



Fig. 1 .... Curves Showing Solubility of Water in Certain Refrigerants<sup>1</sup>

origin as being due to water. Corrosion in a butane or iso-butane system is due to the direct action of water on metals. For further information, see Chapter 48.

Walker and Rinelli<sup>4</sup> have shown that approximately 90 percent of the sludges analyzed by them were due to moisture; the others examined were due to oil. Prevalence of the burnout of hermetic motors has shifted this percentage in favor of sludges formed by motor insulation breakdown. It is probable that many salt type sludges, especially those containing oil decomposition products, were due to thermal reactions of the oil and refrigerant. This reaction was not known until a later date. In some systems, sludges are primarily formed by overheated motors and bearings and by insulation breakdown. Elsey<sup>5</sup> and Steinle<sup>6</sup> have separately shown that a reaction may take place at high temperatures between oil and the halogenated refrigerants with resulting formation of hydrochloric and hydrofluoric acids. In addition, the oil discolors and thickens and, if the reaction goes far enough, carbon is formed. The viscous or carbonized oil may result in severe damage to bearings and valves. The acids cause severe corrosion.

Waring<sup>14</sup> has shown that a relatively large quantity of moisture in a reciprocating system using Refrigerant 12 results in accelerated flapper valve breakage. It was found that the same system, overhauled completely and equipped with an efficient drier, operated indefinitely without flapper valve breakage. Incipient corrosion, probably of an intercrystalline nature, was advanced as the cause of fatigue failure of the flapper valves.

Copper plating may be the result of the action of, or related to, moisture.<sup>11</sup> (See Chapter 48.)

Consideration of the foregoing shows that the amount of water present in a refrigerant system must be small enough to avoid ice separation and corrosion.

Table 1 shows the results of a survey of 20 equipment manufacturers, conducted by ASHRAE Technical Committee 1.11, to determine the maximum tolerable moisture content. These data show that the maximum, as well as the actual, moisture content of machines is generally higher with Refrigerant 22 than with Refrigerant 12. Since the quantity of moisture required to produce corrosion is generally assumed to be above that causing freezing, elimination of freezing should also exclude corrosion of the type due to water. This obviously is not true for systems in which expansion valves or capillary tubes operate above the freezing point of water.

### DRYING METHODS

The final choice of the method used in drying refrigerant systems depends on the desired moisture level, on size, available time and cost. (See Chapter 47.)

It may be useful to give some details concerning some dehydration methods used in various plants. In the compressor plant described by Larsen and Elliot,<sup>12</sup> the parts supplied to the assembly line are dehydrated prior to assembly and then the assembled unit is also dehydrated. The evaporator tubing is baked 8 to 10 hr at 280 F, while dry air is passed through it. After assembling the whole unit, it is leak-tested at 300 psig while immersed in a tank of water. Units passing this test for relatively large leaks are then evacuated to less than 200 microns and heated in an oven at approximately 250 F. Units which cannot hold this high vacuum, have either a leak or contain moisture. While still being evacuated, the unit is placed in an atmosphere of helium. Any leaks will draw helium gas into the system, and these units are rejected at the next station where the gas inside the unit is analyzed with a mass spectrometer. Normally, the unit is then charged, test run, electrically tested, and leak tested, with an electronic leak detector.

Another drying procedure<sup>13</sup> is designed to dehydrate refrigeration units to a maximum moisture limit of 0.03 g residual moisture per refrigerating machine. Dehydration is accomplished by sending the refrigeration units through an oven heated to 300 F for at least 2 hr. While in the oven, the unit is evacuated to below 1000 microns within the first few minutes. It leaves the oven at a maximum pressure of 50 microns. In the oven, electrical power is applied to the motor winding to bring the winding temperature to 300 F as quickly as possible.

A drying procedure for sulfur dioxide machines described by McGovern,<sup>14</sup> includes heating in an oven at 250–275 F under vacuum, greater than 29.5 in., for 4 hr. This is intended to reduce the moisture content of the machines to approximately 0.0095 oz of water per cu ft of internal machine volume. As a means of removing the water vapor remaining in the machine, flushing with dry air is recommended. A discussion of drying by vacuum treatment at room temperature and flushing with dry air is also included in Reference 5.

Anderson<sup>15</sup> has shown a very desirable feature associated with the use of dry air, namely, that when dry air is drawn through the equipment, restrictions and stoppages are revealed; whereas neither is indicated when a vacuum is employed.

It should be noted that, although winding heat is an effective method of removing moisture from a stator, it must be carefully controlled to prevent overheating, particularly when units of various sizes are dehydrated at the same time. Application of the wrong voltage on either a 440-volt stator or a 220-volt stator, for example, may result in poor moisture removal or in overheating, respectively.

The use of either direct or alternating current for winding heat appears to be optional. The application of the latter keeps the windings hotter, due to the eddy current heating of the stator laminations. Since, in a sealed system, the cellulose of the stator contains much water which evaporates slowly, prebaking may be used to reduce dehydration time. Either straight oven heat at 250 F, or storage in a low humidity room is possible. One manufacturer reports the removal of 30 cc of moisture from a 7½ hp, 4-pole stator by prebaking. Recent developments in motor manufacture indicate that slot insulation containing little or no moisture may be used in

### Moisture in Refrigerant Systems

Table 1 .... Results of Survey on Moisture in Refrigeration Systems

| Application                              | Max Tolerable Moisture, PPM |                                              | Moisture in Units, PPM |                                           |
|------------------------------------------|-----------------------------|----------------------------------------------|------------------------|-------------------------------------------|
|                                          | Refrigerant 12              | Refrigerant 22                               | Refrigerant 12         | Refrigerant 22                            |
| Domestic Refrigerators and Freezers      | 10, 10, 10, 15              | —                                            | 5, 8, 10               | —                                         |
| Food Display Cases                       | 10, 15, 15, 20              | 15, 20                                       | 5, 10                  | 5                                         |
| Frozen Food Cases                        | 10, 10, 10, 15              | 10, 15, 15                                   | 10                     | —                                         |
| Room Air Conditioners                    | 15, 25                      | 25, 25, 40, 55, 60, 100                      | 10, 10                 | 5, 15, 15, 15, 20, 60                     |
| Residential and Package Air Conditioners | 10, 15, 15, 25, 50          | 10, 15, 25, 25, 35, 40, 40, 40, 60, 100, 180 | 7, 10, 15, 40          | 7, 10, 15, 15, 15, 20, 25, 40, 50, 55, 60 |
| Field-Built Systems                      | 15, 20, 25                  | 15, 40, 40, 100                              | —                      | 10, 15, 60                                |

Answers Based on: Data 2; Field Experiences 6; Opinion 2.  
Percent of Field Problems Due to Moisture:

0—Negligible  
1—2 percent  
3—4 percent  
1—40 percent

0—Negligible  
1—2 percent  
1—3 percent  
3—10 percent  
1—30 percent  
1—40 percent

\* Indeterminate, because failure due to moisture has the same appearance as failure due to other causes.

hermetic applications. This should materially reduce the stator dryout problem.

Wile<sup>16</sup> describes, in very general terms, a drying method for ice cream cabinet units. Better than ordinary drying, necessitated by the low temperatures involved, is attained by dehydrating each piece of equipment at high temperature and a very fine vacuum. This procedure apparently results in systems sufficiently dry, but silica gel driers are placed on each machine as an additional precaution.

Carter<sup>8</sup> has also dealt with the field removal of moisture. The heat and vacuum, hot air, carbon dioxide and alcohol, and double evacuation methods of dehydration are discussed and illustrated. Methods of heating the equipment include the use of infrared lamps. The double evacuation method is considered most satisfactory, and it is fully discussed and its efficiency calculated. A moisture indicator aids in determining when dehydration is finished.

Fenwick<sup>17</sup> describes a system and apparatus for producing dry air and drying units in the field as well as in the factory. Units of this type are commercially available, and are usually used in pairs for continuous operation.

When conditions in the field do not permit heating of the equipment, *anhydrous methanol* (methyl alcohol) has been used to flush out moisture. Since the alcohol has a lower boiling point than water, it may be removed more readily than water by means of a stream of dry air, carbon dioxide, or oil-pumped nitrogen, or by the application of a vacuum. Under no circumstances should the alcohol in quantity be allowed to remain in the system since it may produce corrosion.<sup>14</sup> Anhydrous methanol, in quantities somewhat less than one percent, does not appear to induce rapid corrosion and, moreover, exerts an antifreeze action.

### MOISTURE MEASUREMENT

Various methods have been developed for checking the moisture level in the refrigerant system. They are described in detail in Chapter 47 and listed in Table 1 of the same chapter. Obviously, the measuring method varies with the type of drying process employed, but unfortunately the moisture limits accepted by the different manufacturers do not always correspond.

One of the most common methods of moisture checking is the cold trap method, and when dry air is used, the dew point of the outgoing air is frequently used as a check on the effi-

ciency of the process. Fenwick<sup>17</sup> advocates the use of a dew point of  $-40^{\circ}\text{F}$  (equal to 0.046 gr water per cu ft) for the air leaving the equipment, as proof that it is dry. Anderson<sup>14</sup> determines the residual moisture in the last machine of a series, which has been dried with air, by drawing off the moisture into a liquid air trap and calculating therefrom the quantity in the machine. McGovern<sup>14</sup> recommends drawing a vacuum on the equipment being tested, closing off the system and observing the pressure rise. If no pressure rise occurs after a time, the machine may be considered dry, since moisture remaining in the machine will create its own gas pressure.

Moisture may also be determined by removing a portion of the liquid refrigerant from a machine which has been operated for several hours until the moisture is in equilibrium throughout. The quantity of moisture in the removed sample is determined by the phosphorus pentoxide method.<sup>11</sup> Walker and Rinelli<sup>18</sup> developed a method applicable to methyl chloride, methylene chloride and Refrigerant 12 which makes possible routine analysis of a very large number of machines. Diniak et al<sup>19</sup> have described a simple rapid method for determining the water content of a circulating refrigerant of the fluorocarbon group. Duncan<sup>20</sup> determined moisture in refrigerant units by collecting it in a cold silica gel drier. The moisture was then expelled from the drier with Refrigerant 12 gas at 370 F and collected in Nesbitt tubes. Elsey<sup>21</sup> used a dew-point method for determining the moisture contents of gas samples taken from refrigerating units in the plant and in the field. Sterk<sup>22</sup> compared various desiccants by using them in operating units. The moisture indicator is a useful device for showing whether a system is wet or dry. See Chapter 48.

### DESICCANTS

Desiccants are used to remove excessive moisture from installed equipment, particularly after it has been overhauled and recharged. A desiccant is a chemical compound capable of adsorbing, or reacting chemically with the moisture contained in the liquid or gaseous refrigerant-oil mixture.

Considerable information about desiccants has been published in the chemical literature,<sup>23–25</sup> but not all data given are directly applicable to the problem of refrigerant drying. Therefore articles dealing specifically with the use of desiccants in refrigerant drying should be consulted.<sup>13–24</sup>

In order that a chemical substance be acceptable for use as a desiccant, it must possess, in addition to the property of