[35] Bulletin published by Aluminum Ore Co., East St. Louis, Ill. and Aluminum Co. of America, Pittsburgh, Pa.

[36] Bulletin 121, Microtraps, Davison Chemical Division, W. R. Grace & Co.

[37] W. A. Patrick and D. C. Jones (*Journal of Physical Chemistry*, 29, 1929, p. 1).

[38] W. A. Hammond (*Journal of Chemical Education*, 12 (9) 1935, p. 446. Bulletin, W. A. Hammond Drierite Company, Yellow Springs, Ohio).

[39] Bulletin, Linde Company, Division of Union Carbide Corp.

[40] W. O. Walker and W. R. Rinelli: U. S. Patent No. 2,163,901.

[41] W. O. Walker: Latest ideas in use of desiccants and driers (*Refrigeration Service & Contracting*, August 1963, p. 24).

[42] A. J. Gully, H. A. Tooke, and L. H. Bartlett: Desiccant-refrigerant moisture equilibria (REFRIGERATING ENGINEERING, April 1954, p. 62).

[43] *Standard Method of Testing Desiccants for Refrigerant Drying* (ASHRAE Standard 35A-1956).

[44] *Standard Methods of Rating and Testing High Side Liquid Line Driers* (ASHRAE Standard 35B-1956). *Standard for Rating Liquid Line Driers* (Air-Conditioning and Refrigeration Institute Standard 710–1964).

[45] *Standard Procedure for Servicing Hermetic Motor Burnouts* (Section 91, p. 9101, *Service Manual*, Refrigeration Service Engineers Society, 433 No. Waller Ave., Chicago, Illinois).

[46] J. E. Hoffman and B. L. Lange: Acid removal by various desiccants (ASHRAE JOURNAL, February 1962, p. 61).

[47] R. L. Mays: Molecular sieve and gel-type desiccants for Refrigerants 12 and 22 (ASHRAE JOURNAL, August 1962, p. 73).

[48] W. O. Walker, J. M. Malcolm, and H. C. Lynn: Hydrophobic behavior of certain desiccants (REFRIGERATING ENGINEERING, April 1955, p. 50).

[49] W. O. Krause, A. B. Guise, and E. A. Beachain: Time factors in the removal of moisture from refrigerating systems with desiccant type driers (ASHRAE TRANSACTIONS, Vol. 66, 1960, p. 465).

[50] W. R. Brisken: Moisture migration in hermetic refrigeration systems as measured under various operating conditions (REFRIGERATING ENGINEERING, July 1955, p. 42).

[51] W. A. Pennington: Role of adsorption-type desiccant in refrigerating units (REFRIGERATING ENGINEERING, March 1951, p. 272).

[52] Evan Jones: Determining pressure drop and refrigerant flow capacities of liquid line driers (ASHRAE JOURNAL, February 1964, p. 70).

CHAPTER 50

LUBRICANTS IN REFRIGERANT SYSTEMS

Functions of Lubricant, Oil Properties, Viscosity, Viscosity Index, Solubility of Refrigerants in Oils, Effect of Dissolved Refrigerant on Viscosity and Sealing Function, Density of Oil-Refrigerant Solutions, Thermodynamics of Refrigerant-Oil Solutions, Mutual Solubility of Oils and Refrigerants, Miscibility and Partial Miscibility, Fluidity of Oil and Wax Separation at Low Temperatures, Solubility of Water and Air in Oils, Volatility, Boundary Lubrication, Oxidation and Refrigerant Resistance, Chemical Reactions in Oil-Refrigerant Systems

THE PRIMARY function of a lubricant is to minimize *friction* and prevent *wear*. In refrigerant systems a second function is to *seal* the gas pressure between the high and low pressure sides. Frequently a third useful function will be to *transfer heat* from the compressor to the external environment either through internal contact with the compressor shell wall or, in some instances, by means of external radiators.

If two perfectly clean metallic surfaces are placed together and one is caused to slide over the other, a resisting force known as the force of *friction* is encountered during the motion. If the surfaces are then separated and examined, either or both will show evidence of having been scraped, gouged, torn or otherwise eroded. This is known as *wear*.

According to the currently accepted theory of lubrication, a lubricant reduces friction and prevents wear by interposing an easily sheared layer between the moving surfaces. Under ideal conditions, this layer or film of lubricant will completely prevent the metallic surfaces from actually touching each other. No real contact occurs. Under less favorable conditions when the lubricant layer may be unable to keep the surfaces apart during their motion, friction and wear are factors to be considered.

OIL PROPERTIES

The properties of a lubricating oil may be classified as either physical or chemical. Among the physical properties important to refrigeration applications are: (1) viscosity, (2), viscosity index, (3) mutual solubility with various refrigerants, (4) fluidity at low temperatures, (5) wax separation, (6) solubility of water in the oil, (7) solubility of air in the oil, (8) volatility and (9) foaming tendency. Significant chemical properties include: (1) boundary film-forming ability, (2) oxidation resistance, (3) refrigerant resistance, and (4) effect of contaminants and additives.

The character of a lubricating fluid is largely determined by its *viscosity* and *film-forming* characteristics. Its other properties, such as pour point, acidity, refrigerant resistance, and solubility, are generally secondary factors in lubrication. But in a refrigerant system, these secondary factors may be very important. Specifications for a lubricant in a refrigerant system must therefore take into account both the primary and secondary factors in order to avoid harmful effects on the system.

Whenever possible, it is desirable to specify the physical and chemical properties in terms of standard test methods. A number of properties, such as color, viscosity, and pour point are readily determined by the standard procedures published by the American Society for Testing and Materials (ASTM). However, many other properties important to refrigeration use have not been standardized. A number of these nonstandardized properties may be determined by special tests described in the refrigeration literature. But regardless of standard or special tests, experience has shown that the proper lubricating oil for a refrigerating system cannot be selected on the basis of laboratory tests alone. *Performance tests* in actual operating systems are necessary since changes in mechanical design often have an unsuspected influence on the behavior of the lubricant.

Ordinarily, the specification of suitable lubricants for a given type of refrigerating equipment is the responsibility of the manufacturer. Servicing practice should follow his recommendations, and it is only rarely that an engineer who is concerned with installation, maintenance, or service will be obliged to depart from this policy.

Viscosity Grades of Refrigerator Oils

Broadly speaking, refrigeration oils may be subdivided into two main types—*paraffin base* and *naphthene base*, depending on the preponderance of paraffin or naphthene hydrocarbons in the refined oil. Table 1 classifies these two types according to viscosity and other physical properties. Table 2 lists viscosity ranges which have long been recommended for refrigeration systems of various types.

In selecting a viscosity for a specific application the compressor designer must take into account the environment to which the oil will be exposed. The viscosity of the lubricating fluid is strongly influenced by temperature changes and also depends on refrigerant concentration if the refrigerant dissolves appreciably in the oil.

Viscosity Index

Viscosities of mineral oils decrease sharply with a rise in temperature. The conventional method of representing this effect is to plot viscosities vs. temperatures on a special type of graph paper uniquely scaled to produce straight line relations. Such a plot is shown for two different oils in Fig. 1.

The slope of the viscosity-temperature lines is different for different oils. This difference is commonly expressed as an empirical number called *viscosity index* (VI) (see ASTM D567). An oil with a high viscosity index (HVI) shows less change in viscosity over a given temperature range than an

The general responsibility for this chapter is assigned to TC 1.8, Lubrication.