Perishables Distribution In The 1970's

Engineering Improved Refrigerated Delivery Vehicles

Food 70's

Describes the U. S. D. A. Multi-purpose Van-container and its new concepts in refrigeration

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How many of us would be content with a poor job of air conditioning in our homes? The interesting part of this question is the reasoning behind the answer. Why do we worry about our personal comfort but do not worry about losing money when our agricultural commodities are not comfortable?

If we find fault with the air conditioning in a new home we get in touch with the builder. If it's an add-on system, we get in touch with the contractor who installed. In either case, we'll run into the same problem so prevalent in present refrigerated trailer construction--we will not be able to pin the blame on anyone. The house has been built to adequate standard requirements for construction and comfort and so has the trailer or container. The same situation exists for the air conditioning or refrigeration unit. The common denominator and, in this case, probably the most important facet of environmental control is the air distribution.

Poor air distribution resulting in misuse of the heat transfer medium in the house or trailer is the real culprit. Now, who do you blame? Who do you go to with your problem? Is the builder responsible for poor air distribution or is the unit manufacturer at fault? The answer is both--one is quite dependent on the other.

The time has come to join these two fine entities, the trailer and the unit, in "wholly" wedlock. The manufacturers of each must begin to understand the problems of the other and to do something about solving them to their mutual benefit and satisfaction. Only you, the buyer and user of such equipment, can get them together. If you understand their problems a little better you should find the job of getting them together fairly easy.

What are some of the problem areas concerned with construction for refrigerated use? Insulation, weight/ cube relation, door gaskets, floors, walls, drains, cleaning and side doors are some of them. Looking at the list you probably should ask, "What's left that's okay?" Very little, if you think in terms of innovation instead of modification. Most design specifications have been based on frozen food requirements and modifications of these basic specifications. What's needed is innovation--a start from scratch with a design based on non-frozen, frozen and ventilated requirements. A balance between these requirements must be achieved based on optimum utilization of the container.

Insulation must be thinner, stronger, possess long-life characteristics, and prevent outside moisture migration. Some of the insulation requirements combined with innovations in air distribution will make possible a lighter weight, higher cube container. New ideas in air distribution will result in better floor and wall design. Better wall design should bring about better door design. As previously stated, these changes must be innovations based on flexible, functional container utilization.

Another problem area and related to those in the container is the refrigeration system. Note I said system not unit. The refrigeration units are generally satisfactory but the low-side or fan and coil systems in the cargo space are not married to the container through an efficient air distribution system.

Air distribution means many things to different people--ducts, floor racks, ribbed walls, stacking patterns. These are some of the things that come to mind when we use the term. I would like you to think of it as the result or effect of <u>all</u> of these things plus a few more. It is the method used to obtain optimum heat exchange between the entire cargo and the environmental control system. This includes efficient use of the fans, blowers, evaporator coils, walls, floor, cargo, and personnel to achieve the optimum heat exchange.

The problem of air distribution <u>through</u> the load in truck trailers was never really worked on, until recently. A problem which has long existed in perishable transport is the freezing of the commodity on the perimeter of the load, combined with the heating of the product in the center of the load. For a time the blame for this problem was placed on the refrigeration system. In the late '50's, the trailer body became suspect as a result of the tests, previously mentioned, which were conducted at the National Bureau of Standards. Rating methods were developed, for both the refrigeration system and the trailer, by means of which a quantitative performance value could be assigned to each.

Now we know what the refrigeration system can do and what the trailer can do, but there are those who still will not accept the marriage of the two by an efficient air distribution system. This marriage has been prevented by several factors, among which have been: weight and cube restrictions; loading techniques; carton design; ignorance, on the part of responsible personnel in the transport industry and in the marketing system, of some of the fundamentals of heat transfer and of the air distribution problem with its related costs.

The insulation used is directly related to the solution of some of the problem areas concerned with air/temperature distribution. Insulation must have resistance to vibration and moisture penetration, and it must be lightweight and still retain a low thermal conductivity. The thickness should be reduced at least 50 percent below that presently used in order to attain the reduction in weight and increase in cube that is needed. The foamed plastics generally meet all of the above criteria. While much progress has been made in recent years in building better refrigerated vans for transporting food and other perishable products, research and operating experience with the vans have shown that there are many areas in which design improvements are urgently needed. These include features which will improve the quality of the environmental protection of the perishable products transported in the vans, and those which will increase the van's efficiency and economy of use. One of the most pressing needs at this time is the improvement of features to provide better air distribution in van containers.

Recognition of these needs led researchers of the Transportation and Facilities Research Division, U.S. Department of Agriculture to develop a concept for a multipurpose van container system with a number of unique features. We believe that this system will go a long way toward solving many of the problems of providing better protection for perishables and toward improving the versatility of the vans for more efficient, lower cost operation. The features we incorporated in the proposed system are not the results of dreams. They are based on many years of research which has uncovered operating deficiencies and other areas where improvements are needed. Many of the innovations of the system are based on ideas of the user and the manufacturer, as well as some of our own.

Approach to Problem

After we set down the features we thought that such a container system should have, we went about trying to find out whether they were practical and, if so, the most feasible way we could reach the goals we had set for the system.

We placed three contracts, each one a step in the development of our concept. Our first contract, or step, was an engineering feasibility study, which was completed more than 3 years ago. Our next step was the building of a 10-foot long test module to test the feasibility of the air circulating system to be used in the vans. The third step, now underway, was the building and testing of a 40-foot long prototype van having as many of the features of the original concept as we could put into it. At this time the van has been completed and is undergoing performance tests.

Description of Prototype Van

If we take a look at the prototype van, perhaps it will help you understand better what the van is and how it will work.

Picture a van container with the wheels attached. The outside looks like a truck-trailer, but, unlike a truck-trailer, the van body has corner fittings for lifting it onto and off ships and for tying it down aboard ship.

Now, let's look inside for the features in which you probably are the most interested. First, we see an adjustable load-locking device attached to each back door to take up the slack in the cargo and hold it firmly in place. (Figure 1) The grooved flooring runs across the width of the van. The ceiling consists of eight 3 x 9 foot panels, with dampered openings, hinged to the false sidewalls (flues) and fastened to the bottom of a bypass duct, located in the middle of the ceiling, which runs the length of the van. The bottom of the duct has small openings with dampers to control the air entering the duct.

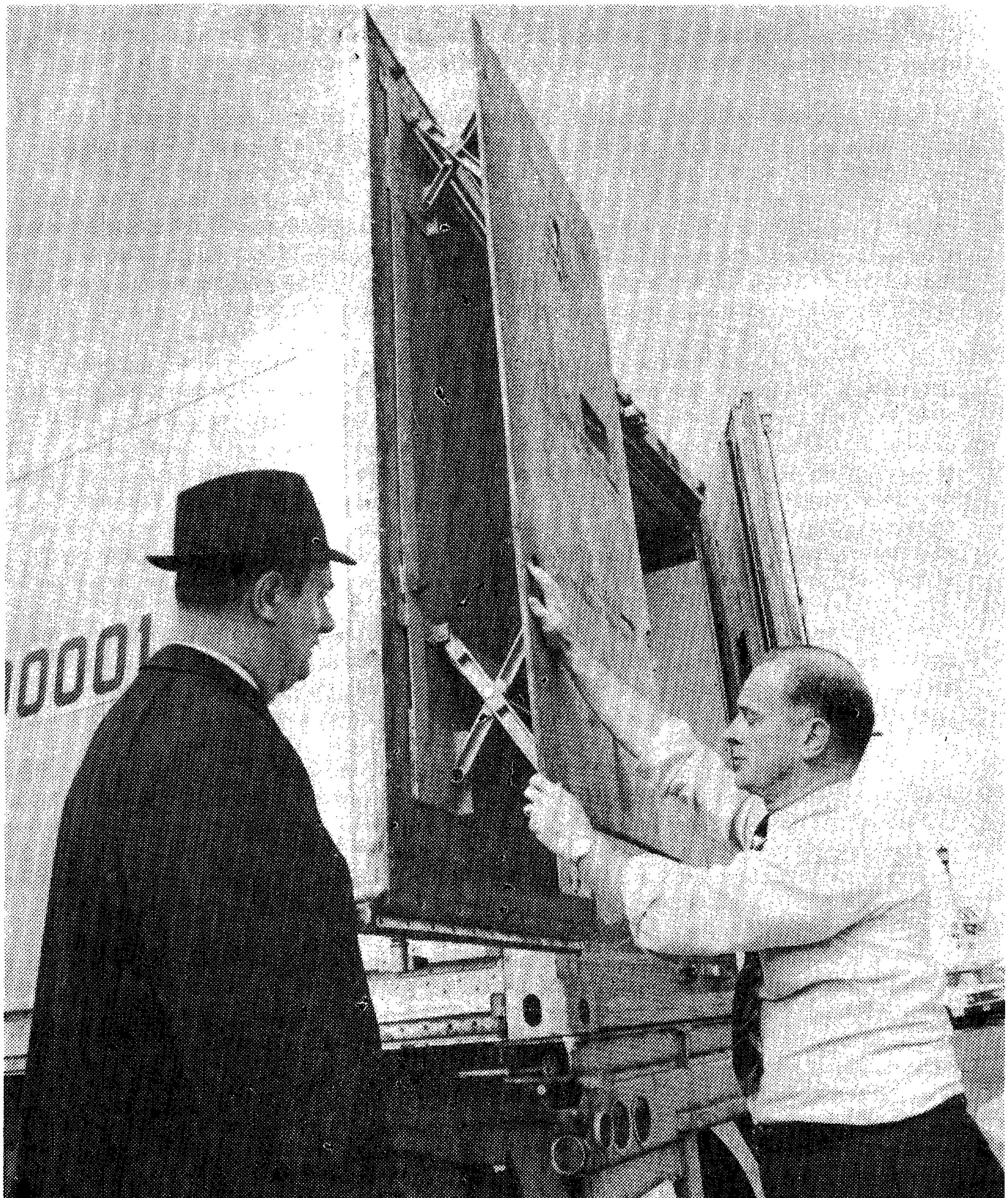
Let's look inside the false ceiling by lowering the ceiling panels. (Figure 2) To lower the panels, all you have to do is turn the thumb-screw latches. Now we can see the evaporator coils mounted on the surface of the true ceiling, previously hidded by the panels. A 40 foot container has eight such coils: four on each side of the ceiling center line, running the length of the van. Each coil is 8 feet long, 3-1/2 inches thick, and 5 inches high. Two 4-inch diameter, squirrel-cage tangential blowers, located at the junction of the f alse sidewall and the ceiling, pull the air across each coil in the cooling cycle. Each pair of blowers is driven by a 1/8-horsepower motor located between the two blowers.

In the refrigeration cycle, the air is pulled across the coils and forced down the sidewall flues, out through the floor grooves under the cargo, up through the cargo, and then into the openings in the panel section to complete the cycle. This pattern of air circulation occurs on each side of the van. (Figure 3)

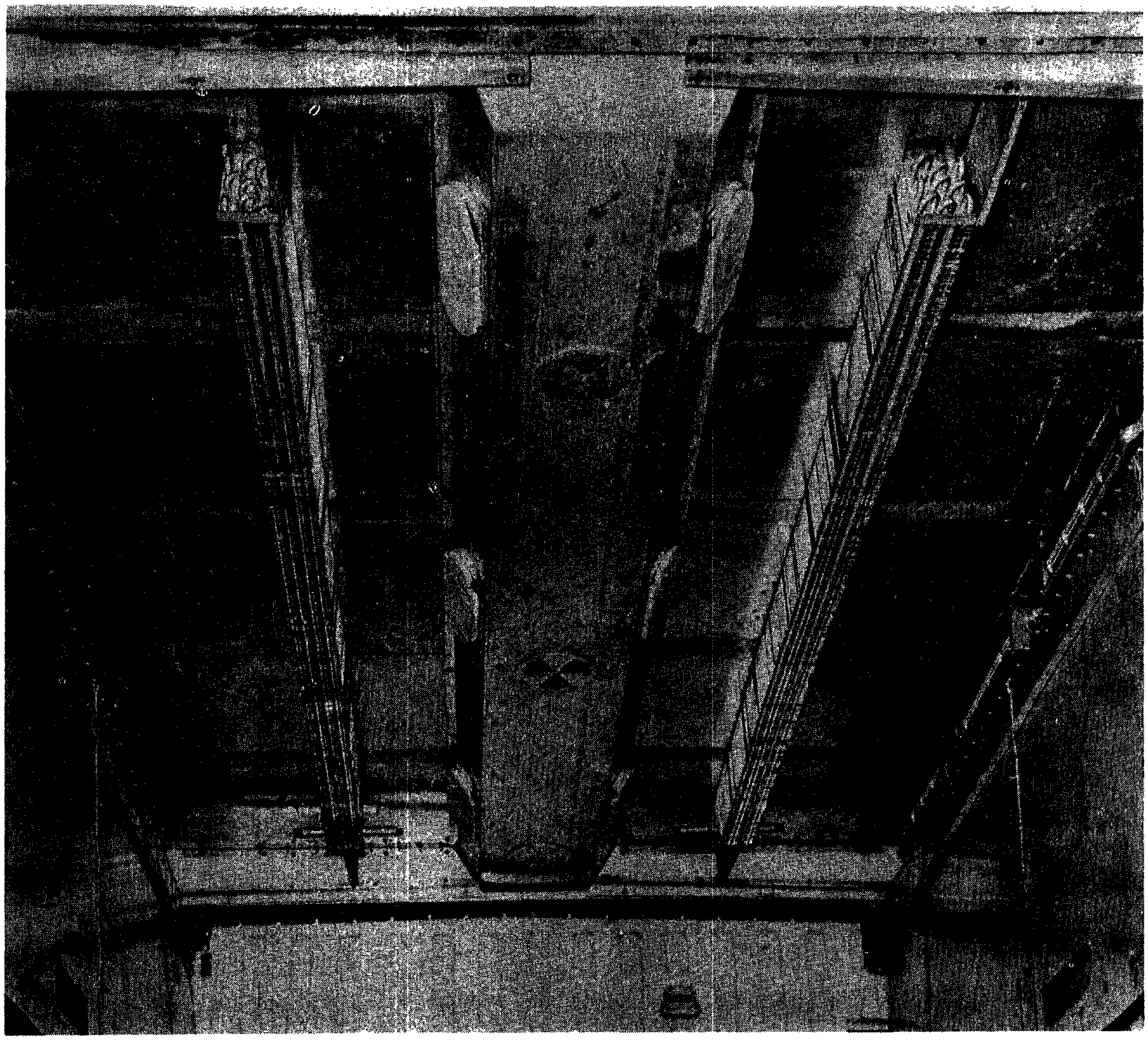
This pattern of air circulation is used for cooling non frozen perishables, thereby removing field heat, heat of respiration, and heat that penetrates the walls, floor, and ceiling. The pattern of air flow for the frozen perishables is one way--down one wall; across the floor under the load, up the opposite wall, and across and above the panels and through the coils. This air circulation pattern provides complete perimeter cooling for the cargo.

Each 10-foot section of the container has its own solid-stage thermostat and other means of independent temperature-humidity control, and can be isolated by means of removable, lightweight, insulated bulkheads. Each 10-foot section can also be ventilated separately, drawing outside air in through the front and exhausting it out the rear of the van through the center ceiling bypass duct after it has been circulated by the air blowers through the cargo area. Heating is accomplished by means of electric elements in the evaporator coils. Coil defrost by these same elements is actuated by a pressure switch. The coil condensate can be heated in an electric defrost pan and returned to the air that is circulated through the cargo area.

The multipurpose van is designed to obtain an inside temperature of 10°F. when the outside temperature is 100°F., and to maintain an interior

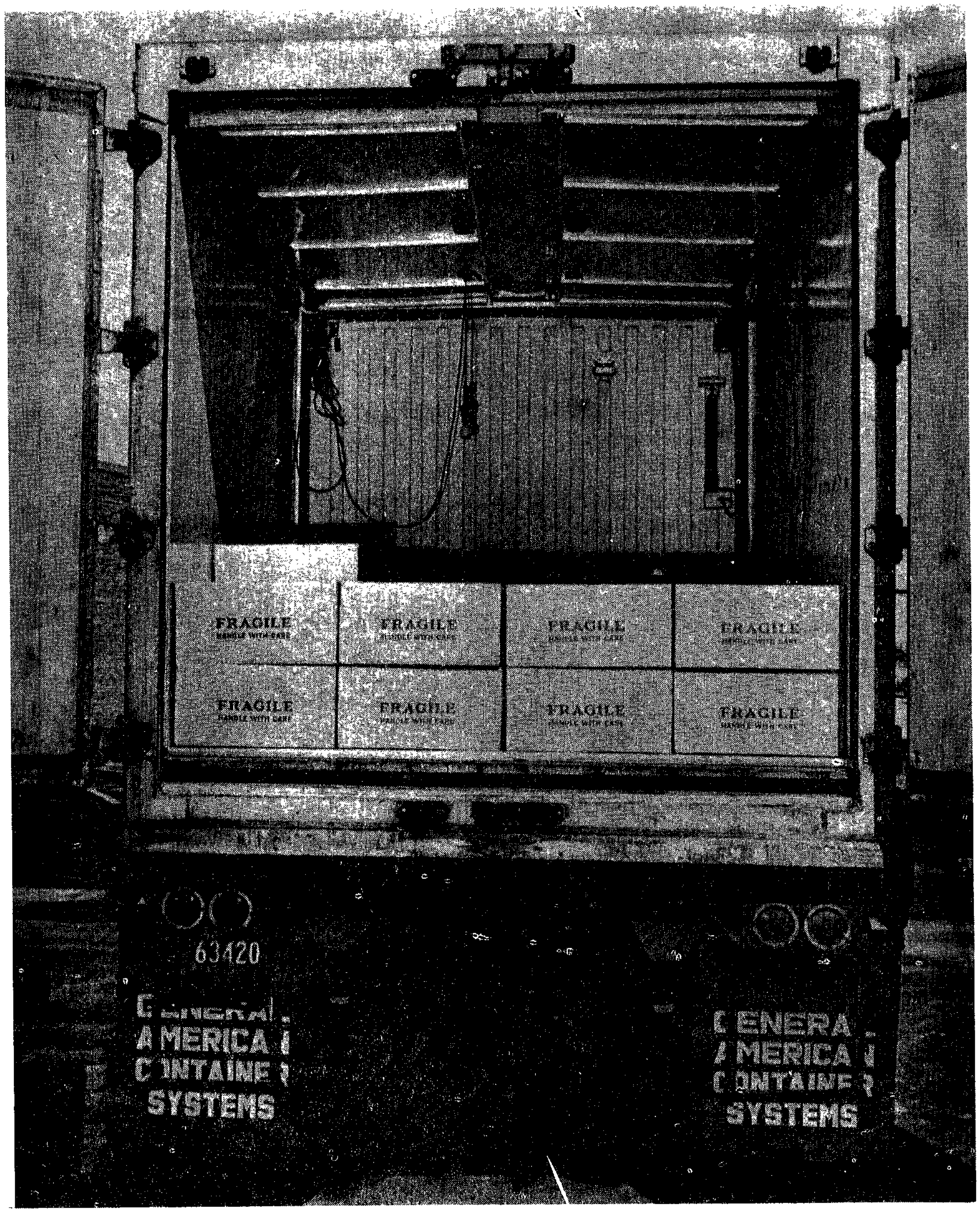


CARGO RESTRAINING DEVICE, ADJUSTABLE
AND ATTACHED TO EACH REAR DOOR



Interior of Compartment - Ceiling Plenum Door Down

Figure 3



General View of Compartment - Close Carton Packing Pattern temperature of 65°F. when the outside temperature is 0°F. The side, front, and rear walls are insulated with 2 inches of styrofoam or polyurethane plastic foam with a density range of 1.5 to 2.0 pounds per cubic foot. This insulation is the core of a sandwich construction consisting of 1/4-inch plywood and 0.025 aluminum sheet interior and exterior facings bonded together. The insulation in the floor is 4 inches thick and that in the ceiling is 3 inches.

Systems and Problems Considered

The original concept for the multipurpose van container system was developed around the modular length adopted by the United States of America Standards Institute and the International Standards Organization. However, the proposed system has a number of features that can be adapted to vans of any length. Probably the most unique feature of the original concept, and certainly one on which much work must be done, is the placement of the high-side refrigeration (power source and refrigerant compressor) on the van container chassis and on some container flat cars.

In the engineering feasibility study of the proposed system, basic engineering designs and bills of materials were developed for vans of the 10-. 20- and 40-foot lengths. We tried to incorporate in the designs as many commercially available components as we could. As we had anticipated, there were a few components which had to be developed specifically for this application.

Six leading manufacturers of refrigeration equipment were contacted. Two expressed their interest and agreed to study the multievaporator concept. They offered to assist in developing the refrigerant controls, and general arrangement of the multizone refrigeration system, and in selecting of control equipment. Since the tangential air blower and finned aluminum coil designs are new developments in transport refrigeration, the combined performance data of these components are not available. Further test work will be required to design the size of the refrigeration equipment for correct air flow, static head loss, cooling coil surface, and electric power consumption.

Four different commercial refrigeration systems were considered:

1. Undermounted diesel mechanical refrigeration system with separate evaporator.
2. Split-nose-mounted electric-refrigeration system, with separate generator set; or a diesel-driven system.
3. Direct cold air "plug in" concept.
4. Chiller-type ethylene glycol refrigerant system (using mechanical or dry ice refrigeration).

A fifth system, cryogenics (low temperature gases) was not considered, but provisions for its use were made in the container design for future evaluation.

Each of the four systems was evaluated on the basis of its adaptability to the multipurpose concept, any unnecessary loss of available cube, plus whether it would add any excess weight to the container.

The "U" factor (heat leakage) and estimated weight of the container were calculated. Insulated load dividers were developed for use in the multizone concept van, and still must be evaluated. Removable meat rail assemblies and permanent sidewall tracks were designed and fabricated. Development of air blower assemblies was begun. A supplier was found for quick disconnect hose assemblies equipped with wing nut locking rings to reduce the possibility of air inclusion and refrigerant loss. An adjustable panel for each rear door was developed to act as a load slack takeup device and air flue. Drawings were made which indicate arrangements, dimensions, design details, and other features of all the components and systems envisioned in the multipurpose concept. Bills of materials for parts were compiled. Finally, a summary of the problem areas inherent in the design of the multizone refrigeration system was prepared and evaluated. Suggested solutions to these problem areas were set forth.

Four basic problem areas evolved:

1. Developing small-diameter, high-pressure, tangential air blowers.
2. Developing evaporator coil configuration.
3. Operating and controlling multievaporators when they are used with a single compressor.
4. Divorcing the high-side refrigeration package from the container.

It was evident that the solutions to these problem areas must be based on empirical data developed through tests. These requirements necessitated additional work which was done under the last two contracts.

The second contract was for the construction of a 10-foot mockup section of the van container and its testing for the feasibility of the concept. Data were collected and evaluated on air flow in a lateral sidewall, under-the-load pattern. Testing was performed on the blower assemblies, the sidewall flues, and the ceiling plenum. The results agreed with those obtained from preliminary tests performed on a 20-foot modified conventional container in December of 1964 in Florida. Air flow down the sidewall flues (7/8-inch deep) is adequate in quantity, velocity, and pressure--about 500 c.f.m., or 760 f.p.m., at a total static system pressure of 0.44 inches of water. Of this total pressure, 0.02 inches represents the pressure drop across the coil. The "fly in the ointment" during this test was the air temperature 40°F. Zero degree air for these tests was required, but not available. The blower motor horsepower may have to be increased when used with the lower temperature air. Additional laboratory and field testing must be completed to determine the effect of this type of air flow on the theoretical overall coefficient of heat transmission ("U" factor).

The face area of the present evaporator coil is 3. 3 square feet, and circulating air has a face velocity of 250 feet per minute, A smaller face area of about 2. 5 square feet may be used, pending on blower design, system characteristics, coil placement, etc. The number of passes, or the coil surface, may be reduced. These are some of the points which must be considered during testing of the equipment.

The temperature variation within the cargo space will be reduced by individual control of the refrigeration in each zone or compartment, and by control of the air distribution in the container. The air will be coldest in the sidewall flues and will absorb some of the heat entering through the outside walls. This heat absorption should raise the air temperature sufficiently to prevent the perishables from being subjected to a very cold blast of air at the floor level. Less temperature variation within the cargo and a lower temperature difference between the floor (inlet) and the ceiling (return) will result in better environmental control.

How the Van May Help

Let me now summarize how we think the multipurpose van container can make transport better, and how insulation used properly can facilitate this objective.

Use of the van container offers possibilities for cost reductions in the transporting of perishable products through greater utilization and more efficient interchange of transport equipment, more efficient handling in the distribution system, and a reduction in commodity loss or damage.

In the area of transport equipment, greater utilization of the van container is accomplished by compartmentation; independent ventilation, refrigeration, and heating; reduction of refrigeration equipment weight through its removal when it is not required for transport of nonrefrigerated cargo; more useable interior cargo space; and intermodel design for interchange between ships, trains, trucks, and planes. The tare weight could be reduced by as much as 50 percent as a result of the lightweight sandwich construction of the van (which results in more efficient use of insulation) and leaving the power unit off. An increase in useable cargo space, combined with the weight reduction, should reduce the ratio of tare weight to cube.

Handling in the distribution system is enhanced by the van container concept in several ways: Through the accommodation of tighter cargo loading patterns, made possible by the container's air distribution system; through facilitation of interchange, made possible because of the container's compatible equipment; and through more interior space in the container. Removable meat racks will promote unitized carcass handling and, when not being used, can be removed to further reduce the van container's weight.

Reduction in commodity loss or damage costs may be accomplished by incorporating a more efficient air distribution system into the container, and by the load-locking back doors. Better air circulation through the load should help to remove field heat not removed from perishables by precooling, the heat of respiration of the perishables, and the heat that penetrates the walls of the van. Shrink or weight losses in fresh meat, caused by "drying out," could be reduced by more efficient air distribution and humidity control. Temperatures will be maintained closer to desired levels by the zoned temperature system, which is controlled by separate solid-state thermostats. Humidity will be controlled by the coil temperature difference and by rehumidification through the use of the coil condensate, when required, or by system modulation. The temperature and humidity requirements become more important as the length of the journey increases, particularly on the long trips to many overseas markets.

Air exchange or ventilation is another feature of the multi-purpose van container. Fresh fruits and vegetables produce carbon dioxide (not oxygen), and some fresh fruits give off ethylene and other volatiles in their natural respiratory and ripening processes. Too much of these gases may adversely affect some perishables. Carbon dioxide may cause physiological injury of delay ripening. Ethylene may accelerate ripening. The air in the container may be exchanged periodically in any one or all of the zones to avoid adverse effects on the cargo.

Also included in the container design is equipment for use of the cryogenic (low temperature) gases for precooling, supplemental refrigeration, or atmospheric modification. Precooling perishables by this method before shipment will reduce the initial heat load, resulting in better commodity condition at the destination. The piping and discharge manifold system for cryogenic gases also may be used to fumigate the van container to kill harmful insects which some perishables may carry with them. Efficient, tight, and thin insulation is a necessity.

More Work Needed

While all this sounds good, there are still some knotty problems to be solved in translating the van design into a working reality. Some of these are technological and some are psychological.

Technologically, there are the problems associated with air-wall and insulation construction and design, refrigerant line disconnection and connection, automatic pump-down of the system, high- and low-side (evaporator coils) equipment placement and construction, air distribution, intermodel requirements for efficient equipment interchange, cargo stabilization and air flow patterns, and others. We visualize either a central refrigeration or electrical power source on the truck-trailer, flatcar, or ship, which would be divorced from the container. When required, the container could be plugged into it. A separate power source would transfer the weight of high-side power equipment from the container to the carrying vehicle, and the power source could be left behind when transporting non-perishable dry cargo.

If the refrigeration disconnect system is used, it will engender problems of automatic-pump-down, dirt and moisture in the lines, oil separation and return, and others. The removal of all highside equipment would result in a considerable saving in weight. If the electric power disconnect system is used, no difficult problem will be encountered, but the weight reduction accomplished will be only about half of that of the refrigeration disconnect system. In either case, placing the refrigeration condenser in the exhaust duct will alleviate some of the heat-removal problems encountered in below-deck operation and stowage of refrigerated containers in shipboard transport.

Some possibly troublesome psychological problem areas, which may be overcome by education are: Transport industry acceptance of changes in floor design required for under-the-load air distribution, the handling of disconnect equipment under operating conditions, the concealed components of the refrigeration system, and the mixing of temperatures and ventilation conditions in the same vehicle.

In developing the multipurpose van container and its associated system, we are now attempting to find answers to the technological problems. Some time later we plan to try to work with the equipment users to show them how to get the most out of their equipment. This latter step may be the most difficult one.

Some of the results of our work with the multipurpose van container system should be useful in stationary refrigerated warehouse design, particularly in air-wall construction and humidity control. I haven't said much about humidity--the parameters haven't "jelled" yet. We know we need control but how much and how it will be accomplished are yet to be determined.

Gentlemen, I wish to thank you for this opportunity to present some of the ideas of the United States Department of Agriculture concerning improved refrigeration for delivery vehicles. I hope we have given you some useful information, answered some of your questions, saved you some money, but most important, enlightened your membership to some problem areas that must be worked on <u>now</u>, not tomorrow.