Controls

L. S. Martin of the National Association of Frozen Food Packers, has stated, *"Frozen foods and allied industries are losing millions of dollars every year because many frozen products are reaching consumers in poor condition. This appalling fact is evidenced from recent market research which shows that marginal quality is a deterrent to further sales growth. Many homemakers are not regular users of frozen foods for this reason."*[39]

Recent studies have demonstrated the importance of temperatures for frozen foods that are not only low enough, but that are maintained at reasonably steady levels. It is not enough to hold an average of, say, 0 F, in a frozen food vehicle; it is important to limit the amplitude of the cyclic variation so that the product does not fluctuate more than a degree or so above the desired temperature during the warm period of the cycle. The Agricultural Research Service of the USDA has described the initial phase of these studies to determine the time-temperature tolerance of perishable products.[40]

The Association of Food and Drug Officials of the United States has prepared a model code which outlines storage and transportation temperature limits for frozen foods. As of March, 1962, at least three states have adopted codes patterned after this AFDOUS code.[14,17,21,31]

To satisfy these more rigid requirements, the primary temperature control device for a refrigerated vehicle used for transporting perishable food products must be capable of holding the vehicle interior and cargo temperature at as near to the required temperature as possible. The sensing element should reflect cargo temperature.

In addition to the primary temperature control for the cargo space, mechanical refrigeration systems need other control devices for safety and proper operation. High and low pressure controls perform the same function as for stationary equipment but must be able to function under vibration. For compressors with pressure lubrication, oil pressure switches either stop the compressor or provide a warning signal in the event of failure of oil pressure. For engine driven equipment on cyclic operation, some form of limit control of cranking time is necessary to prevent damage to the cranking motor or batteries in the event that the engine fails to start. An automatic choke is needed to facilitate starting of combustion engines. Automatic defrosting systems require a control means to initiate and terminate the defrost operation. One such system uses a timing device which starts the defrost after a certain number of hours of unit operation; the defrost is terminated by a temperature-sensitive element on the part of the evaporator which is the last to heat up during the defrost. When this element is above 35 F, it switches the operation back to refrigeration. The termination feature can be incorporated in systems which are manually started on defrost. Many mechanical systems are designed for operation at any cargo space temperature, and because the compressor displacement necessary for, say, −20 F evaporator, would overload the compressor drive at a higher evaporator temperature, various means to prevent this overloading are provided. Thermal expansion valves with a limiting maximum operating pressure are used; crankcase pressure limiting valves are used; and also partial unloading of the compressor. The type of control system provided will determine the balance between temperature pull-down rate and engine loading during precooling. All systems are equipped with some means for determining the adequacy of the refrigerant charge in the system, either a sight glass in the liquid line, or trycocks on the receiver.

For additional information on controls, see Chapters 13 and 36 of the 1961 Guide And Data Book.

Accessory Equipment

Mechanical refrigerating systems with independent engines require batteries for cranking, and fuel tanks and pumps, if connection cannot be made to the vehicle fuel supply. Where liquefied petroleum fuels are used in replaceable vessels, the fuel tanks should be in tandem with an automatic change-over valve with visible indication so that replacement of the empty vessel can be made at a convenient time. If a single permanent vessel is used it should be equipped with a clear indication of the fuel reserve so that recharging can be scheduled. Heavy-duty, weatherproof connections should be provided for units with electric motor standby, and the vehicle should be equipped with a flexible power cable with the necessary adapters to permit connection to the conventional types of power outlets. Indicating gages, lights, etc., which are peculiar to any given system should be easy to understand, and should be readily visible from the operator's seat in the vehicle cab. Where an electric generator is a part of the system, some means for readily checking the operation of this generator should be furnished. Meters which indicate total hours of operating time are particularly useful in scheduling preventive maintenance. Depending on the type of operation of the vehicle, guards for the exposed sections for protection against tree branches, rocks, etc., should be provided. If the evaporator or fan section is subject to damage from loading equipment or commodity, guards should be installed.

CALCULATION OF COOLING LOADS

Cooperative studies recently concluded between the USDA, the National Bureau of Standards and various industry groups represented by the Truck-Trailer Manufacturers Association, have developed a standard rating method for refrigerated trailers. Similar studies for refrigerated trucks are now in progress in cooperation with the Truck Body and Equipment Association. The trailer rating method developed at the National Bureau of Standards is described in *Marketing Research Report* No. 433.[32]

At least one commercial laboratory, in Philadelphia, now offers this rating service.[13,31]

The importance of testing refrigerated vehicles with the interior and ambient temperatures and ambient humidity about the same as would be experienced in actual use is discussed in *AMS Report* No. 250.[41] Fig. 6 shows a method developed by the National Bureau of Standards for measuring the heat gain of a refrigerated trailer under these test conditions.[42] Another method has been suggested by Alteri.[43]

The need for standard heat transfer rating methods for trailers and standard performance rating methods for refrigerating units was indicated by a comparative study in 1956 of several commercial 35 ft trailers and their respective mechanical refrigerating units. The study showed a variation in total heat transfer of nearly 1½ to 1 for the trailers; in temperature pull-down time (a function of both unit and trailer) of more than 3 to 1; and in refrigerating capacity of more than 2 to 1 for the units.

Chieger discussed design and testing of refrigerated van bodies.[31]

Although suitable standards are not in general use for rating the performance of all the various types of refrigerating systems used for refrigerated trucks and trailers, the Air-Conditioning and Refrigeration Institute has a produce section dealing with this problem, and has issued *ARI Standards* 1110–59 and 1120–61, dealing respectively with speed-governed and variable-speed transport refrigeration units employing forced-circulation aircoolers.[44,45]

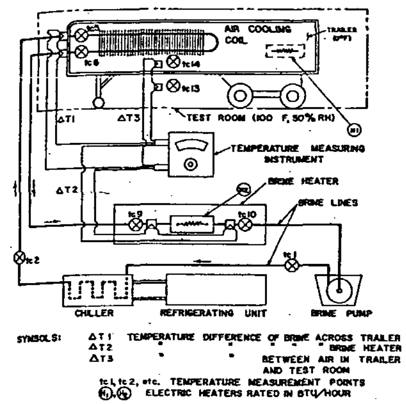

Fig. 6 .... Schematic Diagram of Calorimeter to Measure Heat Gain of Refrigerated Trailers

As indicated by these two standards, and until standards are available for all types of systems, the comparison of refrigerating units, for capacity, should be made on the basis of net refrigerating capacity at specified conditions of air temperature at condenser and evaporator inlet, as for example, 18,000 Btu per hr at 100 F ambient temperature and 0 F trailer interior temperature.

It should be noted that such a unit also could be described as having a capacity of 1½ tons, at these same ambient and trailer temperatures, and is approximately the largest unit in current production for this service. Advertising claims for capacity ratings larger than this should be examined carefully to determine the conditions under which the larger ratings were obtained.

A refrigerating system should be specified for a particular vehicle based on the net refrigerating capacity required at the cooling unit in the vehicle, expressed in Btu per hr at the intended trailer temperature and at the maximum design ambient temperature where the vehicle will be expected to operate.

Because long haul vehicles are subject to widely different service load characteristics from vehicles used in local or retail delivery operation the two categories present different problems in attempting to compute the necessary refrigerating capacity.

Even within one of these categories or the other there is wide variation in the types of operation. For example, a long haul operator may require refrigeration only one way and carry dry freight on the back haul, or may carry frozen commodities and produce on alternate loads. A local delivery operation may be based entirely on customer order delivery as opposed to selling from the truck. Each individual application will determine the combination of insulation thickness, vehicle weight, unit type and capacity selection. Variables to be considered in selecting a refrigerated vehicle and unit have been listed by Strong.[46]

Two examples of vehicle heat gain are given. Rule-of-thumb values are used to approximate the heat transfer effect of framing, air leakage, etc. The effect of framing members on the heat transmission rate can be approximated by computation in many cases if the construction details are known, but such computations are not generally in use at the present time. Some types of construction will certainly have more heat conducting penetrations through insulated spaces than others. For example, a trailer with meat rail supports in the roof presents a different insulating problem than one which does not require this facility. A retail vehicle with 50 stops in an 8 to 10 hr daily schedule, presents a different problem from one with, say, 10 major deliveries in a 16 hr schedule. Various estimators have approached the problem in different ways. Some manufacturers suggest adding 10 percent to the insulation heat transmission to allow for increased heat leakage through framing, others suggest 50 percent. Some suggest that heavy service loads represent 100 percent added to the total heat transmission, others 75 percent. It is known that vehicles in motion increase in heat gain in proportion to the amount of air leakage caused by the motion, and that the effects of solar radiation are greater on a vehicle which is not in motion. Heat gain through the floor of a vehicle in motion is increased because of waste heat from the vehicle engine and from radiation from the road surface.

More information is needed on the effect of solar radiation, air leakage and air exchange during door openings, before the calculation of cooling loads and the selection of refrigerating unit capacities can approach exactness. Current studies by the National Bureau of Standards, U. S. Department of Agriculture, and the Truck Body and Equipment Association are investigating these variables. Preliminary results indicate that solar radiation can increase the cooling load of stationary vehicles more than 15 percent for several hours during a bright sunny day.

Many manufacturers of refrigerating units for trucks and trailers have prepared rule-of-thumb charts, based on empirical information, showing the model of their respective equipment which they recommend for a particular installation and the decision is influenced by data provided by the purchaser dealing with specific operation details.

Perhaps the largest uncertainty is the product load itself. In some instances, the truck operator has been unjustly criticized for failure to provide proper refrigerating equipment when the product was loaded at temperatures so high that reduction of product temperature to the required delivery temperature was not possible during the length of the haul. If reduction in product temperature is to be a part of the hauling agreement, the unit must be selected accordingly, and the rate for hauling adjusted. Trucking operators should become thoroughly familiar with methods of checking product temperature for their own protection against unwarranted damage claims. (Guilfoy and Johnson have described methods for checking temperatures.[47]) As an example, suppose that on a 24 hr haul, 30,000 lb of lean beef were to be delivered at 40 F, and presumably loaded at 40 F, but were actually loaded at 50 F. If the average truck heat gain during the trip was 6000 Btu per hr including pull-down after loading, the additional capacity required of the unit if the meat was to be lowered 10 F, would be

$$30{,}000 \times 0.77 \times 10/24 = 9620 \text{ Btuh}$$

Added to the truck heat gain of 6000 Btuh, the unit would then need a minimum capacity, with the cargo space temperature lower than the usual 40 F, of 15,620 Btuh.

Suppose this meat had been loaded at 35 F instead of 50 F