DOE/CE/23810-11B

# MEASUREMENT OF VISCOSITY, DENSITY AND GAS SOLUBILITY OF REFRIGERANT BLENDS



**Quarterly Progress Report**

1 January 1993 - 31 March 1993

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April 1993

**Prepared for**
**The Air-Conditioning and Refrigeration Technology Institute**
**Under**
**ARTI MCLR Project Number 655-51400:Blends**

This project is supported, in whole or in part, by U.S. Department of Energy grant number DE-FG02-91CE23810: Materials Compatibility and Lubricants Research (MCLR) on CFC-Refrigerant Substitutes. Federal funding supporting this project constitutes 93.67% of allowable costs. Funding from non-government sources supporting this project consists of direct cost sharing of 6.33% of allowable costs; and in-kind contributions from the air-conditioning and refrigeration industry.

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## Abstract

Liquid/liquid miscibilities of four different 32 ISO VG polyolesters and one alkylbenzene at three concentrations were determined. Also a full vapor lubricant equilibrium (VLE) viscosity reduction of a 32 ISO VG mineral oil with HCFC-22 is complete. Partial viscosity reduction information by the fractionate components from R-502 in 32 ISO VG mineral oil is presented from $40°C$ ($104°C$) and $70°C$ ($158°F$) isotherms.

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# Chapter 1

# Scope

The purpose of this study is to measure the viscosity, density and solubility of four refrigerant mixtures using a single polyolester lubricant. The same measurements will be performed on the individual gases that make up the refrigerant mixtures. The refrigerant mixtures are for blends A, B, C and D respectively, HFC-32/HFC-125 (60/40), HFC-32/HFC-134a (30/70), HFC-32/HFC-125/HFC-134a (30/10/60), and HFC-125/HFC-143a/HFC-134a (44/54/2). The lubricant used in this evaluation is a fully miscible 32 ISO VG branched acid polyolester. Solubility information will include the ratio of fractionation of the individual gases.

A base line evaluation of HCFC-22 and R-502 in a 32 ISO VG mineral oil is included so that a comparison of viscosity and density fluid properties can be determined

## 1.1 Statement and Chemical Properties of Lubricants

Lubricants used in this program are proprietary, thus rather than being specific, a generic nomenclature is used. It can be assumed that all of the polyolesters used in this program are pentaerythritol esters. The most effective method of reporting lubricant quality is to determine alcohol type and stoichiometry of carboxylic acids used in the synthesis. The amount of complexing that was used to provide the viscosity and liquid miscibility of the product with the various refrigerants should also be reported.

Unfortunately, due to proprietary concerns, only the miscibility and viscosity differences of a polyolester are reported. Specific structural properties of the polyolester remain with the manufacturer.

The table A.1, placed at the beginning of the report, identifyies trademarks, registered

trademarks or copyrighted names of lubricants used.

# Chapter 2

# Significant Results

## 2.1 Miscibility Determinations

Four different polyolesters and one alkylbenzene were examined, at three different refrigerant/lubricant concentrations, and the temperatures of liquid/liquid immiscibility were determined (Appendix B). Alkylbenzene was introduced into the examination only to examine the aromatic properties toward miscibility. Surprisingly, for blend D a lower temperatures partial miscibility was observed. This suggests a potential for good oil return and inverse miscibility at the higher temperatures, indicating undiluted hydrocarbon lubrication is possible.

Lubricant B, a 32 ISO VG branched acid polyolester, was found to be the most generally miscible. Lubricant C was of similar viscosity but determined to be the least miscible. Lubricants A and D are in the intermediate range of miscibility, making them potential canidates for this study.

Lubricant B was chosen for this study since it represented a polyolester of very high liquid/liquid miscibility and is assumed to have very little influence on the fractionation of the various single gasses that make up the refrigerant blends. One of the objectives of this research is to study the mixed gas vapor solubility behavior at various pressures and temperatures. Fluids showing levels of immiscibility may dramatically impact the fractionation of individual gasses at different temperatures and pressures.

## 2.2 Viscosity Measurements

Viscosity measurements are performed at isothermal temperatures with varing pressure in an oscillating body viscometer. Fluid properties of viscosity, density and solubility are determined simultaneously. Solubility of single and mixed gasses are determined each time viscosity and density data points are taken. The viscometer is also a very accurate densitometer, allowing it to be used in monitoring the consistency of the fluid.

When refrigerant blends are used, the vapor space of the viscometer is maintained to equal the gas composition of the pure refrigerant blend. The fractionation of the mixed gasses is determined at every temperature and pressure. Samples of the fluid/refrigerant mixture are taken to determine the percent refrigerant by weight in the fluid. The ratio of gasses are determined by gas chromatography.

## 2.3 Viscosity of Mineral Oil and HCFC-22

Appendix C details the isothermal viscosity, density and solubility of HCFC-22 in 32 ISO VG mineral oil. The temperature of the viscosity determinations stop at $-20°C$. Attempts to measure the viscosity at a $-40°C$ were unsuccessful, since the fluid became immiscible for refrigerant concentration greater than 9%.

## 2.4 Viscosity of Mineral Oil and HCFC-502

Appendix D details $40°C$ and $70°C$ temperatures of R-502 isothermal viscosity determinations. Purge gas was maintained at the R-502 azeotrope ratio. Percent concentration of refrigerant represents total of both gasses that were soluble in the fluid at that pressure and temperature.

## Compliance with Agreement

Imagination Resources, Inc. has complied with the statement of the contract.

## Principal Investigator Effort

The principal investigators have devoted 270 hours toward the completion of this contract. Activities have gone toward responding and reporting early refrigerant miscibility information and presenting data to the Technical Oversight Group. Experimental facilites are being established for improved productivity. Technical personel have spent 480 hours.

# Appendix A

# Registered Trademarks of Suppliers

**THE SYNTHETIC LUBRICANTS USED IN THIS TESTING PROGRAM ARE REGISTERED TRADEMARKS, TRADEMARKS, OR ARE NONE OF THE RESPECTIVE MANUFACTURER**

**Table A–1**

| Fluid | Name | Manufacturer | Type | Registered Trademark, Trademark, or None |
|---|---|---|---|---|
| A | Icematic SW32 | Castrol | Branched Acid Polyolester | Registered Trademark |
| B | Emery 2927a | Henkel, Emery Group | Branched Acid Polyolester | Registered Trademark |
| C | RL–184 | ICI Chemicals and Polymers, Ltd. | Mixed–Acid Polyolester | Registered Trademark |
| D | Artic EAL 224R | Mobil | Mixed–Acid Polyolester | Registered Trademark |
| E | Shrieve Zerol 150 | Shrieve Chemical Company | Mineral Oil | Registered Trademark |
| F | Sun ISO 3GS | Witco, Corporation | Mineral oil | Registered Trademark |

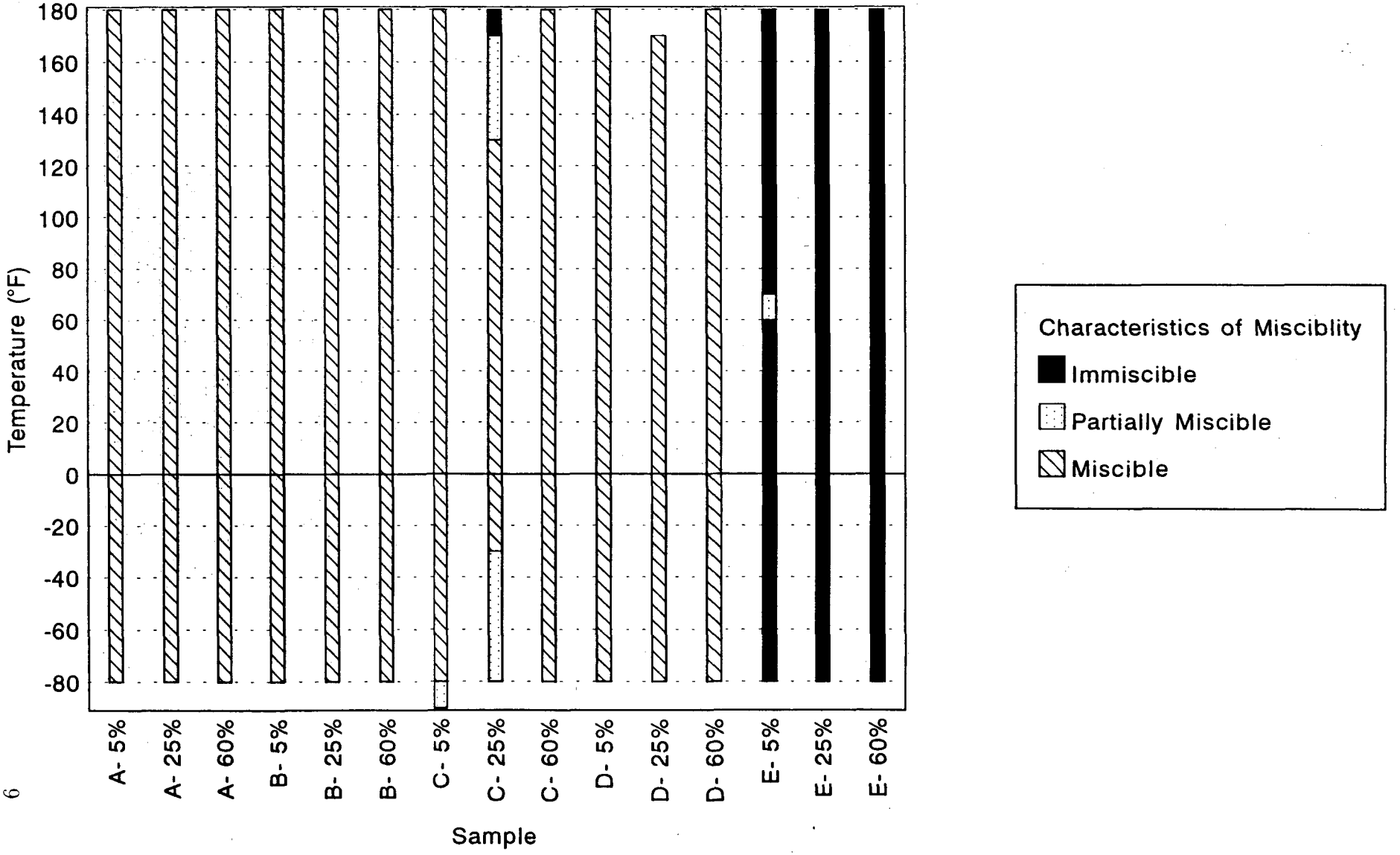
**Note: All fluids are 32 ISO VG viscosity.**

# Appendix B

# Miscibility of Refrigerant Blends with Polyolesters

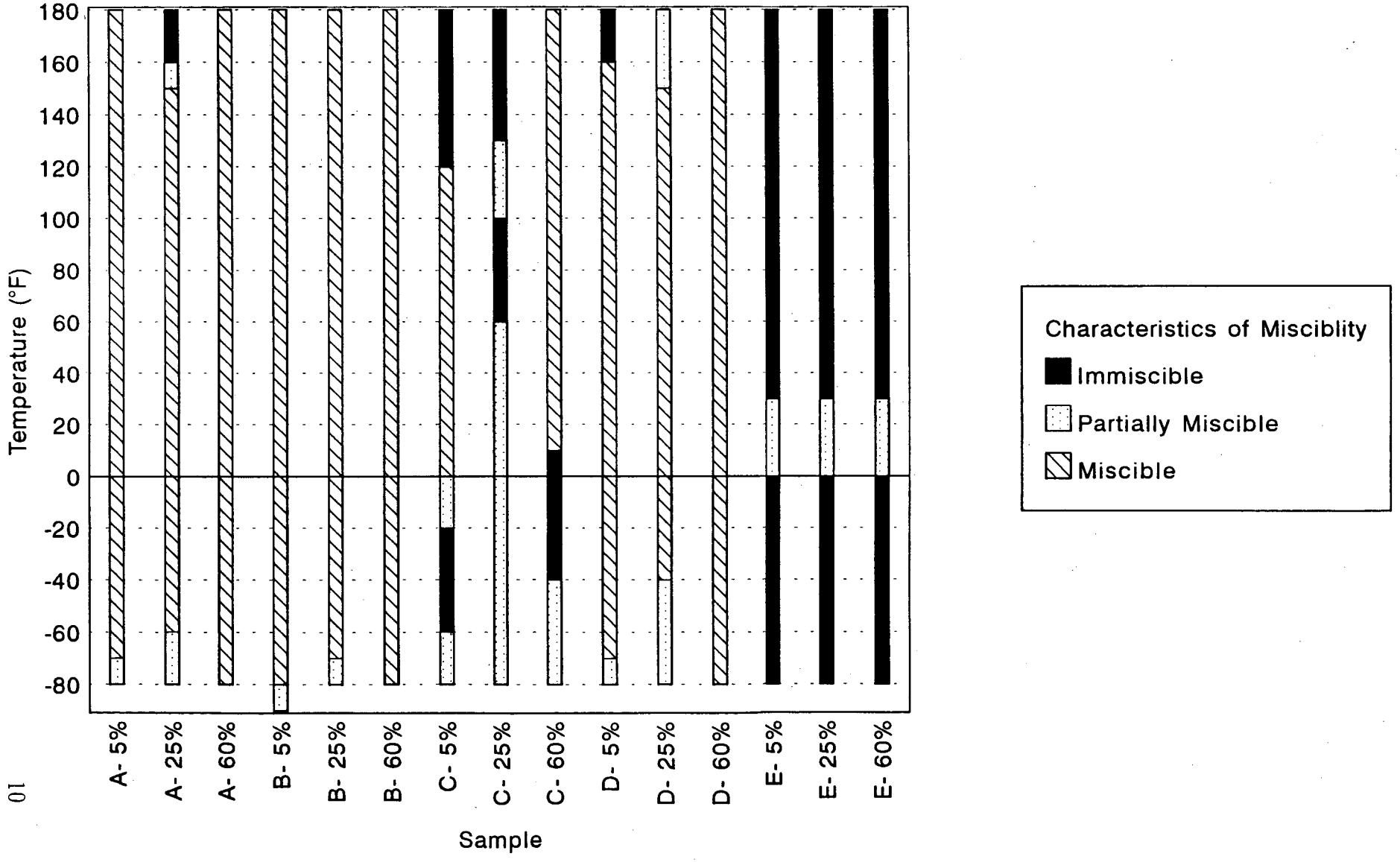
# Miscibility of Refrigerant Mixture

## HFC-32(30%), HFC-125(55%), HFC-134a(20%), and HC-290(5%)



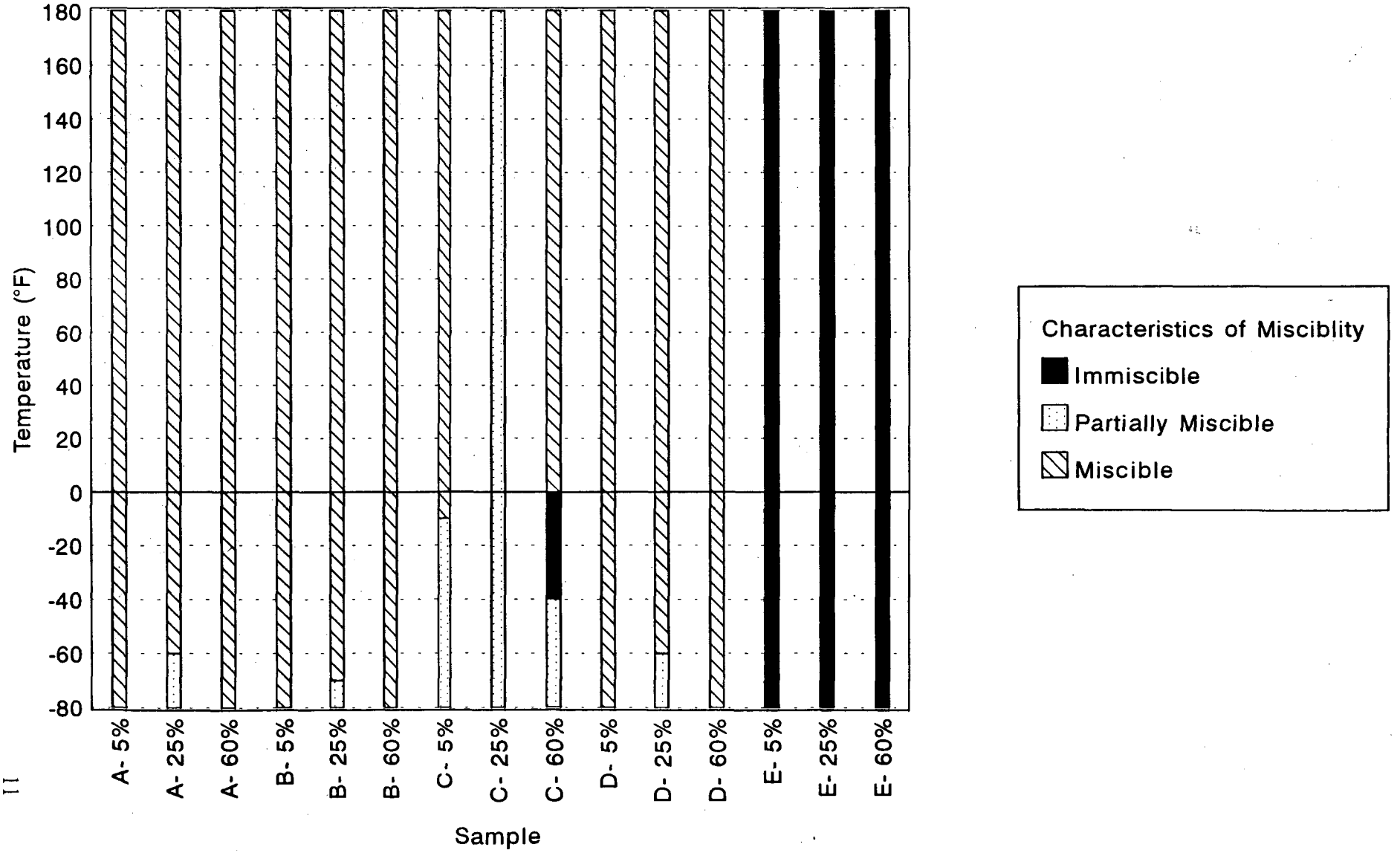
# Miscibility of Refrigerant Mixture

## HFC-32(60%) and HFC-125(40%)



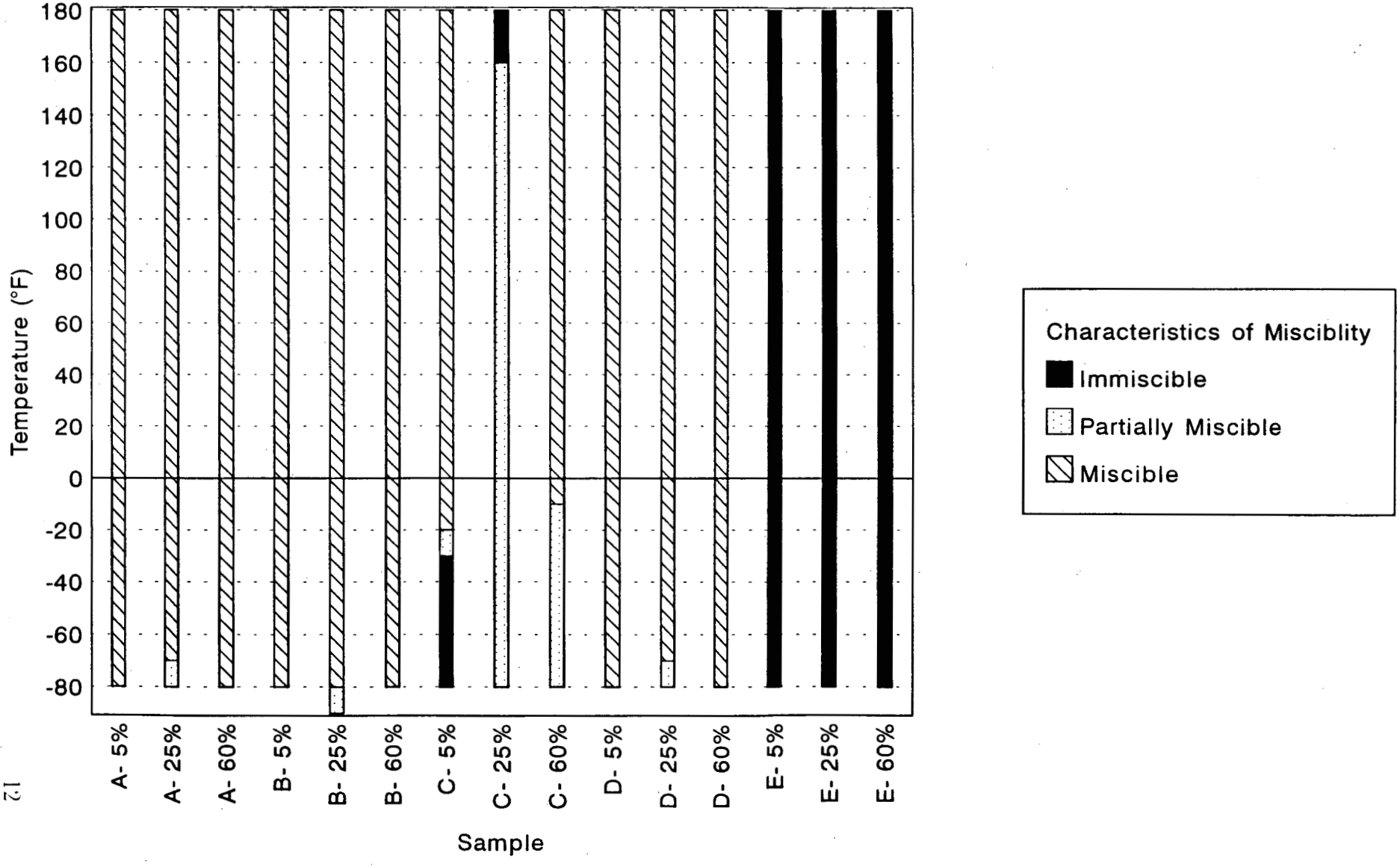
# Miscibility of Refrigerant Mixture

## HFC-32(30%) and HFC-134a(70%)



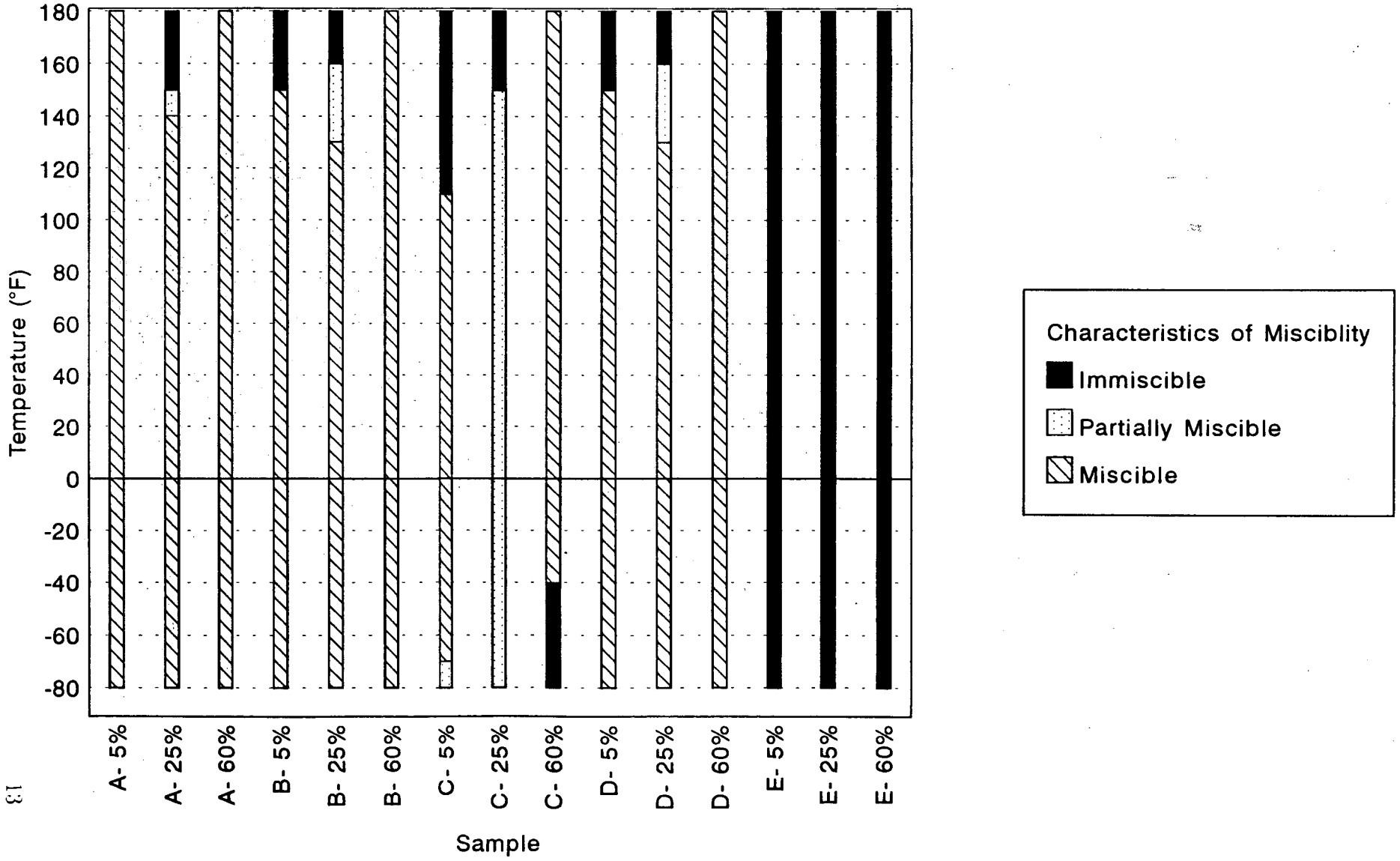
# Miscibility of Refrigerant Mixture

## HFC-32(30%), HFC-125(10%), and HFC-134a(60%)



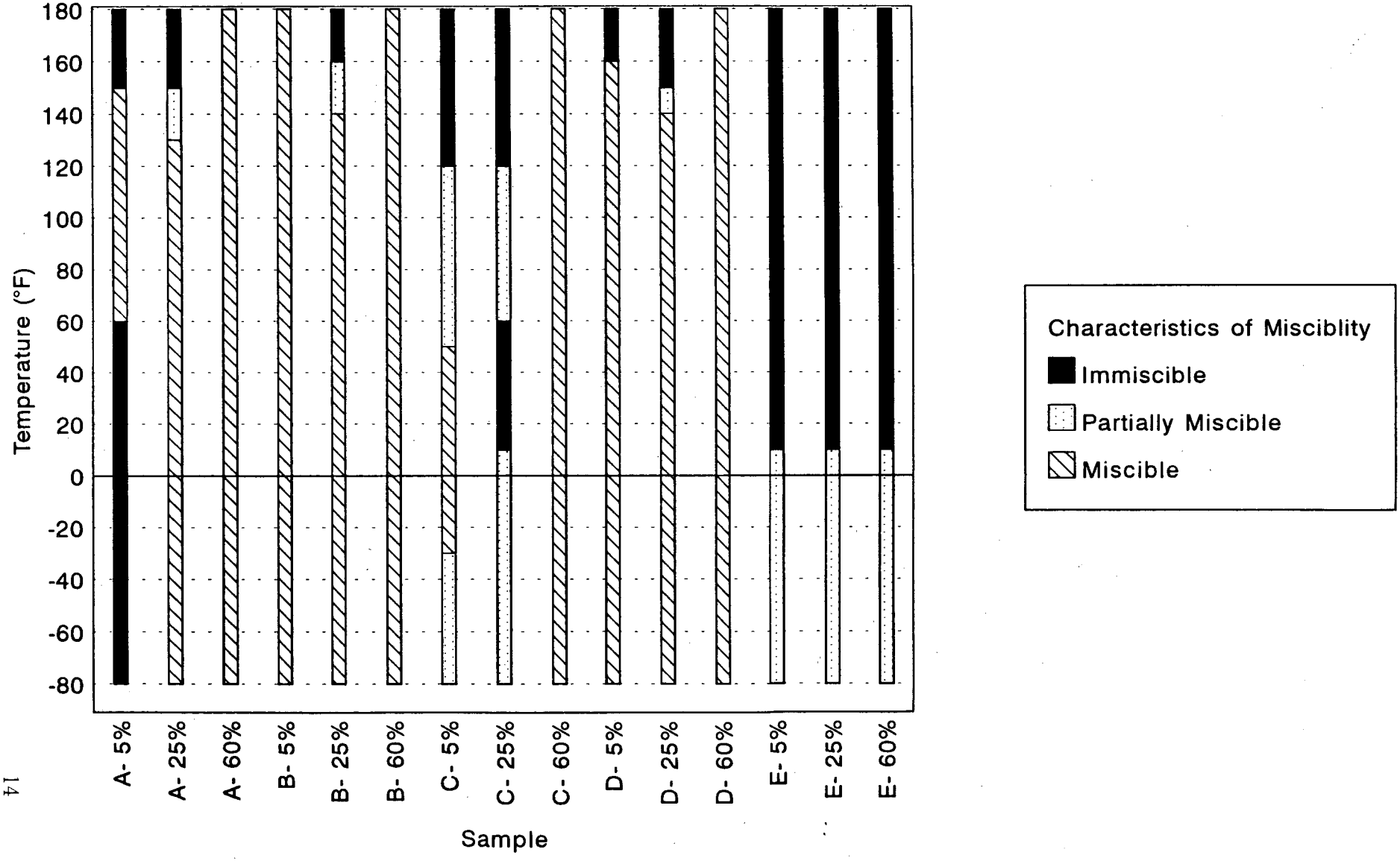
# Miscibility of Refrigerant Mixture

## HFC-125(45%) and HFC-143a(55%)



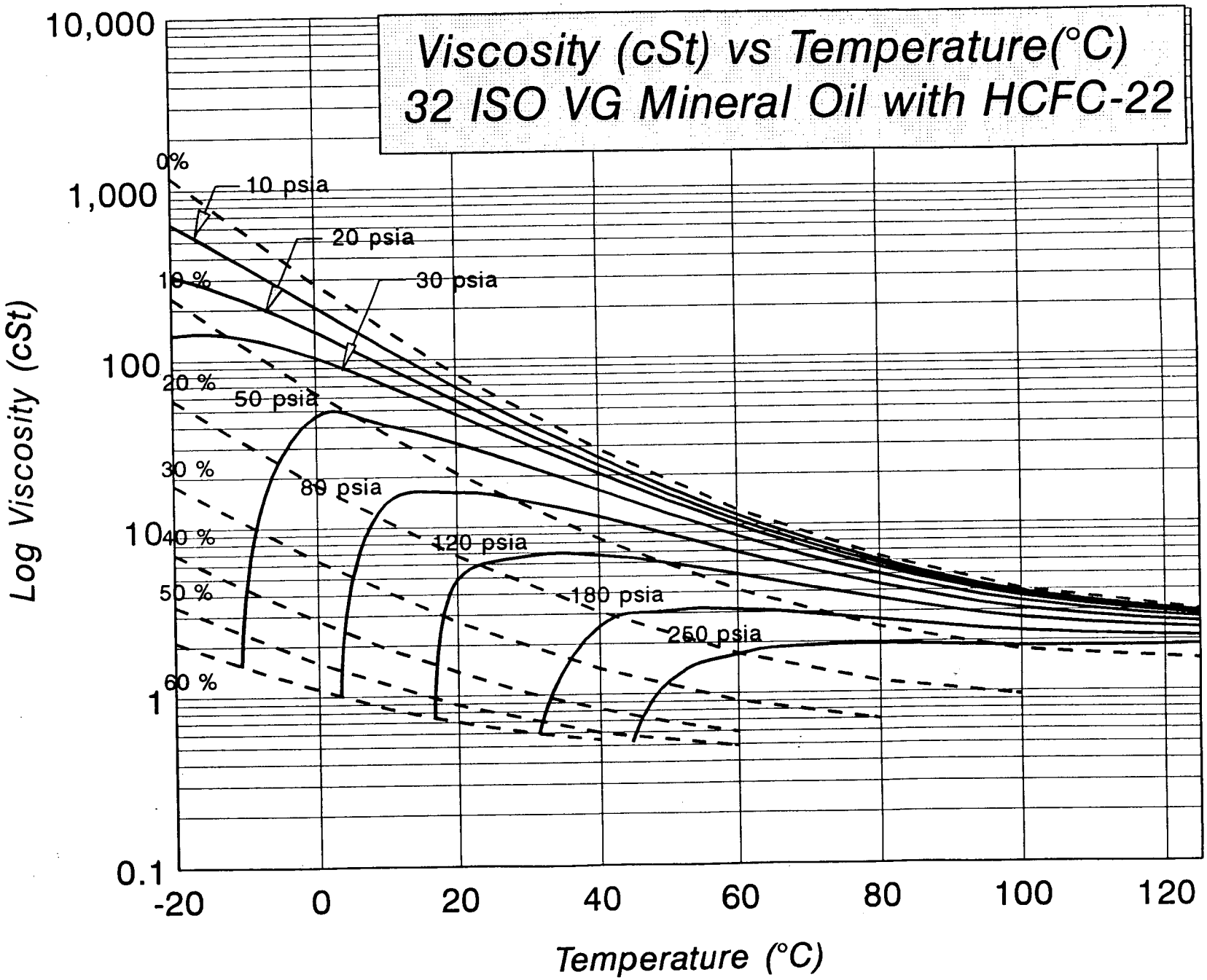
# Miscibility of Refrigerant Mixture

## HFC-125(44%), HFC-143a(52%) and HFC-134a(4%)

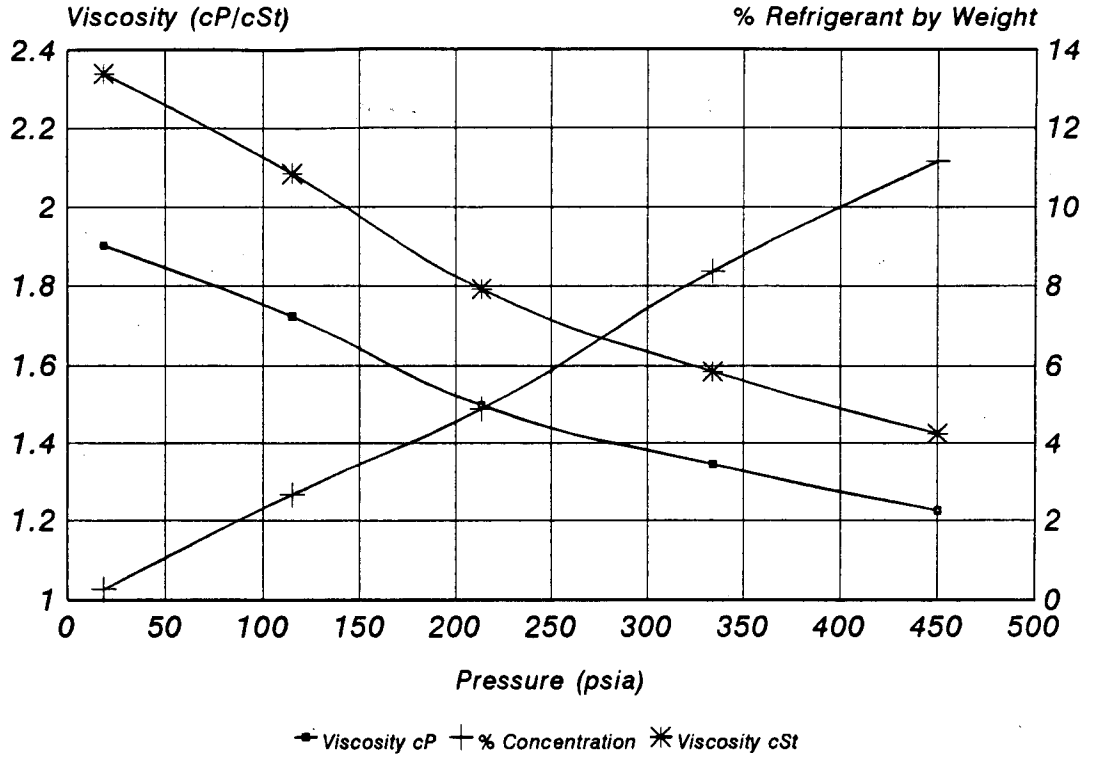


# Appendix C

# Viscosity and Solubility of HCFC-22 with 32 ISO Mineral Oil

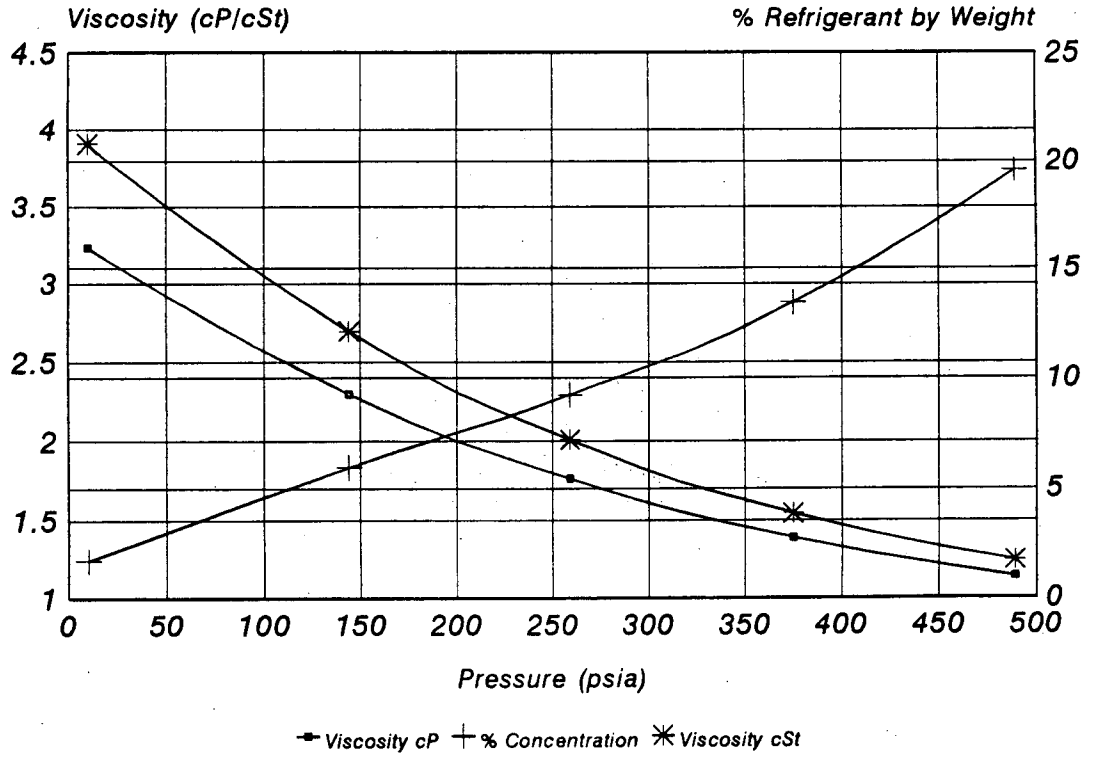

Viscosity (cSt) vs Temperature(°C)
32 ISO VG Mineral Oil with HCFC-22
10,000
1,000
100
10
1
0.1
Log Viscosity (cSt)
-20
0
20
40
60
80
100
120
Temperature (°C)
0%
10 psia
20 psia
30 psia
10 %
20 %
50 psia
30 %
80 psia
40 %
120 psia
50 %
180 psia
250 psia
60 %

## *Viscosity and Solubility of 32 ISO VG Mineral Oil Determined at 125 °C w/ HCFC-22*



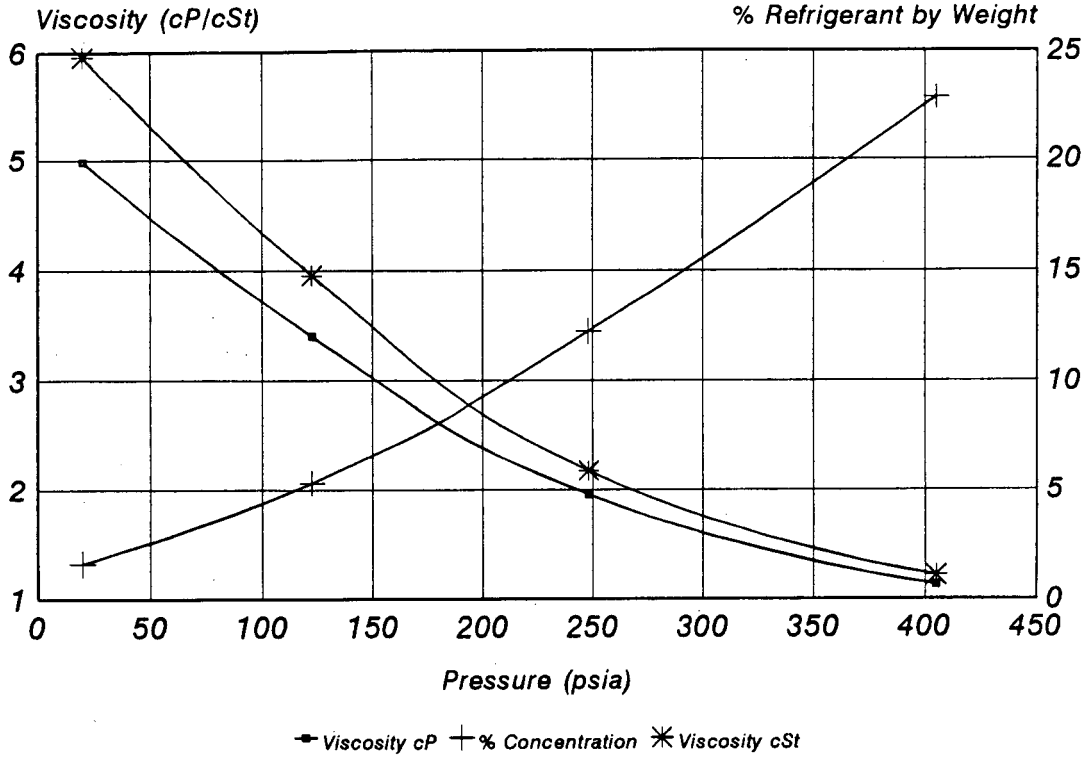

**Viscosity via Gas Solubility Equilibrium**
**Oil degassed to 20 Millitorr**

## *Viscosity and Solubility of 32 ISO VG Mineral Oil Determined at 100 °C w/ HCFC-22*



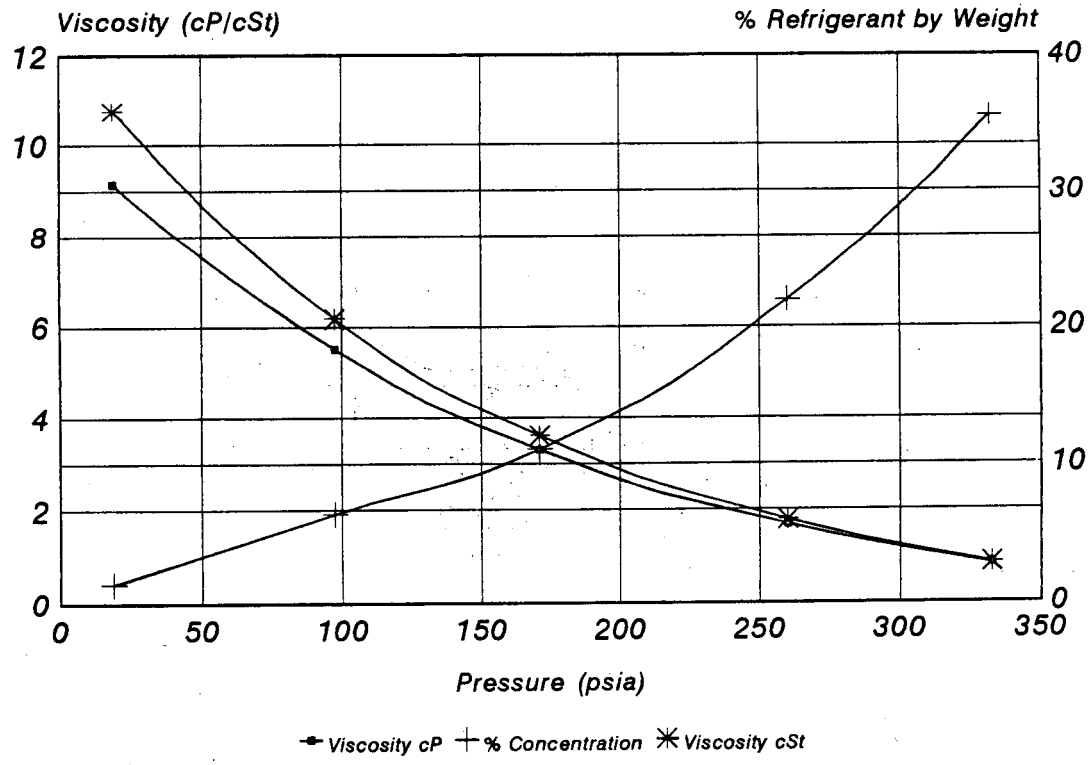

**Viscosity via Gas Solubility Equilibrium**
**Oil degassed to 20 Millitorr**

## *Viscosity and Solubility of 32 ISO VG Mineral Oil Determined at 80 °C w/ HCFC-22*



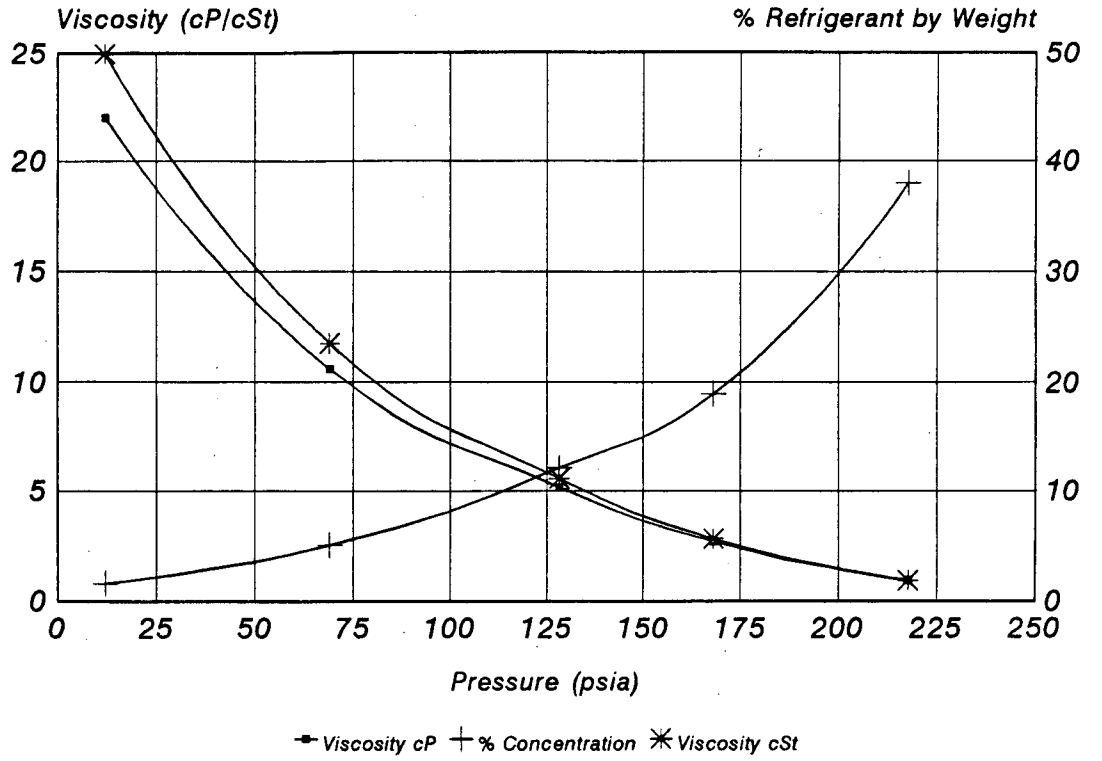

**Viscosity via Gas Solubility Equilibrium**
**Oil degassed to 20 Millitorr**

## *Viscosity and Solubility of 32 ISO VG Mineral Oil Determined at 60 °C w/ HCFC-22*



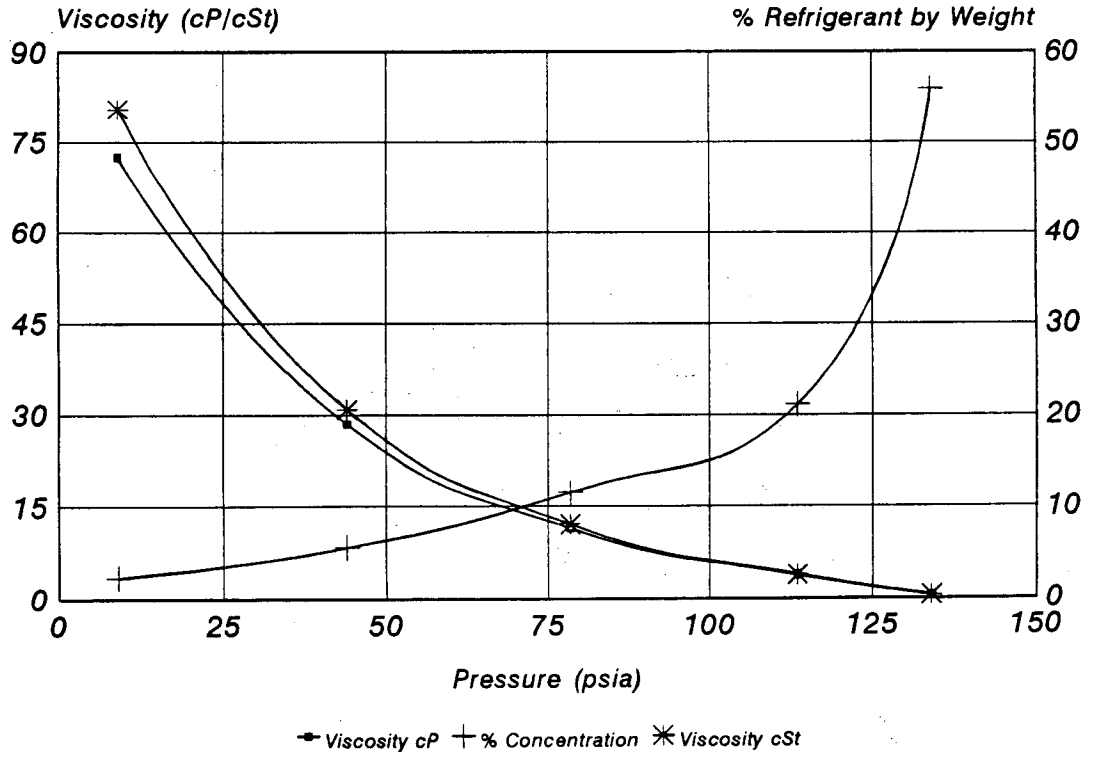

**Viscosity via Gas Solubility Equilibrium**
**Oil degassed to 20 Millitorr**

## *Viscosity and Solubility of 32 ISO VG Mineral Oil Determined at 40 °C w/ HCFC-22*



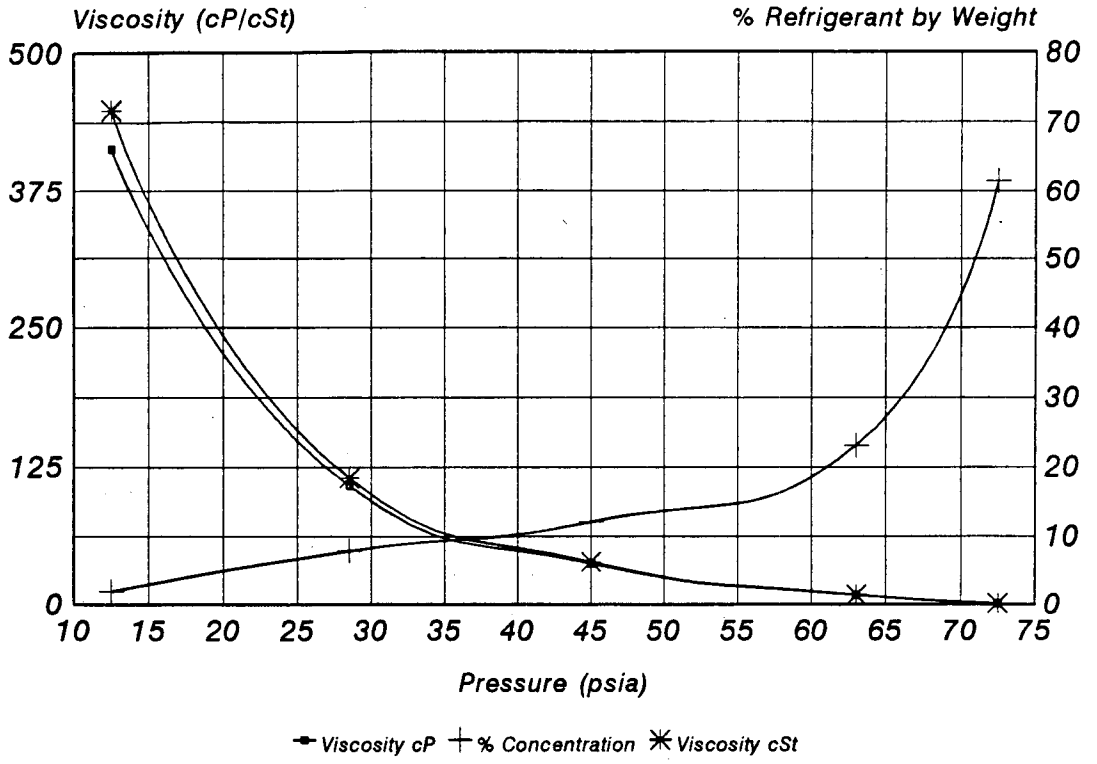

**Viscosity via Gas Solubility Equilibrium**
**Oil degassed to 20 Millitorr**

## *Viscosity and Solubility of 32 ISO VG Mineral Oil Determined at 20 °C w/ HCFC-22*



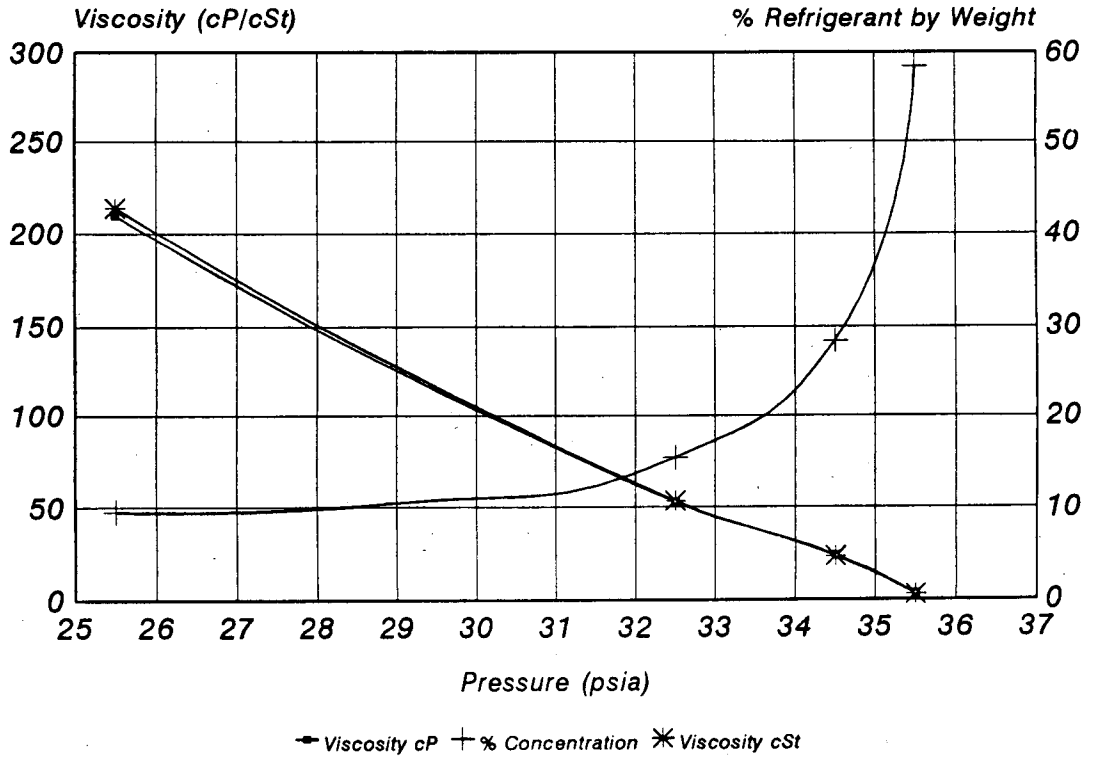

**Viscosity via Gas Solubility Equilibrium**
**Oil degassed to 20 Millitorr**

## *Viscosity and Solubility of 32 ISO VG Mineral Oil Determined at 0 °C w/ HCFC-22*




**Viscosity via Gas Solubility Equilibrium**
**Oil degassed to 20 Millitorr**

## *Viscosity and Solubility of 32 ISO VG Mineral Oil Determined at -20 °C w/ HCFC-22*



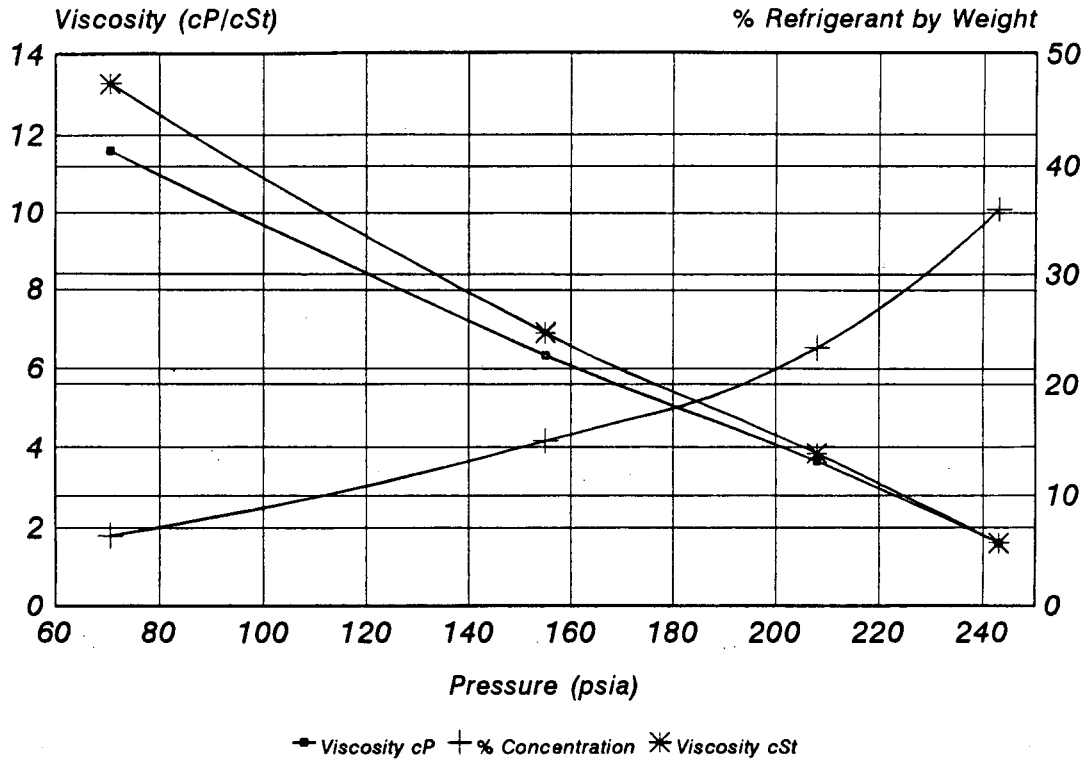



**Viscosity via Gas Solubility Equilibrium**
**Oil degassed to 20 Millitorr**

# Appendix D

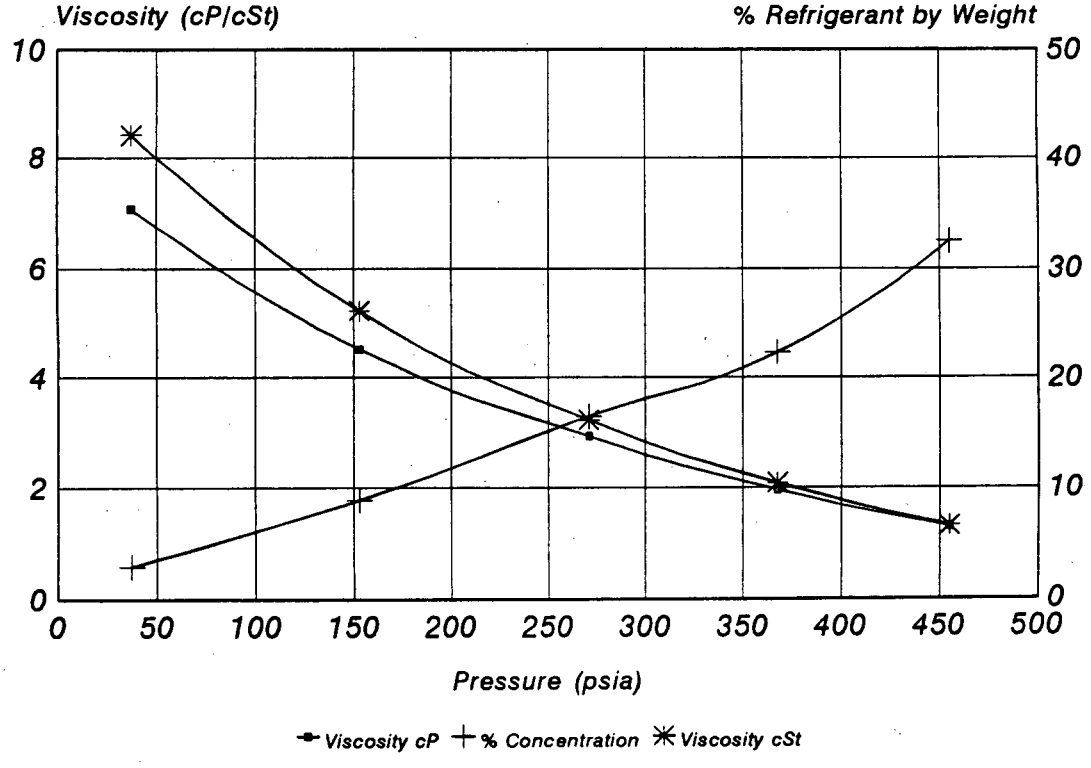
# Viscosity and Solubility of R-502 with 32 ISO Mineral Oil

## *Viscosity and Solubility of 32 ISO VG Mineral Oil Determined at 40°C w/ Blend HCFC-502*




**Viscosity via Gas Solubility Equilibrium**
**Oil degassed to 20 Millitorr**

## *Viscosity and Solubility of 32 ISO VG Mineral Oil Determined at 70°C w/ Blend HCFC-502*






**Viscosity via Gas Solubility Equilibrium**
**Oil degassed to 20 Millitorr**