Perishables Distribution In The 1970's

The Future of Cryogenics in Refrigeration of Delivery Vehicles

Food 70's

Cryogenic refrigeration - its present and future potentials

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INTRODUCTION:

There are two principal methods of refrigerating delivery vehicles for the transportation and handling of perishables. The refrigeration can be manufactured on board the vehicle--as typified by mechanical refrigeration or it can be stored on board as typified by cold plate or cryogenic refrigeration. This paper will discuss stored, on-board cryogenic refrigeration or more specifically --liquid nitrogen refrigeration.

First introduced by Union Carbide in 1961, liquid nitrogen refrigeration has today become a most promising form of in-transit refrigeration. There are now over 6,000 nitrogen-equipped vehicles in service throughout the United States and over 1,200 more installations throughout the free world. These vehicles are hauling most types of refrigerated perishable products from tomato plants to ice cream. The reason for the sizable penetration of this market by liquid nitrogen is simple. Liquid nitrogen offers performance characteristics and economics that are competitive with standard methods of refrigeration, and it offers them over a wide range of refrigeration requirements.

Liquid nitrogen is favored as an expendable refrigerant over other cryogenic gases such as carbon dioxide or oxygen because of its many favorable physical and thermal properties. In addition to a high heat capacity, it is colorless, odorless, tasteless and for all practical purposes inert. The industrial gas industry has made substantial strides in recent years in the production, storage and distribution of liquid nitrogen so that today it is readily available in all sections of the United States. Union Carbide alone maintains over 80 truck stops or liquid nitrogen filling stations for liquid nitrogen refrigeration users. This is in addition to many more bulk storage facilities supplied to individual customers.

Cryogenic refrigeration is essentially the storage and controlled distribution of an expendable refrigeration into the cargo space of a vehicle. The nitrogen refrigerant is stored as a liquid at -320°F in a highly insulated container.

On demand, the liquid is withdrawn and distributed into the cargo space by a spray header. As it leaves the spray header the liquid quickly vaporizes and absorbs heat from the surrounding air. The nitrogen rapidly expands throughout the cargo space providing uniform temperature control.

SYSTEM DESCRIPTION:

A simplified flow diagram showing the basic components of a typical liquid nitrogen refrigeration system is given in Figure 1.

Storage Tank - The heart of the refrigeration system is the container which stores the liquid nitrogen under about 22 psig pressure over extended periods of time with very low losses. The containers are vacuum insulated and they are available in several sizes depending on the needs of the user. Typical tank sizes range from 134 to 2500 pounds of nitrogen capacity. A fill and vent connection, liquid level gauge, and safety devices complete the container assembly.

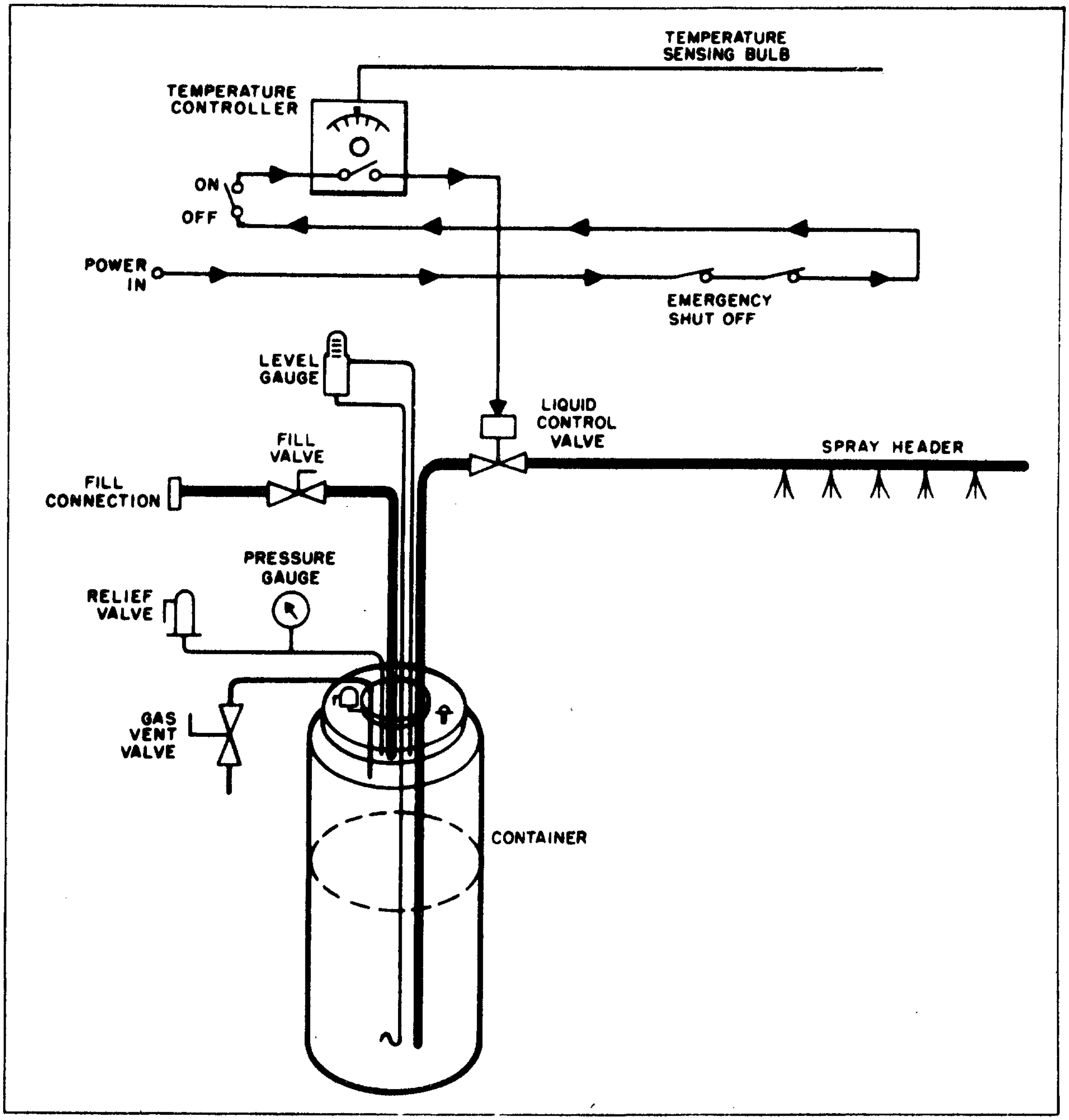
Spray Header - The spray header is located above the cargo near the ceiling of the vehicle. It is basically a straight length of pipe with a series of spray holes sized and spaced to evenly distribute the refrigerant into the cargo space. A liquid control valve provides on-off regulation of liquid nitrogen to the spray header.

Temperature Controller - The release of liquid nitrogen for refrigeration is determined by a temperature controller. It consists of a temperature sending bulb located inside the cargo space and an externally accessible control box for temperature adjustment. Both electric and pneumatic power systems are available. Generally a truck system is electrically operated and a trailer system is pneumatically operated using vaporized nitrogen gas from the liquid nitrogen storage tank.

SYSTEM OPERATION:

Filling or fueling the liquid nitrogen container is an easy operation comparable to filling a gasoline tank. Liquid is simply pressure transferred or pumped from a large storage tank to the onboard tank through a flexible hose and quick disconnect coupling.

To operate the system after it is filled, the temperature controller is set manually to the desired cargo temperature and the power switch is turned to the "ON" position. From this point on, operation of the system is essentially automatic. The temperature sensing element continually monitors cargo air space temperature. When the temperature rises above the control setting, the sending element trips the thermostat and sends a signal to the automatic liquid control valve to start the flow of liquid nitrogen. When the desired temperature is restored, the valve closes and the nitrogen flow stops.



Simplified Diagram of a Typical POLARSTREAM System

Figure 1

The vehicle may be refrigerated to any temperature between ambient and -20°F by setting the desired value on the temperature controller. Once set, the temperature will be held at this level as long as the system is turned on and liquid nitrogen is available in the storage container.

An illustration of a typical liquid nitrogen refrigeration system installed in a truck is shown in Figure 2.

There are several truck and trailer systems available which offer options on the size and location of the liquid nitrogen tanks. The vertical tank shown can be installed in pairs for greater refrigerant capacity. Also available is a horizontally mounted tank that can be located in the upper nose of the vehicle to provide increased cargo floor space, or it can be underslung beneath the chassis of a trailer.

CRYOGENIC REFRIGERATION CHARACTERISTICS:

Liquid nitrogen refrigeration like other types of in-transit refrigeration has certain advantages and some limitations that must be considered by any equipment user.

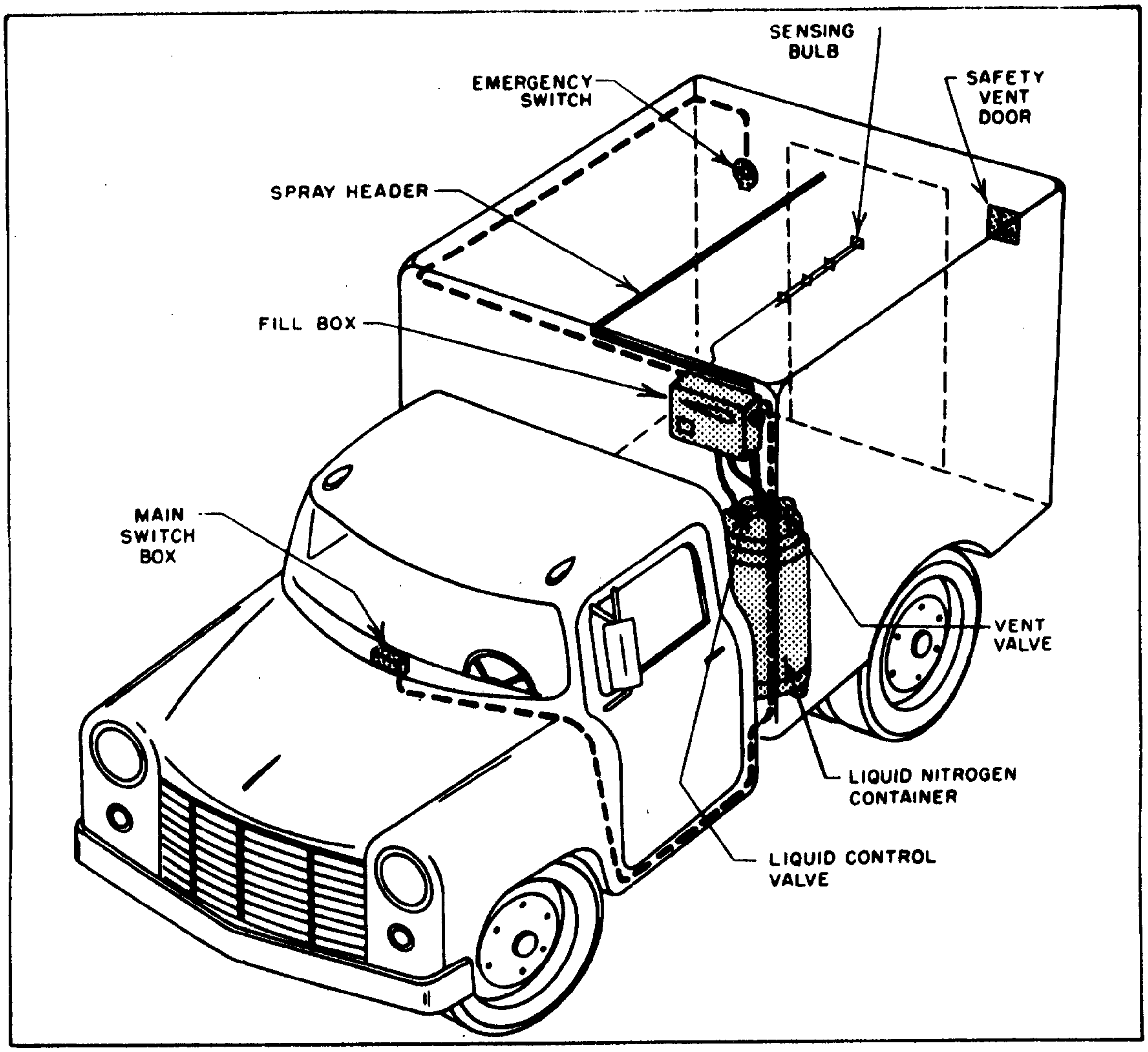
The major advantage lies in its simple, dependable design that requires a minimum of maintenance. It is almost totally non-mechanical. There is no engine, compressor, or belts to wear out or break. The only moving parts are in the temperature controller and the liquid control valve and these are designed for maximum maintenance-free operation.

Liquid nitrogen refrigeration usually means a lower initial investment, it weighs less and provides more usable cube than conventional refrigeration systems. With the underslung horizontal tank system, the entire cargo space is available for hauling product.

From a performance view point, liquid nitrogen refrigeration provides accurate and uniform temperature control. On most local delivery operations no special loading procedures are needed for free air circulation. The rapid expansion of the cold nitrogen vapor forces itself into all cargo areas.

A unique feature of liquid nitrogen refrigeration is its flexibility. One system can provide effective refrigeration over the full refrigeration range from -20°F to outside ambient. It can carry ice cream on one trip or bananas on the next. With dual controls a trailer can be compartmented to carry split loads such as frozen food and fresh produce. This enables the operator, who must carry mixed loads, to control each compartment at different temperature levels while using only one liquid nitrogen tank. An illustration of the multi-compartment concept is shown in Figure 3.

Liquid nitrogen refrigeration unlike forced air circulation systems does



A Typical POLARSTREAM Refrigeration System

Figure 2

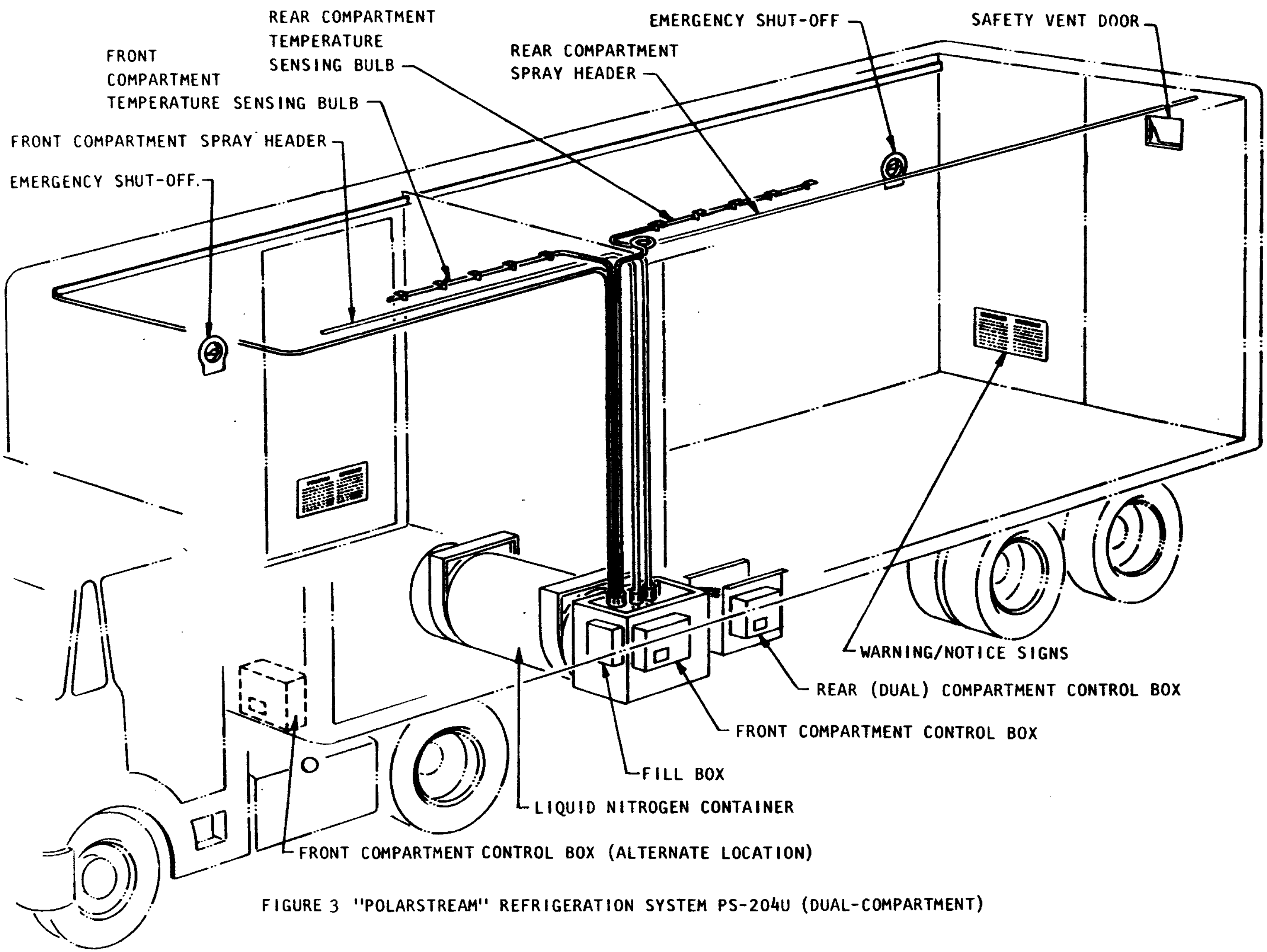


FIGURE 3 "POLARSTREAM" REFRIGERATION SYSTEM PS-204U (DUAL-COMPARTMENT) not remove moisture from the product. This is a useful feature in the long haul shipments of products such as meat where dehydration can cause substantial weight loss. On the other hand, moisture condensation and accumulation can be a problem for some local delivery, multistop operations when warm moist air enters the vehicle each time the doors are opened. In local delivery meat service, our customers often found that although the meat temperature was maintained quite well, the surface became wet from accumulated moisture condensed during door openings.

To solve this problem, a dehumidifier was developed to remove moisture that accumulated from door openings. The unit contains a fan and a moisture condensing coil through which liquid nitrogen flows before being sprayed into the cargo space. The fan circulates the air over the coil. The new accessory was introduced just within the past few months and has proven to be very effective.

Probably the least understood aspect of liquid nitrogen refrigeration is liquid nitrogen consumption and on-board storage capacity. Liquid nitrogen refrigeration operates on a demand basis and consumption varies directly with the degree of refrigeration required. On the hottest days, liquid nitrogen usage will be greater than on cool days, likewise operation at $0^{o}F$ requires more refrigerant than operation at $45^{o}F$. The stored liquid nitrogen capacity must be sized to meet the anticipated demands.

When we have had user complaints of running out of nitrogen usually we have found that the cause could be traced to either a change in their operation or misuse of the refrigeration system. User difficulties are most often encountered in the shipping of mixed loads. If warm groceries or produce are added to a meat operation, then LN_2 consumption will undoubtedly increase. If the system were originally sized to haul only meat, then there can be capacity problems on the hottest summer days.

This problem is not unique to just liquid nitrogen refrigeration systems --mechanical systems also are limited to their design capacity and any increase beyond this point will show up in product temperature rise.

One of the most difficult refrigeration jobs for any in-transit refrigeration system is the multi-stop delivery operation where long and frequent door openings allow considerable heat input into the vehicle. This can cause excessive warm-up of the product regardless of the amount of refrigeration applied between stops. We have found the use of one or more partitions to divide the load will significantly reduce the amount of heat input to the product during door openings by restricting outside air exchange. We are currently developing a new concept in partitions to be used with our systems. The partition is a nylon fabric material that extends the full height and width of the vehicle. It rolls up against the ceiling similar to a window shade for convenient storage, entirely out of the way while loading and unloading cargo. The liquid nitrogen system can provide proper refrigeration to each compartment between the partitions by virtue of its spray header design that does not require air circulation to function.

The use of dividing partitions will not only minimize produce temperature rise but also considerably reduce liquid nitrogen consumption. The partitions are rolled down during the loading operation and remain in place until rolled-up out of the way as the product is removed from the vehicle.

FUTURE ACTIVITY:

We in Union Carbide are most optimistic on the future of cryogenic refrigeration. Our past growth and experience in developing and marketing this unique form of in-transit refrigeration has proven that there is a need for cryogenic refrigeration in the food transportation industry. Accordingly our current and future development efforts and marketing applications are being directed into those areas we feel offer the greatest market potential.

In the equipment line, new and more efficient components and system designs are continually being developed. For instance a new liquid nitrogen system design soon to be introduced features a module design concept that is more compact and easier to install than existing systems. It features the horizontal liquid nitrogen tank with the fill and vent lines, liquid level gauge, control valve and safety devices integrally mounted into a compact housing at one end of the tank. This will eliminate the need for a separate fill box which will greatly simplify installation. Almost the entire system is assembled at the factory prior to shipping.

We have established more exacting environmental specifications and these are continuing to be refined so that today we are confident of the design criterion necessary for road and rail transportation equipment. As a result, today's components must pass a series of rigid tests designed to measure resistance to vibration, humidity, shock, sand and dust, and life cycling to failure.

Additional equipment improvements to be expected include larger capacity liquid nitrogen tanks for trailer systems, more efficient spray header designs, plus new and more dependable temperature controllers. Through our new equipment designs we expect to make cryogenic refrigeration even more reliable and cheaper to operate and thus broaden its applicability to ever increasing markets.

In addition to new equipment and system designs, we feel cryogenic refrigeration will also benefit from the current trend in the food industry towards higher product quality standards. This emphasis is focusing greater attention on the total perishable food distribution system. Warehousing and handling procedures are being improved, loading docks are being refrigerated and trucks and trailers are specified with higher quality insulation.

These and other improvements indicate that users of refrigeration equipment are becoming more sophisticated in the selection and operation of their delivery vehicles. In-transit refrigeration should benefit from these improvements since in the past the in-transit refrigeration system was often asked to make up for the deficiencies in warehousing and handling procedures.

Cryogenic refrigeration should benefit in particular because most of the improvements will directly reduce heat loads on the in-transit refrigeration system and thus reduce total liquid nitrogen consumption. Since the major cost in cryogenic refrigeration is fluid consumption, these improvements will directly lower the cost of the cryogenic system operation while providing better product protection. Though these improvements will help provide better product protection with any in-transit refrigeration system, no other system will show as great a reduction in operating cost as will cryogenics.

An example on the selection of equipment can be made in the ice cream industry. As we know, product temperature is very critical in shipping ice cream. Once ice cream melts, it's gone. Large volume ice cream processers are finding that the ideal in-transit refrigeration system involves a combination electrical plug-in and liquid nitrogen refrigeration system. The electrical system offers a reliable inexpensive method for vehicle cooldown and hold operations, and the liquid nitrogen provides light-weight, economical refrigeration for over-the-road delivery. This system is particularly effective for multi-stop delivery operations where liquid nitrogen's rapid cooldown capability is important. For weekend or overnight hold operations the electrical plug-in system is unmatched for economy of operation.

For many ice cream truck operations, we have found that a similar mating of liquid nitrogen refrigeration with cold plates is ideal for the peak summer months. The liquid nitrogen system provides that additional refrigeration necessary during July and August and at substantially less cost than other forms of refrigeration.

For ice cream applications with refrigerated loading docks and little or no holdover operations, a straight liquid nitrogen refrigeration system is usually satisfactory.

Another advance favoring liquid nitrogen refrigeration is in the meat industry where the trend is towards centralized packaging centers. The meat is cut, packaged, labeled and even priced all in one location. It is then stored and distributed direct to the retailer.

To further reduce handling and labor expense, we have several customers who distribute the packaged meat using a containerized system. In this operation, the meat is completely processed and then loaded aboard truck body size shipping containers. The containers are then transported 3 or 4 at a time aboard flat bed trailers to the major delivery areas. From here the containers are off loaded onto truck chassis for local delivery of the product to retail stores.

Each shipping container has its own liquid nitrogen refrigeration system. Liquid nitrogen was chosen because of its economy and its ability to be installed completely inside the shipping container. The result is a completely self-contained refrigeration system that permits easier loading of the product and more efficient mounting of the containers on the shipping trailer.

SUMMARY:

It has been the purpose of this presentation to highlight operating and equipment concepts of cryogenic refrigeration and to provide some insight into the present and future potential for cryogenics in the refrigeration of delivery vehicles.

We feel that new equipment developments will improve the refrigeration capability, reduce costs, and broaden the applicability of liquid nitrogen refrigeration in the food transportation market.

The penetration of liquid nitrogen refrigeration into the market will also be enhanced by general improvements in warehousing, faster more efficient handling of cargo, and better insulated delivery vehicles. The net gain for the perishable food industry will be better in-transit refrigeration at reduced costs.

In summary, we feel cryogenic refrigeration has a bright future in the food transportation industry.