Marketing Research Report No. 689

# AIRFLOW LOADING PATTERNS FOR TRUCK SHIPMENTS OF EARLY POTATOES

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Service

## PREFACE

This study was aimed at improving the circulation of air through the potato load by new loading patterns. A number of individuals and organizations contributed to the study. Cooperators were the F. H. Vahlsing Co., Hasting Potato Growers, Winn Dixie Stores, Food Fair Stores, Abney Cox, and numerous individual truckers. Staff members of the U. S. Department of Agriculture who helped with the study were William R. Black, William F. Goddard, Kenneth Myers, Thomas H. Camp, and Boris P. Rosanoff. General supervision was furnished by P. L. Breakiron, Transportation and Facilities Research Division, Agricultural Research Service.

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## HIGHLIGHTS

During three seasons, five airflow loading patterns were developed for bagged potatoes shipped by motortruck. These patterns use a single basic design for improving air circulation by providing a number of continuous longitudinal channels through the load.

Data from test shipments showed that when the trucks operated at approximately 50 miles per hour under ventilation, the average velocity of air ranged from 141 feet per minute to 274 f.p.m. in the circulation channels and from 280 f.p.m. to 472 f.p.m. over the top of the load. Air movement through the channels provided by the stacking pattern caused temperatures throughout the load to change directly with the ambient (outside air) temperature. The air moving through the channels sometimes made it possible to remove excess moisture from damp potatoes.

These patterns are easy to load in any size vehicle and provide the trucker a full payload with proper weight distribution. The patterns are stable, remaining intact during transit, and do not increase damage to containers or product.

# AIRFLOW LOADING PATTERNS FOR TRUCK SHIPMENTS OF EARLY POTATOES

By Russell H. Hinds, Jr., *transportation economist*, and J. Kenneth Robertson, *industry economist*,
Transportation and Facilities Research Division, Agricultural Research Service

## BACKGROUND OF STUDY

Motortrucks carry a large portion of the Nation's potato crop to market. Overheating and spoilage during transit often are excessive in early-crop potatoes shipped in the spring from southern producing areas and in summer and early-fall shipments from northern producing areas. Potatoes harvested in warm weather should have field heat, respiratory heat, and sometimes excessive moisture removed during transit.

Desired transit temperatures for early crop potatoes intended for the fresh market are in the 55° to 65° F. range.[1] Temperatures of most early-crop potatoes when loaded for shipment are considerably above this range. The product also generates additional heat during transit in its normal respiratory process. A ton of potatoes at 60° F., for example, produces 4,000 B.t.u. for each 24-hour period immediately after harvest.[2] This means that a 30,000-lb. load of early potatoes at 60° F. produces 60,000 B.t.u. of heat per day. As the rate of respiration of potatoes varies directly with the temperature, many shipments produce more than this amount of respiratory heat. Because decay originating from bruises, cuts, and skinned areas or heat injury during harvest can be controlled by relatively low temperatures, excess heat from all sources should be removed as rapidly as possible. Ventilation or use of outside air for cooling is the least expensive and most widely used present method of accomplishing this removal.

Temperature variations among potatoes in the load may cause condensation. Some of this temperature variation depends upon the location of the potatoes in the load.[3] Those at the outer edges of the trailer are generally cooler than those in the middle, and water vapor may condense on the cooler potatoes. This condensation. if not removed, has two adverse effects. First, prolonged exposure to excessive moisture promotes the development of decay. Second, part of it is absorbed by the paper shipping bags. This weakens the container and detracts from its appearance.

Moisture in shipments of potatoes is also attributable to factors other than variation in pulp temperatures. Some moisture develops from condensation when cool potatoes are exposed to warm, humid air. Additional moisture is given off by the product in respiration. As temperature variations of both air and pulp contribute to condensation, the variations should be kept as small as possible. This is best achieved with the circulation of outside air through the load.

Bagged potatoes are usually tight-stacked in the trailer, and effective cooling or moisture removal is difficult to accomplish throughout the entire load. This is because air circulation inside the truck in both the ventilated and refrigerated tight-stack loads is over the top of the load. Consequently, there is little cooling effect on any bags except those in the top layer and some sidewall rows. For this reason many loads of the conventional tight-stack patterns arrive at market with pulp temperatures only slightly lower than at the shipping point. This is true even though refrigeration is supplied or cool outside air allowed to enter the trailer during transit.

This study was undertaken to develop new loading patterns for bagged potatoes which would facilitate the removal of excess heat and moisture more effectively by promoting better air circulation.

## DEVELOPMENT OF STACKING PATTERNS

Many truck loading patterns are used by shippers only because they are simple, easy to learn, and provide an easy method of counting the containers. The stacking patterns most often used by potato shippers are illustrated in figures 1 and 2. These patterns overlook or neglect some of the more important considerations of damage reduction and temperature

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[1] Redit, W. H., and Hamer, A. A. protection of rail shipments of fruits and vegetables, U.S. Dept. Agr., Agr. Handb. 195, 108 pp. illus. July 1961.

[2] Claycomb, Richard S. pallet boxes for handling and storing potatoes. U.S. Dept. Agr., AMS-455, 56 pp., illus. October 1961.

[3] Edgar, Alfred D. shell ventilation systems for potato storages in the fall crop area. U.S. Dept. Agr., Mktg. Res. Rpt. 579, 43 pp., illus. January 1963.

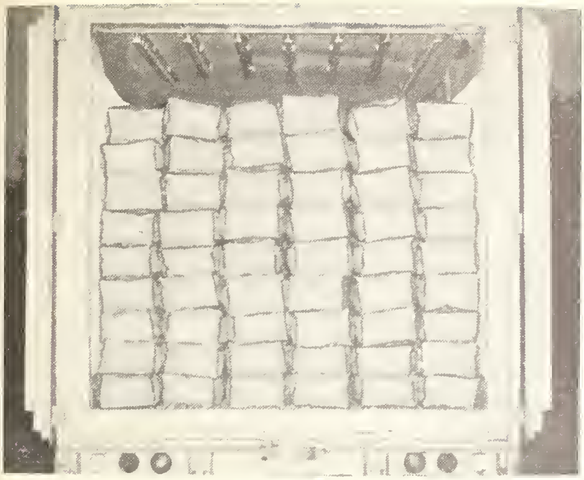

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FIGURE 1.—Conventional tight-stack pattern for 50-pound paper sacks without provision for air circulation through center of load.

maintenance that are necessary to reduce product loss.

A good stacking pattern must satisfy the following requirements:

1. It must be practical and not too complicated for the loaders to use.
2. It must lend itself to rapid stacking.
3. It must be readily adaptable to any size trailer.
4. It must have sufficient density to provide a full payload.
5. It must have adequate channels to provide air circulation throughout the load.
6. It must be sufficiently stable to remain intact during transit.
7. It must help prevent container failure and commodity damage.
8. It must be acceptable to shipper, receiver, and trucker.

To meet these requirements, a general airflow design was used in developing the loading patterns. This design provided numerous longitudinal channels, extending from front to rear, for improved air circulation in all parts of the load. By special arrangement of the front stack, these channels were open at both ends for better circulation. This arrangement enables the front stack to serve as a plenum to direct the incoming air to each of the individual longitudinal channels. The path of air movement through these channels for both ventilated and refrigerated loads is shown in figure 3.

## Patterns for 50-Pound Paper Sacks

The dimensions of 50-pound paper sacks vary according to the type of pack and method of bag closure. These variations in size are shown in figure 4 for both the master, or baler bags, and the bulk-pack sacks using the taped and wire-twist closures. The general airflow design had to be modified to accommodate these variations and the differences in the inside widths of trailers. Although almost all refrigerated and nonrefrigerated trailer vans have an overall outside width of 96 inches (8 ft.), the interior widths vary from 80 to 92 inches, but mostly from 84 to 89 inches.

Three airflow patterns for loading 50-pound sacks proved suitable for most of the van widths. Any of the three patterns may be used for the four sack sizes, the determining factor being the width of the cargo area of the trailer.

Pattern No. 1 using the 50-pound twist-tie master bag is shown in figure 5 in a trailer with 2 inches of insulation in the sidewalls. View A illustrates the front or header stack. This stack consists of seven layers and three rows of two-bag length. It is capped by the seventh and top layer: one bag placed lengthwise along each sidewall, one placed lengthwise over the top of the middle row, and two bags placed crosswise over each of the two vertical channels so that they rest almost equally on the middle row and adjacent sidewall row. This particular pattern may contain more or less than seven layers, depending on the height of the trailer and the local weight limitation imposed upon the vehicle. View A also shows the screened opening in the bottom of the bulkhead adjacent to the header stack. This opening provides access for the incoming air to each of the longitudinal channels in the various layers.

View B shows the pattern for all subsequent stacks in the load. These stacks are constructed of alternating layers. The first layer is identical to the first six layers of the header stack. The second layer is constructed the same as the cap layer of the header stack. These alternating layers provide continuous lengthwise channels for distributing air throughout the load.

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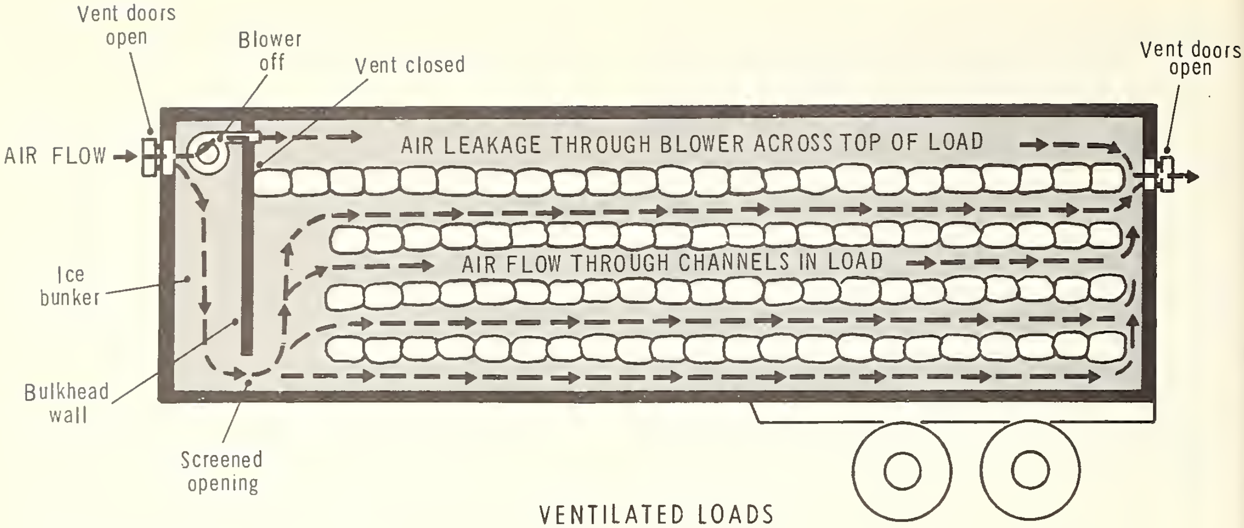
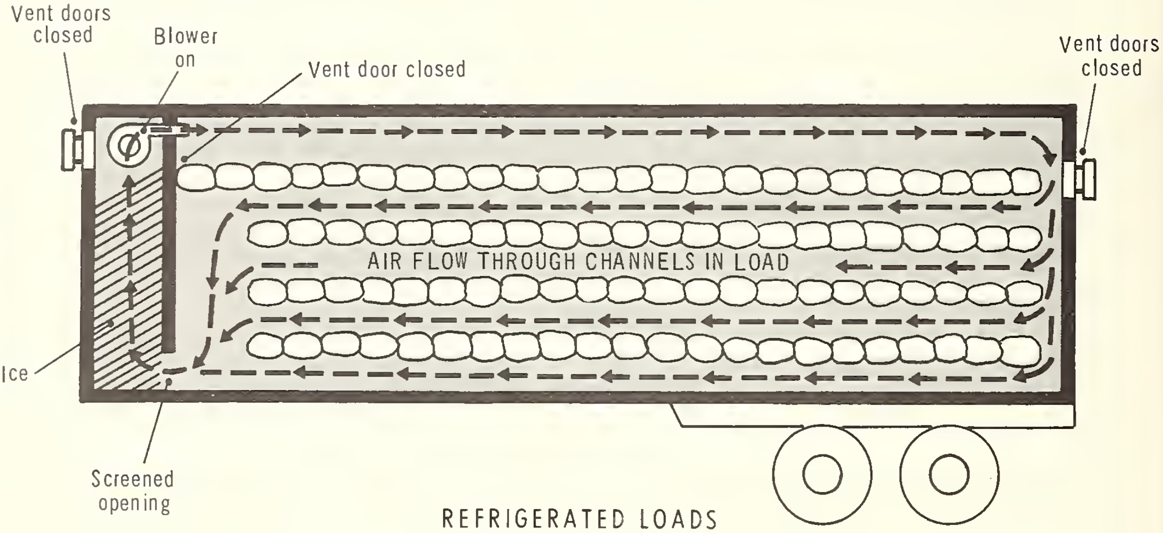
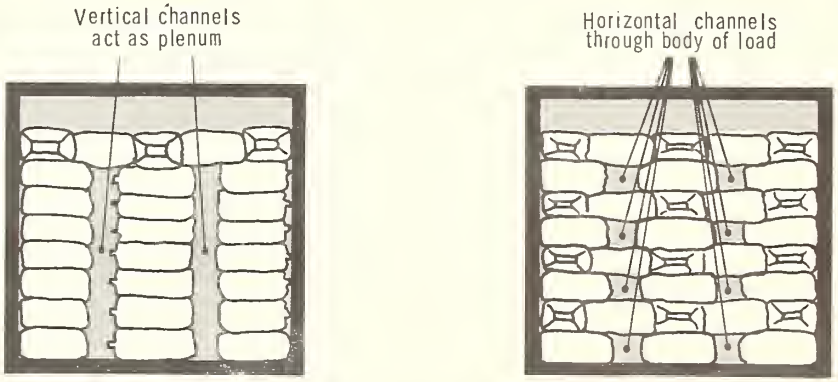
FIGURE 2.—Conventional stacking pattern for 100-pound burlap bags with a single air channel in the bottom layer.



VENTILATED LOADS



REFRIGERATED LOADS



FIRST STACK NEXT TO BUNKER WALL

ALL STACKS OTHER THAN FIRST STACK

Figure 3.—Air circulation patterns in airflow loads moving under ventilation and refrigeration.

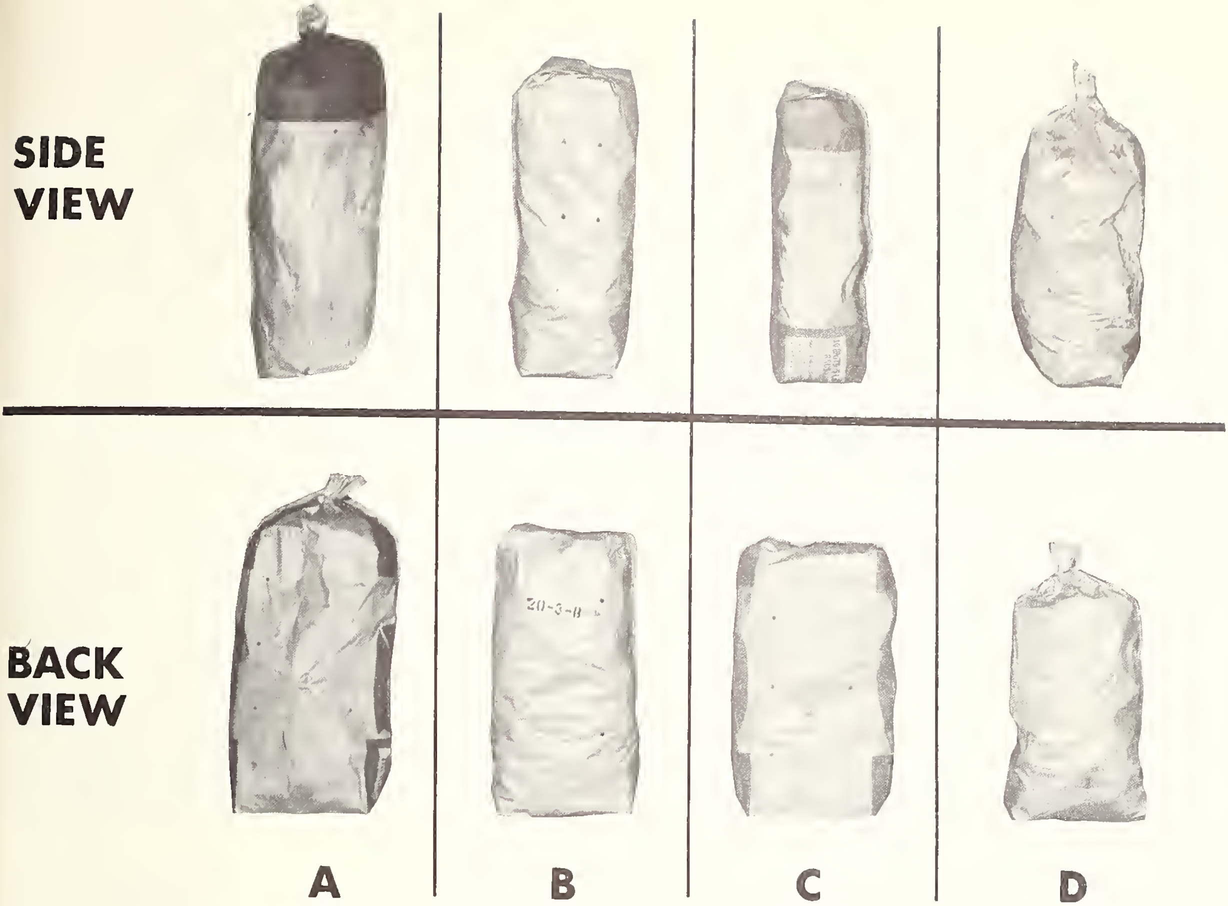


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FIGURE 4.—Various sizes of 50-pound paper sacks.
A. wire-twist closure master
B. tape closure bulk
C. tape closure master
D. wire-twist closure bulk

Pattern No. 2 using the 50-pound master sack with tape closure is shown in figure 6. This pattern differs from pattern No. 1 in three respects. First, it is designed for a thickly insulated trailer. Second, this pattern provides a greater number of continuous lengthwise channels per stack. Third, the cross-sectional area of the channels is greater than that of pattern No. 1. View A is the front or header stack. This stack consists of seven layers and four rows with bags placed lengthwise. The capping layer is constructed three bags wide and two in length, resting on the middle and adjacent rows.

Subsequent stacks of pattern No. 2 are shown in view B. These stacks are constructed by alternating the bottom and cap layers of the header stack.

Pattern No. 3, a slight modification of pattern No. 2, is shown in figure 7. This modification, which is usable in a trailer with very thin sidewall insulation, yields more channels per stack, but the cross-sectional area of the channels is not changed. The header stack for this pattern is the same as for pattern No. 2. The remaining stacks are constructed by alternating the first layer of the header stack with a modified layer. The modified layer consists of three bags placed lengthwise over the outside and middle channels, and two bags placed crosswise over the two remaining channels.

### Patterns for 100-Pound Burlap Sacks

Two airflow patterns were designed for loading the 100-pound burlap sack. The first, pattern No. 4 shown in figure 8, can be used only in trailers with 2 inches or less insulation in the sidewalls, since three bags placed end to end crosswise of the vehicle take up all the available space in this size trailer. View A shows the header stack, which is constructed by stacking two rows of bags crosswise and capping the stack with three bags also placed crosswise. The other stacks are constructed by alternating the first and cap layers of the header stack. Stacks may consist of more or less than five layers, depending upon weight laws and trailer size.

The second, pattern No. 5 shown in figure 9, can be used for trailers of any width by adjusting the air channels. The channels in this pattern are more numerous and larger in cross-sectional area than those of pattern No. 4. The header stack, view A, is constructed of four rows of lengthwise sacks capped with three crosswise sacks resting across the rows. The remaining stacks, View B, are constructed by alternating the first layer and a modified layer of the header stack. The modified layer has one sack lengthwise over the center channel and two crosswise sacks over each of the outside channels.

## SHIPPING TESTS AND RESULTS

Each of the five loading patterns was tested in over-the-highway shipments. Observations were made at the loading point, during transit, and at destination. Trailers with various inside dimensions were used in the tests. In each test the patterns were adapted to the length and width of the trailers, and the weight of a full payload was properly distributed within the vehicle for compliance with legal axle-loading limitations. The test shipments originated in New Jersey and were consigned to Florida markets.

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FIGURE 5.—Airflow pattern No. 1 using 50-pound paper sacks with twist-tie closure. (A) First or header stack. (B) All subsequent stacks.

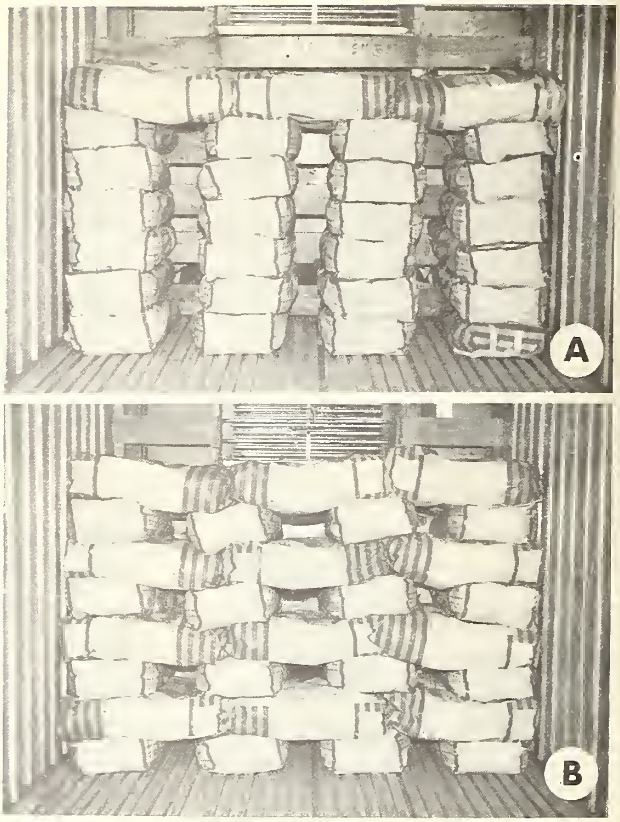

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FIGURE 6.—Airflow pattern No. 2 using 50-pound tape-closure master paper sacks. This pattern is designed for use in narrow trucks. (A) First or header stack. (B) All subsequent stacks.

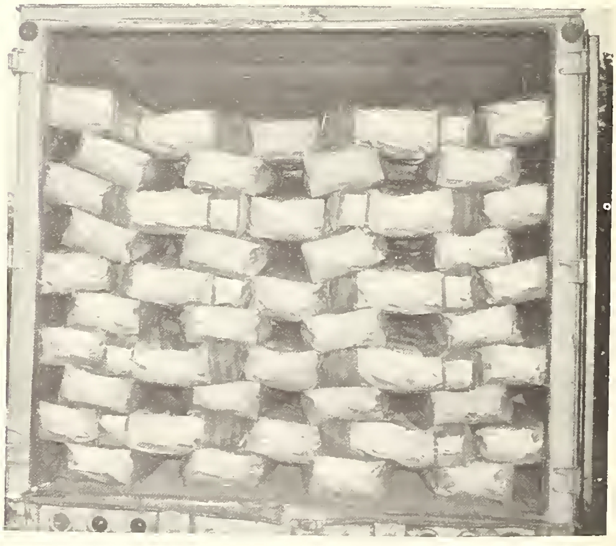

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FIGURE 7.—Airflow pattern No. 3 using 50-pound tape-closure master paper sacks, each of which contains five 10-pound bags. This pattern is designed for use in wide trucks with header stack as shown in figure 6(A).

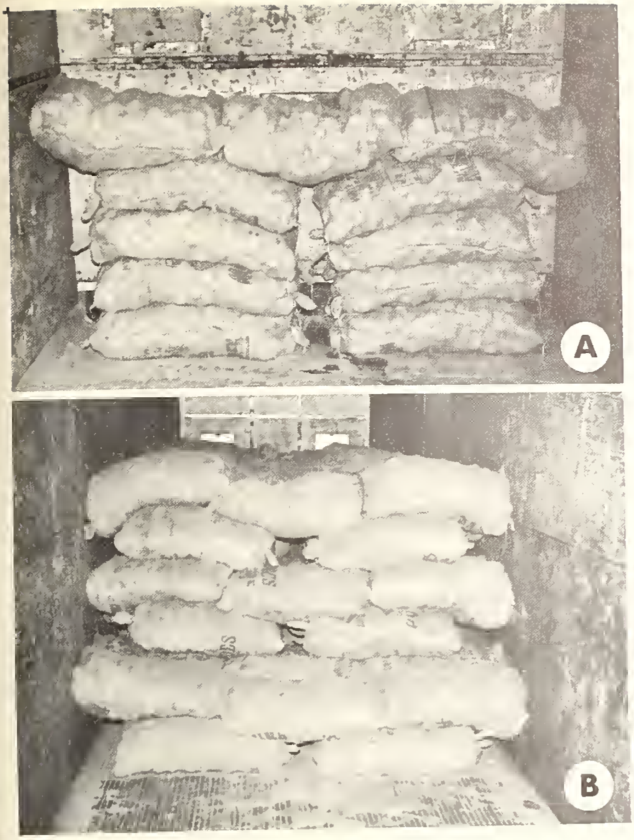

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FIGURE 8.—Airflow pattern No. 4 for 100-pound burlap bags; for use in trailers with 2 inches of insulation or less. (A) First or header stack. (B) All subsequent stacks.

### Air Circulation

The data in table 1 show the average rate of air movement in the longitudinal circulation channels and over the top of the load for each pattern under ventilation while the trucks were moving at approximately 50 m.p.h. Variations in these rates for the different patterns resulted from size and number of channels and irregularities in stacking. A minimum flow rate for satisfactory cooling has not been established.

### Air Temperature

In one test shipment both the airflow pattern and conventional tight-stack pattern were used in the same trailer for a direct comparison of the two systems. The load was divided in half lengthwise from front to rear of the trailer. The tight-stacked pattern was used on one side of the trailer and the airflow pattern on the other. Figure 10 compares air temperature in the center of each stacking pattern with the ambient (outside air) temperature. This comparison reveals that as the ambient changes, temperatures along the channels of the airflow pattern varied directly, indicating a good rate of airflow in the channels. At the same time, air spaces in the conventional tight-stacked half of the load showed little response to the change in the ambient.

Although air temperatures in the load correspond more closely to the ambient temperature on the side of the trailer where the airflow pattern was used, this does not necessarily mean effective heat removal was achieved. With a given amount of air moving through the load, the effectiveness with which excess heat can be removed depends upon the difference between the air temperature and product temperature. The lower the temperature of air moving through the load compared to the product temperature, the more effective will be the heat removal. Using the airflow pattern in ventilated shipments will not remove heat during transit if the air is warmer than the product. In such instances, refrigeration should be used.

### Moisture Control

Weather conditions caused excess moisture at the shipping point in some of the test loads. At destinations these same potatoes appeared dry in the airflow shipments. When moisture removal in transit is desirable, the airflow pattern should be used if the weather expected warrants it. Temperature and humidity requirements of the product must be correlated with outside weather conditions to determine whether ventilation or refrigeration should be used.

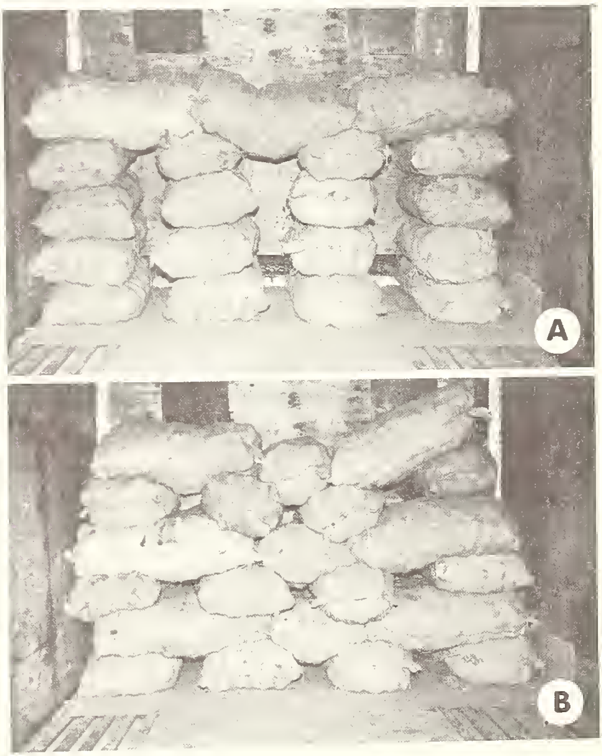

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FIGURE 9.—Airflow pattern No. 5 for 100-pound burlap bags to provide air circulation channels; for use in either wide or narrow trailers. (A) First or header stack. (B) All subsequent stacks.

TABLE 1.—*Air velocities in circulation channels and across top of load for the five patterns while moving under ventilation* [1]

| Air channel | Airflow pattern 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| | *Ft./min.* | *Ft./min.* | *Ft./min.* | *Ft./min.* | *Ft./min.* |
| Average of all longitudinal channels | 271 | 235 | 141 | 159 | 274 |
| Across top of load | 320 | 280 | 310 | 472 | 320 |

[1] Velocities are given in feet per minute. Truck speed approximately 50 miles per hour.

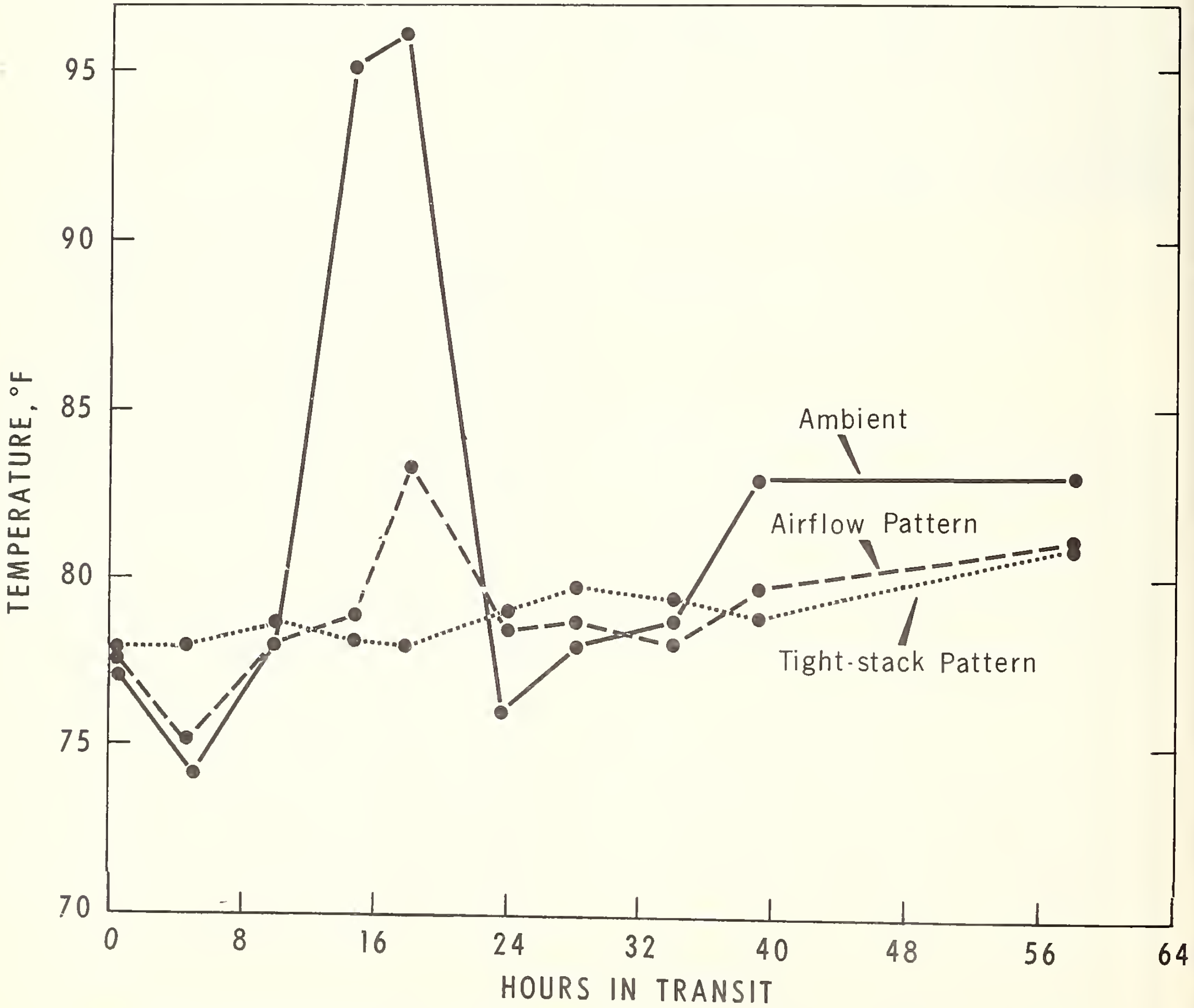

FIGURE 10.—Air temperatures in center of conventional tight-stacked and airflow patterns in relation to the ambient.

One pair of test shipments from New Jersey to Florida was made in late September during a period of cool weather at the shipping point. Consequently, the potatoes were quite cool when loaded. Both the airflow and tight-stack pattern shipments arrived at destination with little or no condensation on tubers or bags. But, unlike the potatoes shipped in the airflow pattern, the tight-stack shipment became wet from condensation within about half an hour after removal from the truck at destination. Moisture collected on these potatoes because pulp temperature had changed very little from that at the time of loading and did not reflect ambient condition. The absence of condensation on the airflow shipment one-half hour after unloading was a result of the slow rise in product temperature achieved by circulating outside air through the air channels in the load.

### Stability and Damage

The loading patterns remained generally intact during transit when they were properly stacked at loading time. Some minor load shifting was noted at destination in the rear stacks but the movement was slight and the channels remained open. Figure 11 shows the same load at shipping point and at destination after a 1,150-mile trip. Only a slight amount of load shifting can be noted in the top layer of the rear stack which was typical of most of the test shipments.

Container failure and commodity damage were not increased by the new loading patterns. A few paper sacks were torn, but this damage was caused by rough or improper handling of the bags.

### Loading Difficulties

With only a few minutes of instruction before the first load and some assistance in getting the patterns started, the loading crews were able to follow the patterns without difficulty. The first shipment of each pattern took slightly longer to load than the tight-stack method previously used. However, after the loaders became familiar with the new pattern, subsequent loadings were completed in about the same time required for the conventional patterns.

No major problem was encountered in loading the potatoes in airflow patterns 1, 2, 3, and 4. Pattern No. 5 for the 100-pound sack caused some difficulty to the loaders in placing lengthwise bags more than five layers high. Lifting 100 pounds to the sixth or seventh layer is done regularly, but the bags are usually in a crosswise position so they can be swung and thrown by two men. The bags are difficult to handle at that height when they are placed lengthwise.

### Refrigerated Loads

No shipping tests were conducted under refrigeration using these patterns. However, air velocities in the longitudinal channels were satisfactory when the blower units were put in operation and all vent doors closed to simulate the pattern of air movement that would prevail in refrigerated shipments.

## CONCLUSIONS AND RECOMMENDATIONS

Motortruck shipping tests of bagged potatoes showed that air circulation can be increased in all parts of the load. The new airflow patterns can be advantageous when shipping shed-run potatoes by providing increased flow and more uniform distribution of air along the perimeter and through the center of the load to: (1) Facilitate the removal of heat and excess moisture from potatoes during transit, (2) reduce condensation, and (3) provide more effective cooling of loads shipped under refrigeration.

Shippers will obtain maximum benefit from the airflow loading patterns if these recommendations are followed:

(1) Arrange front or header stack so that the vertical opening will match the longitudinal air channels in the remainder of the load.

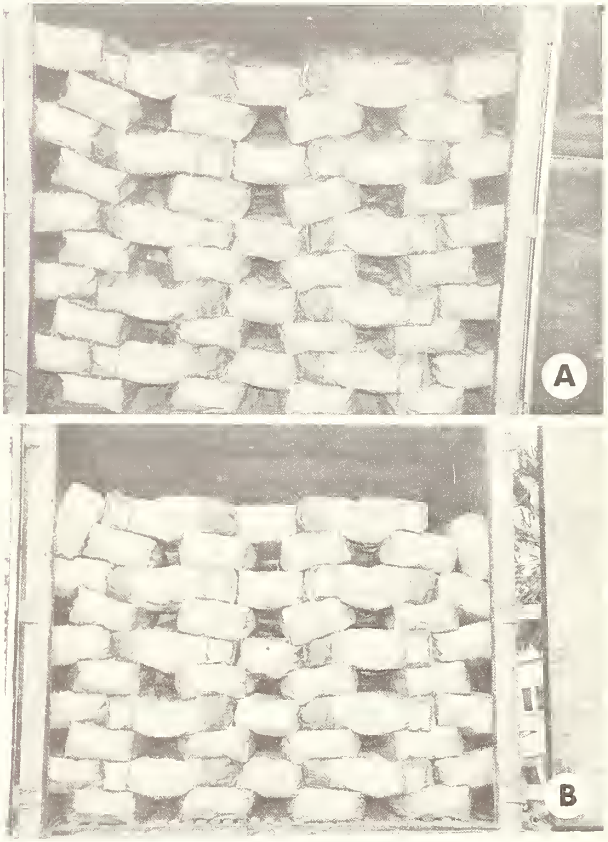

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Figure 11.—Rear stack of airflow loading pattern showing comparative stability of pattern during transit. (A) Rear stack after loading at shipping point. (B) Same shipment upon arrival at destination.

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(2) Close inside vent doors at the top of the bulkhead during transit of ventilated loads. Air entering the ice bunker through the outside vent door will be forced through the screen opening at the bottom of the bunker and into the vertical spaces in the front or header stack where it can enter all longitudinal air channels in each subsequent stack. If the inside vent doors remain open, most of the incoming air will follow the most direct course over the top of the load and pass out the rear vent doors. This will greatly reduce the effectiveness of the airflow pattern.

(3) Arrange the bags in the pattern so that the channels are not too large. Oversize channels allow the bridge sacks to sag or fall into the channels and restrict the airflow.

(4) Give consideration to weather conditions in relation to the temperature and humidity requirements of the commodity before deciding to ventilate or refrigerate.

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