer B (without the air ducts) the carcasses near the front of the trailer were subjected to greater airflow than those in the rear of the trailer, and the relative humidity in the rear of the trailer was lower than in the front. Under such different conditions shrinkage might well vary considerably with location. In future tests, every tenth carcass, perhaps, should be weighed accurately to obtain shrinkage figures.

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