Table 6 .... Critical Miscibility Values of Refrigerant 22 with 18 Different Oils

| Oil Base Type | Approx Viscosity Grade | Oil No. | Viscosity at 122 F (Converted to SUV) | Critical Solution Temp., F | Critical Solubility, Weight % Oil |
|---|---|---|---|---|---|
| Naphthene | 75 | 2 | 63 | −35 | 15 |
| Naphthene | 75 | 3 | 60 | 21 | 25 |
| Naphthene | 150 | 1 | 92 | 27 | 20 |
| Naphthene | 200 | 8 | 116 | 75 | 22 |
| Naphthene | 200 | 7 | 125 | 68 | 22 |
| Naphthene | 200+ | 5 | 131 | 3 | 16 |
| Naphthene | 250 | 4 | 136 | −4 | 18 |
| Naphthene | 250 | 6 | 140 | +1 | 22 |
| Naphthene | 500 | 13 | 252 | None[a] | None[a] |
| Naphthene | 500 | 12 | 280 | None[a] | None[a] |
| Naphthene | 700 | 11 | 320 | None[a] | None[a] |
| Naphthene | 1000 | 10 | 430 | 61 | 18 |
| Naphthene | 1200 | 9 | 500 | 48 | 18 |
| Paraffin | 200+ | 18 | 137 | None[a] | None[a] |
| Paraffin | 250 | 17 | 148 | None[a] | None[a] |
| Paraffin | 300 | 16 | 165 | None[a] | None[a] |
| Paraffin | 350 | 15 | 210 | None[a] | None[a] |
| Paraffin | 400 | 14 | 232 | 111[b] | 18 |

[a] Never completely miscible at any temperature.
[b] A second (inverted) miscibility dome was observed above 136 F; above this temperature the oil-Refrigerant 22 mixture again separated into two immiscible solutions.

temperature. And it is also true for the temperature plot, as was shown for the vapor pressure plot on graph (b), that all points outside the dome represent mixtures which are completely miscible, and all points inside the dome represent mixtures which form two immiscible solutions.

More than one curve of this type may be plotted on a *miscibility diagram*. Each single dome then represents the immiscible ranges for *one* refrigerant mixed with *one* oil.

Miscibility curves or diagrams have been published for Refrigerants 13,[8] 13B1,[8] 22,[17,19,20] 114,[1] 502,[8] and mixtures of Refrigerants 12 and 22.[13] Typical curves selected from these references are shown in Figs. 30 to 35.

## Miscibility of Refrigerant 22 with Mineral Oils

The miscibility of Refrigerant 22 with oils, both mineral and synthetic, has been the subject of numerous studies. Among the synthetic oils, a polybutyl silicate oil has been reported as showing improved miscibility with Refrigerant 22 (and also Refrigerant 13) at low temperatures.[21] However, synthetic oils have not yet won general acceptance for refrigerant systems and will not be considered further in this chapter.

Several reports have dealt with miscibility differences resulting from the use of different types and viscosity grades of mineral oil with Refrigerant 22. Fig. 32 shows one of the miscibility diagrams reported by Bosworth.[17] Oil A is a paraffin base oil; oil B is a mid-continent oil; and oils C and D are naphthene base oils. All are 300 SUV dewaxed refrigeration grade oils. The diagram indicates that Refrigerant 22 is less miscible with the paraffin base oil.

Walker and his coworkers have also reported on the miscibility of different oils with Refrigerant 22.[19] Twelve different brand-name oils commonly used for refrigerating machines were tested, and miscibility curves were constructed for each oil. Four of these curves are shown in Fig. 33, but only in part. The purpose of Fig. 33 is to illustrate the typical conditions required to form two liquid phases in refrigerant-rich mixtures, such as may exist in an evaporator; hence the horizontal scale has been magnified in the low oil concentration range, and the miscibility curves have been cut off above twelve percent oil. The oils represented are 150 SUV and 300 SUV viscosity grades of naphthene base refrigerator oils. The curves show the following miscibility relations for Refrigerant 22 mixtures:

| Oil Content of Refrigerating Liquid in the Evaporator | Temperatures at Which Two Liquid Phases Appear | |
|---|---|---|
| | 150 SUV | 300 SUV |
| 2 percent | −28 to −37F | −13 to −16F |
| 5 percent | + 8 to 0F | +26 to +22F |
| 10 percent | +35 to +23F | +54 to +45F |

Thus Walker's data indicate that, if a Refrigerant 22 system, and especially the evaporator, can be designed to limit the oil content of the circulating refrigerant to two percent or less, there will be little danger of oil separation, except at fairly low temperatures.

An extensive study of the miscibility of Refrigerant 22 with 18 different oils has been reported by H. J. Löffler.[20] Most of these oils were experimental products, intended not so much for ultimate practical use as to provide a working range of low, medium and high viscosity gaders in both naphthene and paraffin base types. Considerable variation in miscibility was found. Complete miscibility diagrams are shown in Löffler's original paper; however, only the reported critical values (as converted) are summarized in Table 6.

In general, addition of Refrigerant 12 to Refrigerant 22 systems increases oil solubility and lowers the critical solution temperature. This latter effect appears as a drop of about 40

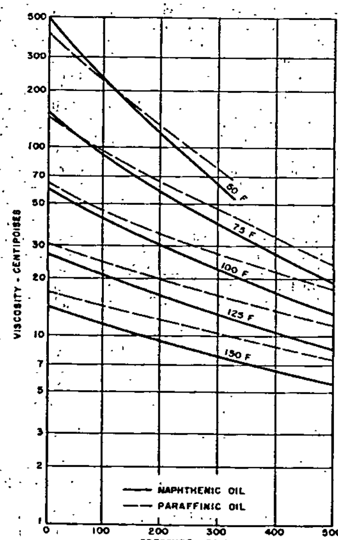



Fig. 16 .... Viscosity of Mixtures of 300 SUV Oils and Refrigerant 13[13]

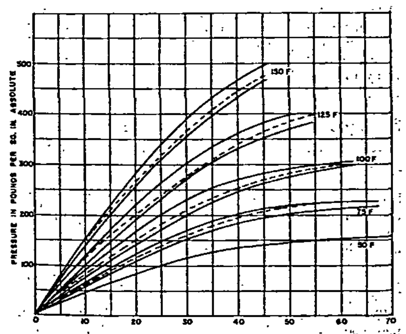


or 50 F when the mixed refrigerants contain 85 percent Refrigerant 22 and 15 percent Refrigerant 12.[12,19] It has been reported[12] that, for a given weight concentration of oil cooled below the critical solution temperature, the minimum temperature at which the oil-rich phase will still flow is not as low when the refrigerant mixture contains Refrigerant 12. However the Refrigerant 12 addition also narrows the immiscible range and extends the solubility of the refrigerant on the oil-rich side, e.g., from 18 weight percent refrigerant for pure Refrigerant 22 to 24 weight percent refrigerant for the 85/15 Refrigerant 22-12 mixture, both measured at the minimum flow temperature. Thus the oil-rich phase is automatically further diluted by refrigerant when Refrigerant 12 is added to Refrigerant 22 and hence the minimum flow temperature actually drops instead of rising. The decrease is from −89 F to − 107 F for the 15 percent Refrigerant 12 addition mentioned above.[12] The naphthene base oil tested in this particular case had experienced a critical solution temperature of + 27 F when diluted with pure Refrigerant 22 and about − 23 F when diluted with the Refrigerant 22-12 mixture.

## Partial Miscibility in Evaporators

Immiscibility of oil-refrigerant solutions in the evaporator may lead to problems. Some oil always finds its way to the evaporator since oil separators, if they are used at all, are never perfectly efficient, and the condensing gas always carries a certain amount of entrained oil. Just as oil within a system always contains dissolved refrigerant, liquefied refrigerant in the system always contains dissolved oil.

A problem of major concern may be adequate return of oil from the evaporator to the crankcase. This is frequently accomplished by providing for entrainment in the suction gas. But if the refrigerant has poor solvent power at the evaporator temperature and an immiscible oil-rich phase separates, this viscous, nonvolatile liquid may migrate and collect in pockets or blind passages which are not easily reached by entrainment. Thus, it is possible for the rate of oil return to be affected and in some instances, a particularly obnoxious condition known as oil-logging may occur. Evaporator temperatures also may be affected, particularly in the case of flooded systems, if a




*Broken lines represents 150 SUV paraffin base oil; solid lines, 80 SUV and 300 SUV naphthene base oils. Lower solid line in each group and also 50 F line represents the 80 SUV grade. Redrawn from Reference 14.*

Fig. 17 .... Solubility of Refrigerant 13B1 in Oils

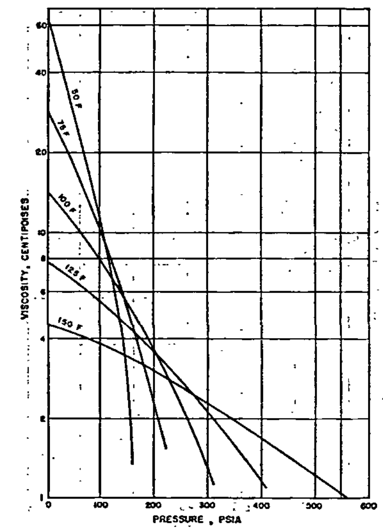



Fig. 18 .... Viscosity of Mixture of 80 SUV Naphthene Base Oil and Refrigerant 13B1[14]

separated oil layer floats on the boiling liquid. The design of the system should take into account all these possibilities, and evaporators should be designed to promote good entrainment. Oil separators are frequently required in the discharge line to minimize oil circulation when refrigerants of poor solvent power are employed.

Parmelee[8] has shown that the viscosity of the oil, or rather the oil-rich solution, in the low side of a system is an important factor in providing good oil return. The viscosity of the oil-rich liquid that accompanies the suction gas will change as it meets rising temperatures on its way back to the compressor. Two influences seem to be at work. First, since the temperatures are increasing, this in itself would be expected to cause a decrease in viscosity. On the other hand, the increasing temperature also tends to drive dissolved refrigerant out of solution, and if the suction pressure remains unchanged, this second influence would be expected to cause an increase in viscosity. Parmelee studied the variation of viscosity with temperature and pressure for five oil-refrigerant solutions at temperatures ranging from −100 F to 70 F. These data are shown in Figs. 36 through 40, inclusive. The oil in each case was a 150 SUV naphthenic oil and the dissolved refrigerants were Refrigerants 12, 13, 13B1, 22, and 502. In all cases, the viscosities of the solutions passed through maximum values as the temperature was changed at constant pressure, a finding that was also consistent with previous data obtained by German workers.[8b,19] According to Parmelee, the existence of a viscosity maximum is significant, since at a given suction pressure the oil-rich solution will become most viscous, not in the coldest regions in the evaporator, but at some intermedi-