stability more easily. This test requires either pre-heating of the air to a relatively high temperature, or in the case of an air-cooled unit, that the air leaving the condenser be used for the evaporator. The second arrangement is simple and inexpensive, but may cause wide variation in performance if the system is not controlled carefully.

The primary function of the factory performance test is to assure that a unit is constructed and assembled properly. Therefore, all equipment must be compared to a standard unit. Normal causes of malfunction in a complete refrigeration system are overcharging, undercharging, presence of noncondensable gases in the system, blocked capillaries or tubes, and excessive power. To determine the validity and sensitivity of any test procedure, the best approach is to use a unit with known characteristics, and then to establish limits for deviations from the test standard. If the established limits for charging are ±1 ounce of refrigerant, for example, the test unit is charged first with the correct amount of refrigerant, and then with one ounce more and one ounce less. If this procedure does not establish clearly defined limits, it cannot be considered satisfactory. This same procedure should be followed with regard to all variables which influence performance and result in deviations from established limits. Once more it must be emphasized that all equipment must be carefully maintained and calibrated if tests are to have any significance. Gages must be checked at regular intervals and protected from vibration. Capillary test lines must be kept clean and free of contamination. Power leads must be kept in good repair to eliminate high-resistance connection, and electrical meters must be calibrated and protected if consistent data are to be secured.

In plants where testing of components and manufacturing control have been perfected to such a degree that the average unit may be expected to perform satisfactorily, units are tested only long enough to find major flaws. Complete testing of some units from time to time assures product reliability. This approach is sound and economical, because complete testing of all units greatly taxes power and plant capacity.

When the evaporator load is static, as in the case of refrigerators or freezers, time, temperature, and power measurements can be utilized to measure performance. The time elapsed between start and first compressor shut-off, or the average *on-and-off* period during a predetermined number of cycles in either a controlled or known ambient temperature, can be used to determine performance. Also, suction and discharge temperatures in connection with power readings are used to establish conformity to standard. On units where the necessary connections are available, pressure readings may be taken. Such readings, however, are usually possible only on units where loss of refrigerant is not critical, because gages can hardly be connected and disconnected without some loss of refrigerant.

In factory performance testing, plus or minus ten percent deviation from rated capacity, and from ten to fifteen percent from rated power are accepted. This takes into consideration both deviations due to the test method used and the normal system variance. Results under calorimeter measurement should vary less than five percent for a well designed unit.

Testing of Components

Testing of components used in refrigeration systems must be based upon a thorough understanding of use and purpose of the component. Pressure switches are calibrated and adjusted with air in a bench test, and need not be checked again, if there is no danger of blocked passages or pull-down trip-out during the operation of the switch. However, if the switch is brazed into the final assembly, precautions are needed to prevent blocking of the switch capillary.

Capillaries used in refrigeration systems are checked by air testing. When the capillary limits are known it is relatively easy to establish a flow rate and pressure drop test for eliminating crimped or improperly sized tubing. When several capillaries are used in a distributor, a series of water manometers are used to check for unbalanced flow and to find damaged or incorrectly sized tubes.

In plants having good manufacturing control, only sample-testing of evaporators and condensers is necessary. Close control of coils during manufacture will lead to the detection of improper expansion, poor bonding, split fins, or uneven spacing. Proper inspection, therefore, will often eliminate the need for costly test equipment. In testing the sample, either a complete evaporator or condenser, or a section of the heat transfer surface is tested. Since liquid-to-liquid furnishes the most easily and accurately measurable heat transfer medium, a tube or coil can be tested by passing water through it while it is immersed in a bath of water. The temperature of the bath is kept constant, and capacity found by measuring the coil flow rate and the temperature differential between water entering and leaving the coil.

REFERENCES

1 M. B. Goddard: Moisture in Freon refrigerating systems (Refrigerating Engineering, September 1945, p. 215).

2 L. W. Larsen and J. Elliot: Factory methods for dehydrating refrigeration compressors (Refrigerating Engineering, December 1953, p. 1325).

3 H. A. Blair and J. Calhoun: Evacuation and dehydration of field installations (Refrigerating Engineering, August 1946, p. 125).

4 Private communication to ASRE from R. R. Pickett.

5 E. W. McGovern (*Refrigeration Service Engineering*, Vol. 7, No. 3, 1939, p. 23).

6 W. B. Anderson: Domestic refrigerating units—their manufacture and testing (Refrigerating Engineering, May 1941, p. 323).

7 W. P. Griest: Notes on moisture determination in refrigerant (Refrigerating Engineering, May 1941, p. 316).

8 A. M. Fenwick: Paper presented at 1940 meeting of Refrigeration Service Engineers Society.

9 H. L. Flenner and W. R. Calverly: The determination of moisture in liquid sulfur dioxide (Refrigerating Engineering, May 1931, p. 344).

10 R. H. Dinsmoor (*Refrigeration Service Engineering*, Vol. 7, No. 8, 1939, p. 34).

11 W. A. Pennington (*Analytical Chemistry*, No. 21, 1941, p. 766).

12 *Standard Methods of Rating and Testing High-Side Liquid Line Driers* (ASHRAE Standard 35B-1956).

13 F. T. Reed: Moisture determination in refrigerant oil solutions by the Karl Fischer method (Refrigerating Engineering, July 1954, p. 65).

14 *Methods of Testing Electrical Insulating Oils* (*ASTM Specification* D 117-58).

15 J. D. Morton and L. K. Fuchs: Determination of moisture in fluorocarbons (ASHRAE Transactions, Vol. 66, 1960, p. 434).

16 A. F. Benning, A. A. Ebert, and C. F. Irwin: Water determination in Freon-12 by infra-red spectrometry (Refrigerating Engineering, February 1948, p. 166).

17 R. A. Gray: Improved method to test desiccants, driers use drier refrigerant in recirculating unit (*Air Conditioning and Refrigeration News*, November 11, 1957).

18 E. S. Taylor: New instrument for moisture analysis of "Freon" fluorinated hydrocarbons (Refrigerating Engineering, July 1956, p. 41).

19 W. R. Brisken: Moisture migration in hermetic refrigeration systems (Refrigerating Engineering, July 1955, p. 42).

20 E. R. Weaver and R. Riley (National Bureau of Standards Research Paper RP1865, 1948, p. 40).

CHAPTER 48

CONTAMINANT CONTROL IN REFRIGERANT SYSTEMS

Contaminants: Moisture; Copper Plating; Residual Solvent; Metallic Contaminants, Flux, and Dirt; Noncondensable Gases; Antifreeze Agents; Design and Operating Conditions; High and Low Temperatures; Field Assembly; Materials in Systems: Experimental Methods for Evaluation; Refrigerants; Lubricants; Hermetic Motor Insulation; Driers

THE contaminants in a refrigerant system include not only dirt and moisture which may remain after manufacture and installation but also acid, sludge, and other products of the chemical reactions which take place while the system is operating.

This chapter will discuss the various contaminants, the effect of design and operating conditions, and the characteristics and limitations of various materials used in refrigerant systems.

The major factors in the formation of contaminants in a refrigerant system during operation are: (1) the design and operating conditions, and (2) the system components and materials. An improper combination of these two factors generally is the cause of contaminant problems.

Because many of the problems involved have complicated inter-relationships which cannot be studied in the laboratory, some problems found in actual systems cannot be explained completely on the basis of laboratory tests. However, there has been increasing interest in and investigation of the problems caused by various contaminants in refrigerant systems.[1]

CONTAMINANTS

Contaminants are those substances present in the refrigerating system which do not serve any useful function in the proper operation of the equipment. They originate as residuals from manufacturing processes, assembly, and installation, or from the malfunction of the equipment itself. Some contaminants, such as moisture, are always present. Others are formed when adverse operating conditions are imposed on the equipment or from reactions caused by an improper choice of components. Generally, they are present in small quantities which do not adversely affect operating characteristics. Equipment manufacturers generally take extreme care to remove, or avoid the formation of, undesirable substances (see Chapter 47). When equipment is properly engineered, processed, and maintained, contaminants are kept at a low level. It must be recognized, however, that in mass production processes a small quantity of substandard equipment may be produced in spite of rigid quality control. If manufacturing processes go out of control or if recognized practices for assembly and maintenance are not followed, contaminants can remain or form, in quantities that may lead to eventual equipment failure.

Moisture

Water or moisture is always present in refrigerating equipment. The control of moisture in refrigerant systems is discussed in Chapters 47 and 49.

The general responsibility for this chapter is assigned to TC 1.17, Contaminants in Refrigeration Systems.

Copper Plating

The formation of a film of metallic copper on metallic surfaces in refrigeration compressors is known as copper plating. In some cases, the copper deposit may become heavy enough to interfere with the operation of the compressor and, in extreme cases, lead to failure. The causes and mechanism of copper plating have been studied[2,3,4,5] and explained in general terms, although the reactions are complex and complete details are lacking.

It is apparent that copper plating takes place in two steps. First, copper must be dissolved in the oil. Then, in a separate reaction, it must be precipitated or plated from the solution. Some factors which affect these two steps are listed in Table 1.

The most important factor in dissolving copper is the quality of the oil, but there is at present no universal agreement on how to measure the quality of the oil. Steinle[4,5] has shown a direct correlation between the composition of the oil and its ability to dissolve copper. He concluded that an oil will not cause copper plating if it meets the following tests: oleoresin content below 0.3 percent, sulfur content below 0.2 percent, aniline point above 212 F, and a Philipp-Tiffany test of at least 96 hr. Oleoresin is a term used by Steinle for a portion of a lubricating oil that can be removed from the oil by chromatographic separation because of its more polar nature compared with the bulk of the oil. It is interesting to note that Kvalnes and Parmelee did not find direct relationship between any one of these chemical characteristics and refrigerant breakdown in sealed-tube tests.[6]

Divers[7] found good correlation between: (1) the *Modified Continental Oxidation Test*, (2) a simple copper plating proclivity test using carbon tetrachloride with the sample oil, and (3) many years of service experience.

Steinle[4] and McGovern[5] have shown that when copper is dissolved by lubricating oil, it is present as an organic copper compound and is not soluble in water. Steinle isolated such a compound and determined its composition. The copper is associated with carbon, oxygen, and sulfur, indicating that it is dissolved by the polar or oleoresin constituents in the oil. The low incidence of copper plating in modern equipment seems due primarily to the improved quality of available lubricating oils.

The presence of oxygen contributes to the solubility of copper by reacting with the oil to form additional polar compounds which have an effect similar to the oleoresins which may already be present. This is one reason why air should be removed from refrigeration equipment.

The rate of solution of copper by lubricating oils is considerably increased at higher temperatures. McGovern[5] found that more than 40 times as much copper was dissolved at 200 F as at 75 F in a one-month test. However, the temperature is more difficult to control than the other factors affecting