

pressor and to provide temperature control are used, such as a flywheel-mounted clutch which operates electro-magnetically. A direct drive arrangement with a two-speed gear shift which operates on a power take-off shaft in the truck transmission has been used. Since the gear shift is manual there is danger that the compressor will be over-speeded.

One system has a condenser-evaporator assembly mounted in the nose of the truck with the compressor driven directly by a power take-off at the transmission. When the vehicle is garaged, an electric motor is used to drive the compressor and house current is rectified to operate the direct current condenser and evaporator fan motors.

One manufacturer has a flexible shaft drive for the unit compressor and condenser fan.

Fig. 4 shows the manner of installation of the flexible shaft and condensing unit, with a belt-driven electric clutch at the forward end of the flexible shaft. The clutch is mounted below the truck engine crankshaft pulley. In this system, of course, the compressor speed is a function of engine speed. A variation of the power transmission mechanism for use with a belt driven flexible shaft provides for driving the compressor with a standby electric motor. The flexible shaft attaches to the tang at the left hand end and drives the electric clutch which is attached to the universal joint. The three-groove pulley on the right hand end drives the compressor, and the two-groove pulley is for the standby electric motor. The two-groove pulley is mounted on an overrunning clutch and the electric motor is idle when the compressor is being driven by the flexible shaft. When the electric motor is operating, the electric clutch is disengaged. The flexible shaft is driven by belt from the engine crankshaft, using the electric clutch for temperature control.

One or more types of hydraulic clutches have been used, with primary power taken from the truck transmission or drive shaft. As is the case with other systems using power take-off from the truck engine, the use of eutectic plates is common to provide continuous refrigerating effect when the truck engine is not operating.

Since there are many combinations of features and styles of power take-off equipment available, for defrosting, heating, standby, fans, and other equipment, prospective users are advised to study the particular needs carefully in order to take advantage of the wide selection.

The hydraulic power transmission system is a special case of the range of types using some form of power take-off from the truck transmission or engine. It is becoming increasingly popular and several manufacturers are offering equipment utilizing this principle. The hydraulic pump is either mounted in the truck engine compartment and belt driven from the engine crankshaft or is direct driven from a power take-off in the truck transmission. Fig. 5 is a schematic of the hy-

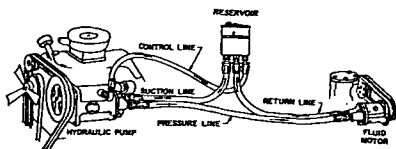


Fig. 5. . . . Engine-Mounted Hydraulic Pump with Fluid Motor to Drive Truck Refrigeration Compressor

draulic system with the pump mounted on the truck engine and belt driven from the crankshaft pulley.

In a hydraulic system, the pump provides, by means of internal valving, a constant power source for a designed range of engine speed. A hydraulic motor drives the compressor, and an electric motor can be furnished for standby operation. Most hydraulic systems are available as a package, designed for a particular temperature range and class of service.

Any type of evaporator can be used in a system with a hydraulically driven compressor, the choice depending on the type of truck operation intended. Temperature control is effected through valving which unloads either the hydraulic pump or hydraulic motor.

MECHANICAL REFRIGERATION EQUIPMENT

Power and Drive Equipment

Any mechanical refrigeration system consists of three elements: highside, with a compressor; lowside, with refrigerating surface; and some means of providing power for driving the compressor, and condenser and evaporator fans. This section deals with the power and drive equipment.

The simplest units are those driven by electric motors, either hermetic or conventional type for the compressor, conventional type for the fans, operating on regularly available house current when the vehicle is garaged. Because this type of unit operates only when the vehicle is idle, the system must store up refrigerating capacity by using eutectic plates. If fans are required for the evaporator during use of the vehicle, they must be driven by motors which will function on power available when the truck is in operation.

In contrast to these are the systems which derive power from the vehicle engine, and which can provide refrigeration only when the vehicle engine is operating. It is economically unwise to operate a 100-plus hp engine solely to operate a refrigerating system requiring at most 15 hp, so these systems are not recommended where the vehicle schedule on the road contains long idle periods. If the road operation consists of a large percentage of moving time, this system is suitable. Many means of power take-off are available and several are described elsewhere in this chapter. Various means for controlling the temperature in the cargo space are available, and range from manual to fully automatic. For reasonable ratios of moving versus idle time on the road, truck engine driven units in conjunction with eutectic plates are satisfactory. Most units driven by the truck engine can be equipped with standby electric motor drives for use while the vehicle is garaged.

The majority of long haul vehicles and many local delivery vehicles which use mechanical refrigerating units are equipped with systems powered by an independent engine which may be operated on either gasoline, diesel fuel or liquefied petroleum gas. Some detailed descriptions of several independent engine driven systems are given elsewhere in this chapter and include engine driven generators which electric motors for the compressor and fans, engine driven compressors under the vehicle with evaporator and fan sections in the cargo space, and engine driven compressors integral in a one piece plug type unit which contains the entire refrigerating system. Most of these systems are fully automatic, with the power and drive equipment arranged for either start and stop cyclic operation at the demand of a thermostat, or for variable or multiple step speeds for temperature control.

Two general size groups of independent gasoline (or butane or propane) engines are used for truck and trailer refrigeration. The first group consists of those engines used to drive a

fan or blower for moving air through a bunker, and possibly to drive a pump for brine. The largest use in this group is with water ice bunkers in trailers used for perishable produce hauling. The size range is generally from 1½ to 3 hp and the weight will seldom exceed 100 lb. The other group consists of the many styles of engines used to drive mechanical refrigerating units of many sizes. Generally the required brake horsepower will be in the range from 4 to 15, although many systems are purposely equipped with engines having maximum speeds and ratings when new which are much higher than required to assure a longer life and adequate capacity as the engine ages. It should be noted that a refrigerating unit usually imposes its full load on the driving engine continuously when running, as contrasted with the vehicle engine, which operates only a portion of its running time at more than half throttle. Most of the engines used in either group are four cycle and operate at not more than 2800 rpm, some as low as 1800 rpm. For small gasoline engines, a rule-of-thumb estimate of fuel consumption is one lb per hp hr. A seven hp load, for example, would require about one gal of gasoline per hr. Generally, the fuel consumption per hr-hr decreases slightly as the engine size increases. Engines used for the 4 to 15 hp loads will vary in weight from 5 to 15 lb per rated hp, and may be either air or liquid cooled. They may be separate from the compressor and either belt or direct connected to it, or may be made integral with the compressor. The use of diesel engines for the larger units is increasing.

High Side Equipment

High sides for the units in smaller vehicles which are electrically operated when the vehicle is garaged are very similar to those used on stationary units of equal capacity. They may be made of heavier materials to withstand vibration, but since they are inoperative when the vehicle is in motion, they do not require special attention to those features which can be affected by motion, such as adverse movement of oil or liquid refrigerant, effect of motion on normal direction of air through the condenser, etc.

The high side for any system which operates when the vehicle is in motion must include several safeguards not normally required of a stationary unit. The possibility of severe motion shock, and vibration, must be considered and all mechanical components designed with this in mind. Short rigid lines are subject to coldworking and likely to fail. Heavy objects such as driers, valves and sight glasses must be individually anchored. The presence of water and dirt must be protected. Bearings for all parts which are exposed must be protected. Shaft seals, particularly, must be sealed against dirt or abrasive material penetration. Electric motors must be shielded from splashed or air-carried water, and all wiring must be adequately waterproofed. Where compressors are mounted on the truck engine or made integral with an engine, consideration must be given to the higher ambient temperatures. Any standard compressor can probably be made to operate for transport refrigeration but the wide range of operating conditions has resulted in special designs for compressors which have reduced both weight and size without sacrificing capacity. A modern lightweight, 3-cylinder compressor, developed for transport refrigeration, using Refrigerant 12 and at 2200 rpm, is rated at 1.15 tons at -20 F saturation suction temperature, and 4.5 tons at 30 F saturation suction temperature, in 100 F ambient temperature, and weighs 87 lb.

Condenser air flow must be designed so that normal air motion created by the movement of the vehicle does not pre-

vent adequate air circulation. All components of the high side which may require service must be installed in such a manner that the service operation can be accomplished readily; some units are constructed with the high side capable of pull-out servicing; others provide for the condenser to swing out exposing the other items, etc. Items requiring periodic lubrication should be clearly identified by paint or tags and all service should be scheduled on a regular preventive maintenance basis. Permanently installed gages are of distinct help to preventive maintenance personnel, and should be checked at regular intervals for calibration. Sight glasses, driers, valving and other accessories are similar to standard items.

Low Side Equipment

Various types of evaporators are used for truck and trailer refrigeration. They include finned tube or pipe coils for both forced and gravity circulation, pipe coils, plate surfaces and eutectic plates. Each is suited to a particular type of vehicle and/or operation. Some of these evaporators are described elsewhere in this chapter. Because the finned tubing coils have the largest heat transfer coefficient per unit of weight they are the most popular with operators of for-hire vehicles, which competitively need to employ the highest possible ratio of payload to vehicle weight.

Various types of finned coil evaporators which mount inside of the truck body are available and are connected by tubing to a remote mounted condensing unit.

Large capacity eutectic plates are most practical where there is a need for continued refrigeration of a particular vehicle when the condensing unit cannot be operated continuously or when the plates are station-charged. Where a vehicle is used under refrigeration for both storage and transportation, such as is experienced in some captive fleet operation, the use of plates finds favor in spite of the weight penalty. This is particularly true in the ice cream and frozen meat industries. When refrigerated shelves and compartment dividers are used, plates are ideal.

Plate surfaces are customarily defrosted by manually scraping the surfaces if the vehicle is maintained under constant refrigeration. Failure to keep frost formation from plate surfaces reduces the effectiveness of the surface area. One manufacturer states that failure to keep frost from plate surfaces results in as much as 25 percent over design of plate surface required for a given vehicle. Finned coil evaporators are usually defrosted by cyclic operation if the vehicle is operated at temperatures above 32 F. This type of low side for operation continuously below 32 F is usually defrosted by means of hot gas or reverse cycle operation of the refrigerating unit. Not all hot gas defrost systems are full reverse cycle; some merely permit the discharge gas from the compressor to bypass the condenser and enter the evaporator. If defrosting is done frequently enough, or if only limited heating is needed this type of operation will be adequate. For removing thick layers of frost at less frequent intervals, or for higher heating capacity, full reverse cycle, where the evaporator is used as a condenser, and the normal condenser, or other surface, is used as an evaporator, can provide heating capacities as high as the compressor capacity and ambient conditions will permit. During defrosting operations, various types of damper arrangements are used to isolate the evaporator from the air in the cargo space, and fans are either turned off, or the air flow blocked. For heating the cargo space, of course, fan operation and air flow is maintained. Thermal expansion valves are the primary means of refrigerant liquid flow control for transportation equipment low sides.