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PVT & Daniel Charts in ASHRAE HB

Utilizing Lubricant-Refrigerant Interaction Data for Compressor and System Design and Reliability

Joe Karnaz 23 years with Tecumseh

CPI Engineering ~~Lubrizol~~

Sunday July 15th, 2012

CPI ENGINEERING SERVICES — is Division of → Lubrizol

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Special thank you to Chris Seeton from Honeywell for contributing some of this information

Agenda

- Important Interactions
- Stability
- Understanding Miscibility
- Understanding Solubility
- Pressure-Viscosity-Temperature
- Utilizing Lubricant ↔ Refrigerant Interaction Data
- Questions

oil in liquid refr = miscibility
refr in oil (compr sump)

— Oil return?

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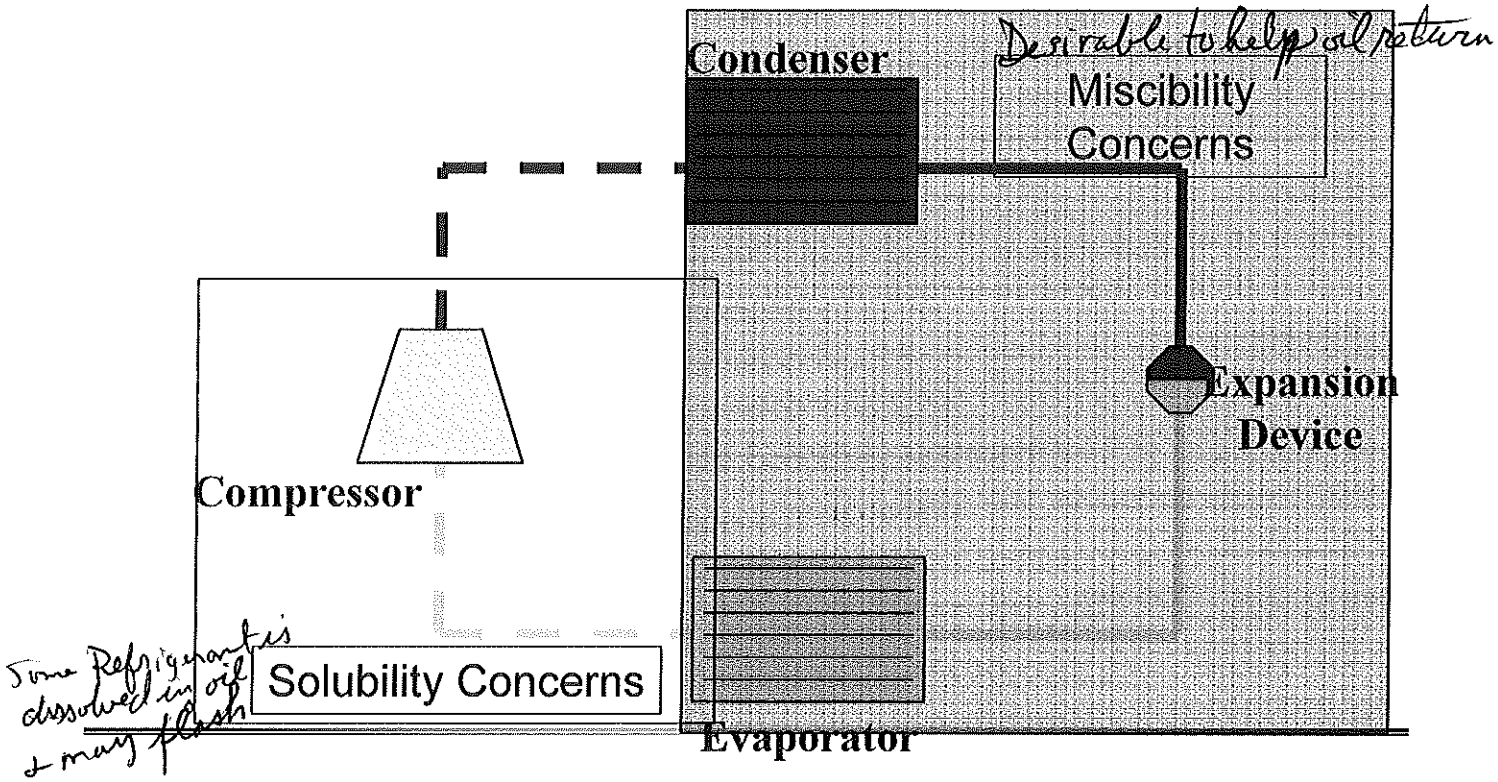
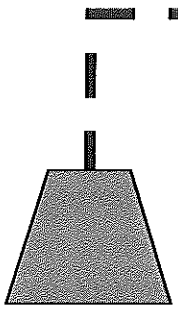
Important Interactions

Refrigeration Cycle



Refrigeration Cycle - Compressor Discharge to Condenser



Refrigerant 1-2% oil discharged with gas

- **Gas**
- **Discharge High Pressure**
- **Heat of Compression Heats Gas**

Lubricant

- **Lubricate Compressor**
- **Remove Heat of Compression**
- **Majority (> 99%) Separates From Gas with Separator**
- **Usually less Than 1-2% Discharges into system**

Applicable Properties

- **Solubility**
- **Stability (High Temperature)**

Refrigeration Cycle - Condenser to Expansion Device

Refrigerant
- Changes From Gas to Liquid
- Lower Temperature
- High Pressure

Lubricant
- Dissolves with Liquid Refrigerant (lowers viscosity)
- No Possible Additional Separation Occurs

Lubricant
- Float or Sink with Liquid Refrigerant
- Additional Separation in Condenser
- Excessive Amount of Oil Reduces Ability to Liquefy Refrigerant
- Plug Expansion Device or intermittent liquid/gas passing thru TXV

Applicable Properties
- High Temperature Miscibility

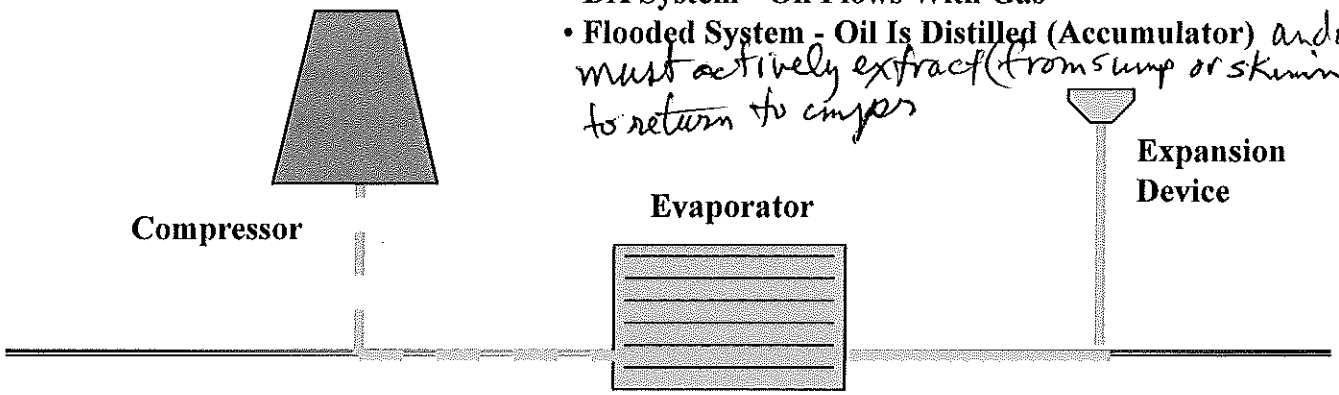
Refrigeration Cycle - Immiscible Oil Expansion Device to Compressor

Refrigerant
- Changes From Liquid to Gas
- Low Temperature
- Low Pressure

Applicable Properties
- Low Temperature Miscibility
- Solubility - To the Compressor
- Sealed Tube Stability - Durability

Lubricant
- Low Temperature Causes Lubricant to 'Stick" to Evaporator
- Detrimental to Heat Transfer
- If Oil Sinks, Use Accumulator. If It Floats, Skim

Lubricant
- Lubricant Stay's Dissolved in Refrigerant
- No Impact on Heat Transfer at Low Concentrations (< 5%)
- DX System - Oil Flows With Gas
- Flooded System - Oil Is Distilled (Accumulator) and one must actively extract (from sump or skimmer) to return to compr



Stability

System Stability

- Number of interactions to consider in refrigeration systems.
  - » Refrigerant
  - » Lubricant
  - » Metals
    - – Ferrous
    - – Yellow (copper brass)
    - – Aluminum
  - » Plastics, mylar & varnish magnet wire
  - » Elastomers
  - » Processing Chemicals
  - » Contaminants
    - – Water
    - – Air

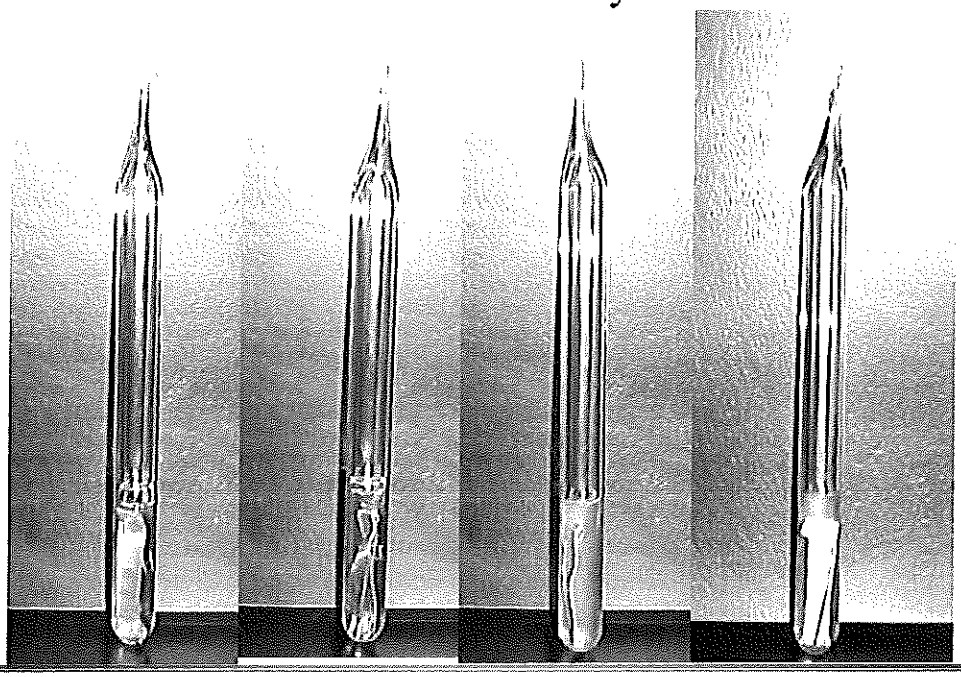
- ❑ Thermal
- ❑ Hydrolytic
- ❑ Oxidative
- ❑ Chemical

Stability: Thermal, Hydrolytic, Oxidative

ASHRAE Std 97

heat aging (accelerated testing)

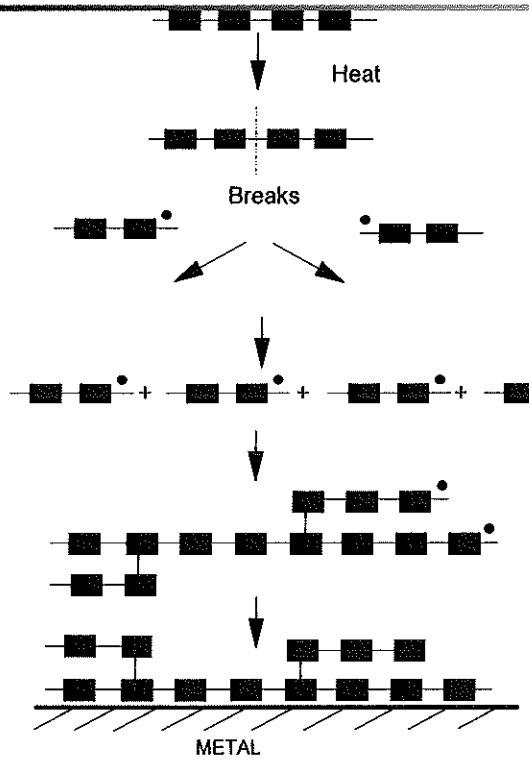
Sealed Tube Stability



New Oil Week 2 Week 4 Week 8

11

Potential Degradation Example



Lubricant reaches an unacceptable temperature at a hot spot and cleaves.

Reactive byproducts formed. Acids are produced.

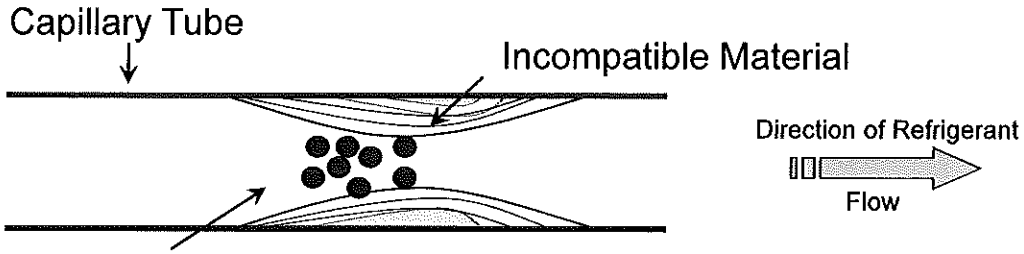
Reactive byproducts rapidly react with each other to form high molecular weight polymers. ↓/poor solubility

Increased molecular weight may lead to increased viscosity.

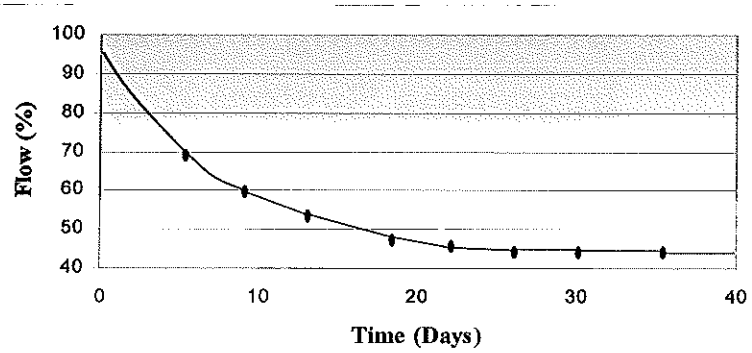
High molecular weight polymer has poor solubility and sticks to the metal surface.

System Stability

- Problems involved with incompatibility and contaminants



Refrigerant Flow Restriction



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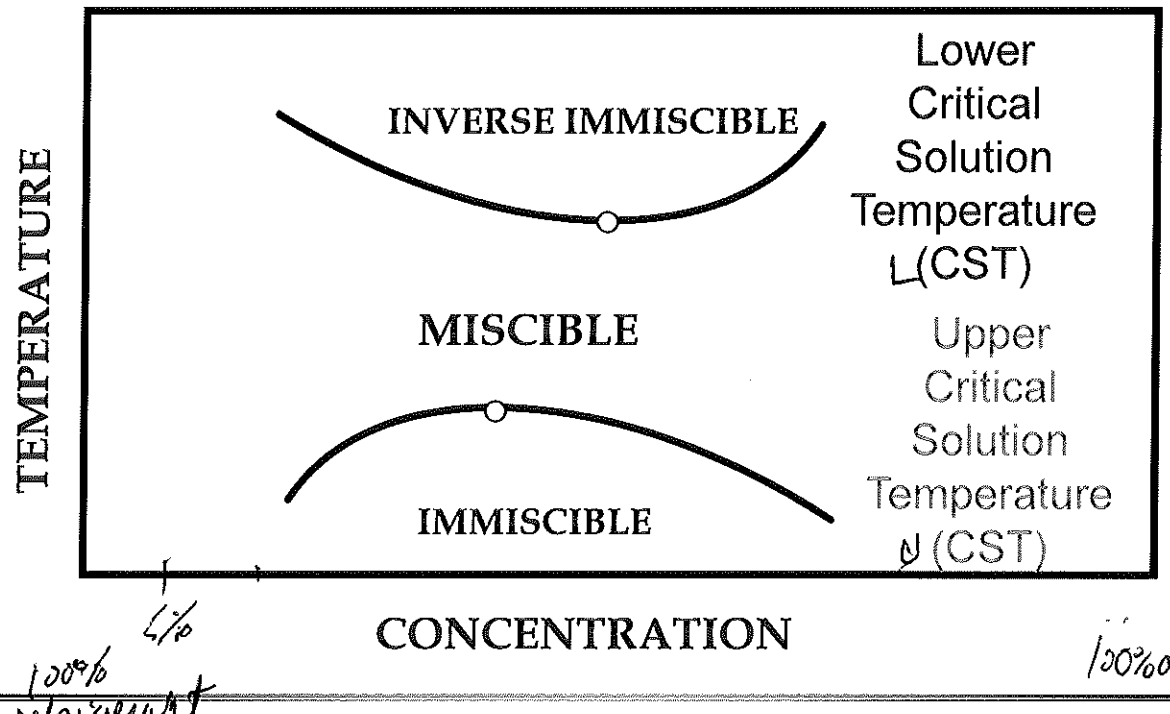
Understanding Miscibility

Miscibility

- Ability of Lubricant to Dissolve Liquid Refrigerant into a Single Phase
  - Miscible - One Clear Phase
  - Immiscible – Cloudy - Two Phases
- Understanding Miscibility Characteristics Increases System Knowledge
  - Oil Return Properties
  - Heat Transfer Properties

Miscibility Profile

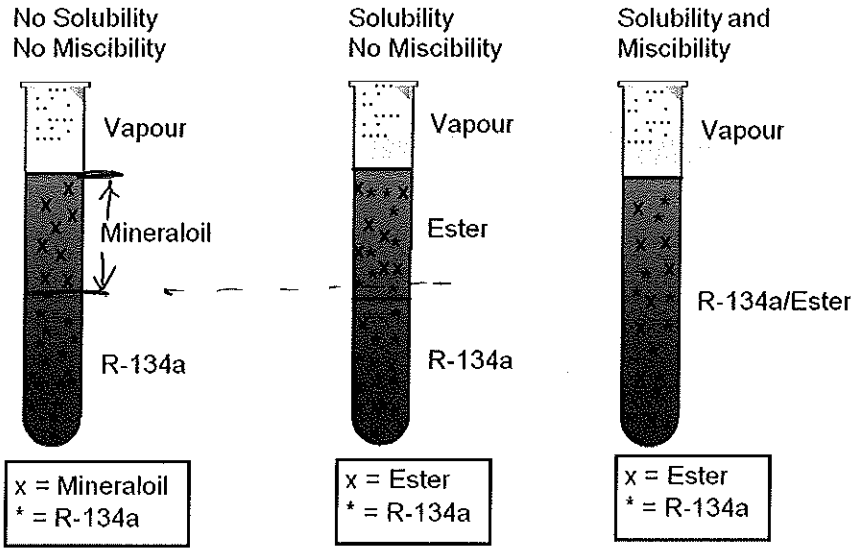


Understanding Solubility

Refrigerant Solubility

- Ability of Lubricant to Dissolve Gaseous Refrigerant
- Value is Dependent on Several Properties
  - Pressure
  - Temperature
  - Affinity Between Refrigerant and Lubricant
- Dynamic Value T, P
- Useful for Evaluating "Bearing Viscosity" "working viscosity"

Miscibility versus Solubility



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Pressure-Viscosity-Temperature

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Lubricant

Bearing Design

Solubility

Refrigerant

Working Viscosity

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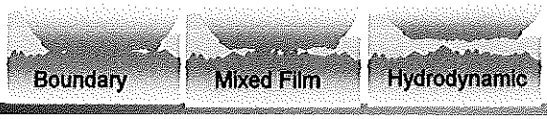
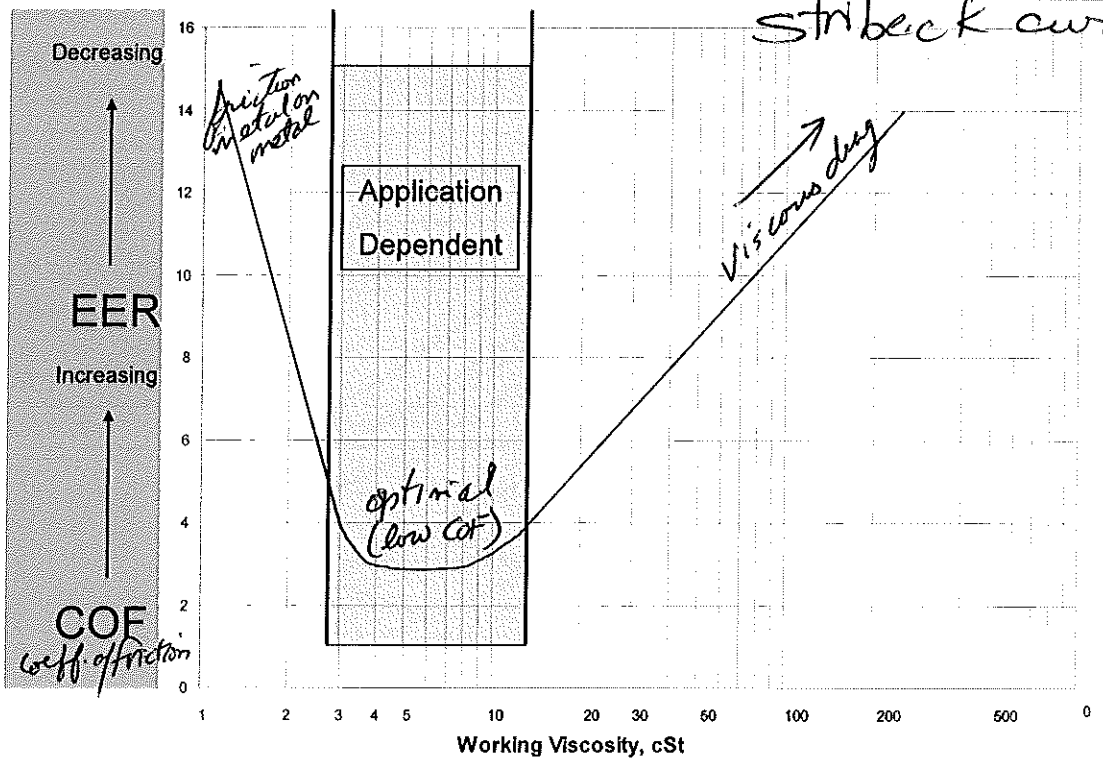
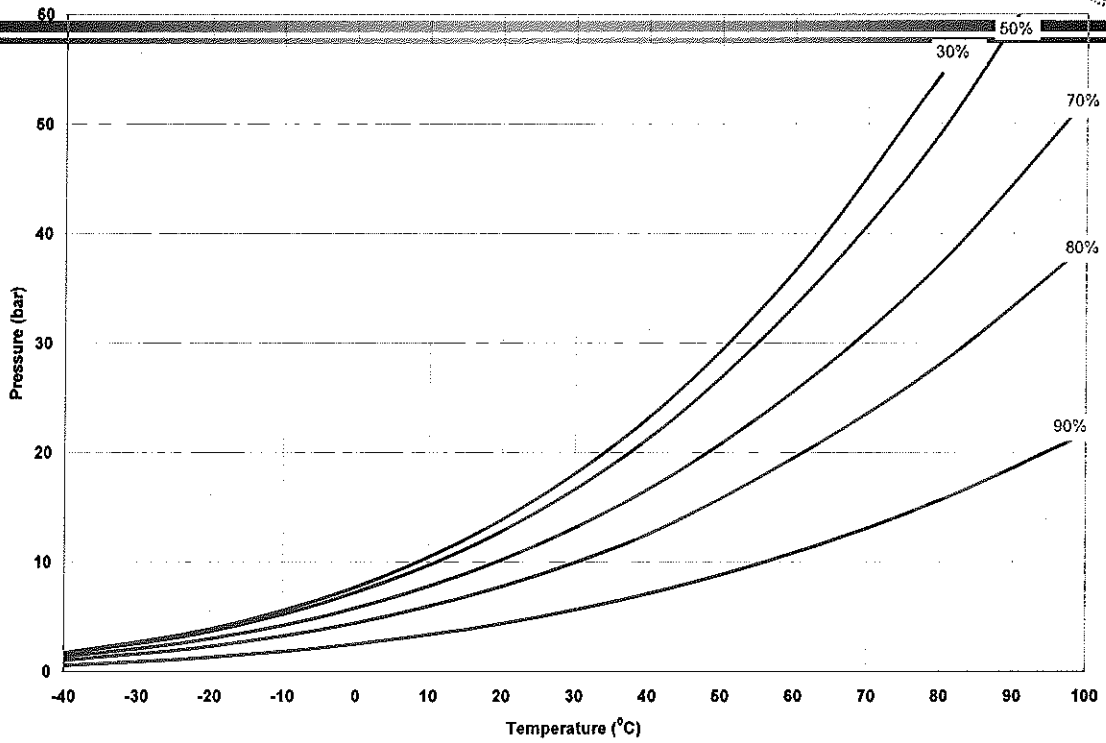


Optimizing Bearing Lubrication

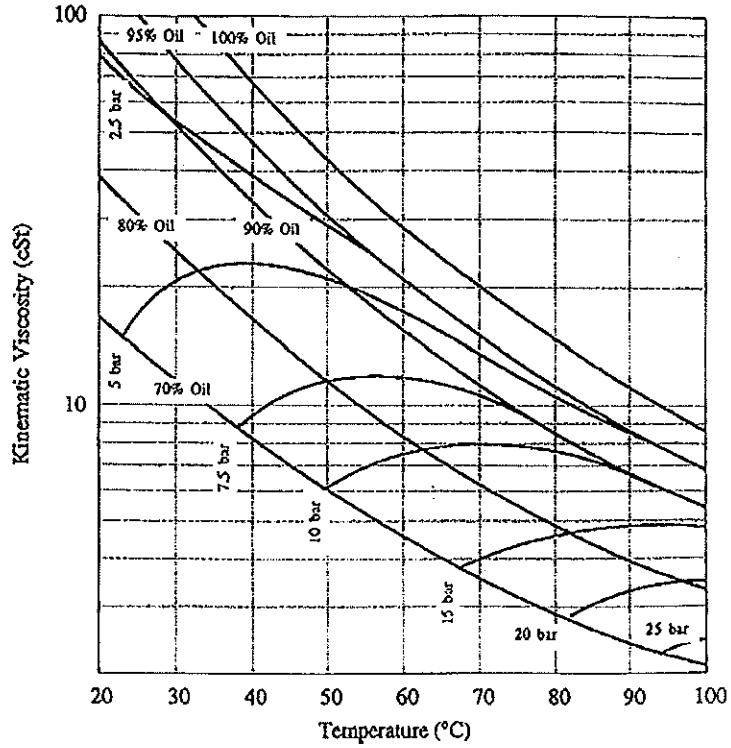


Bearing Viscosity
Sliding Viscosity

Solubility

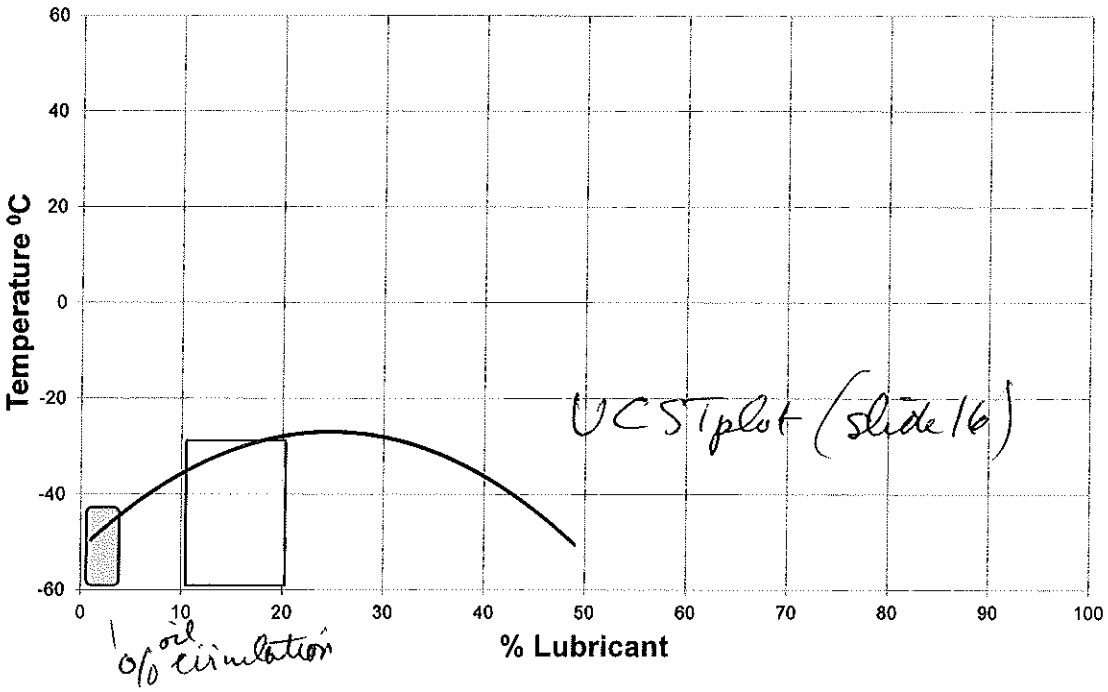


Bearing Working Viscosity



Utilizing Lubricant – Refrigerant Interaction Data

Miscibility



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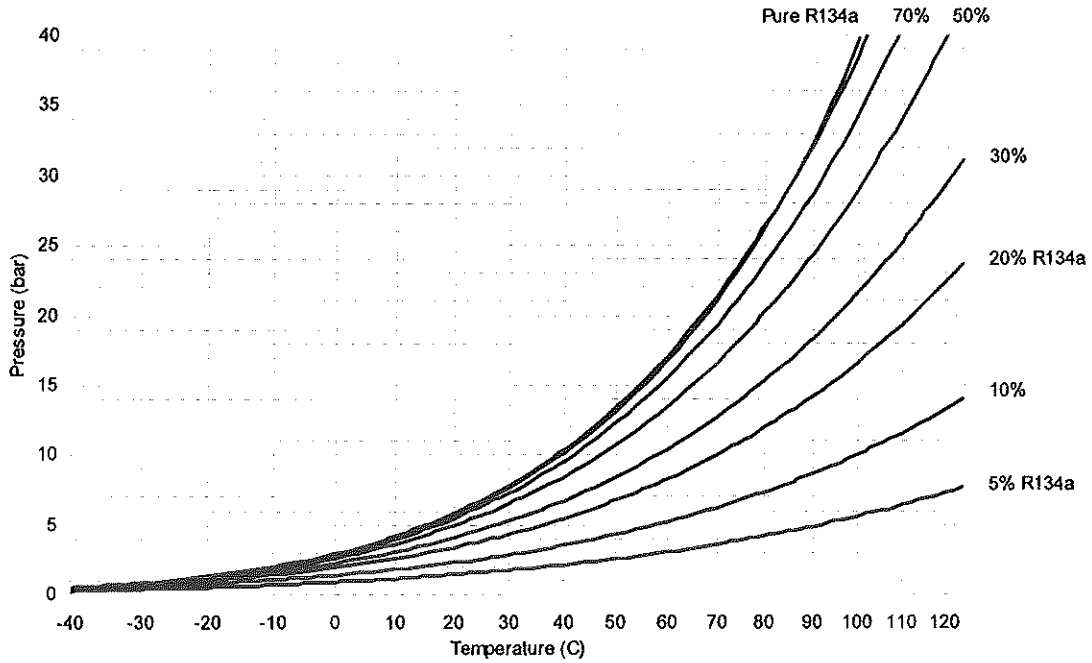
Solubility Measurements



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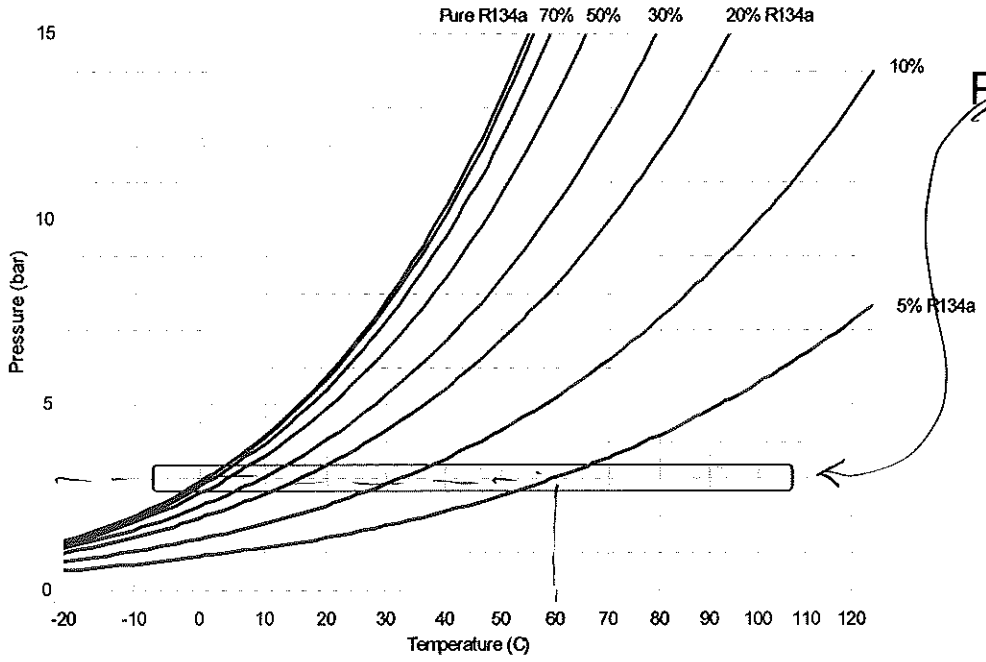
Solubility Measurements



Pressure ≈ 3 bar

Conc. % R134a	Temp. °C
5%	60
10%	32
20%	15
30%	10
50%	5
70%	2.5
90%	1.3
100%	0.67

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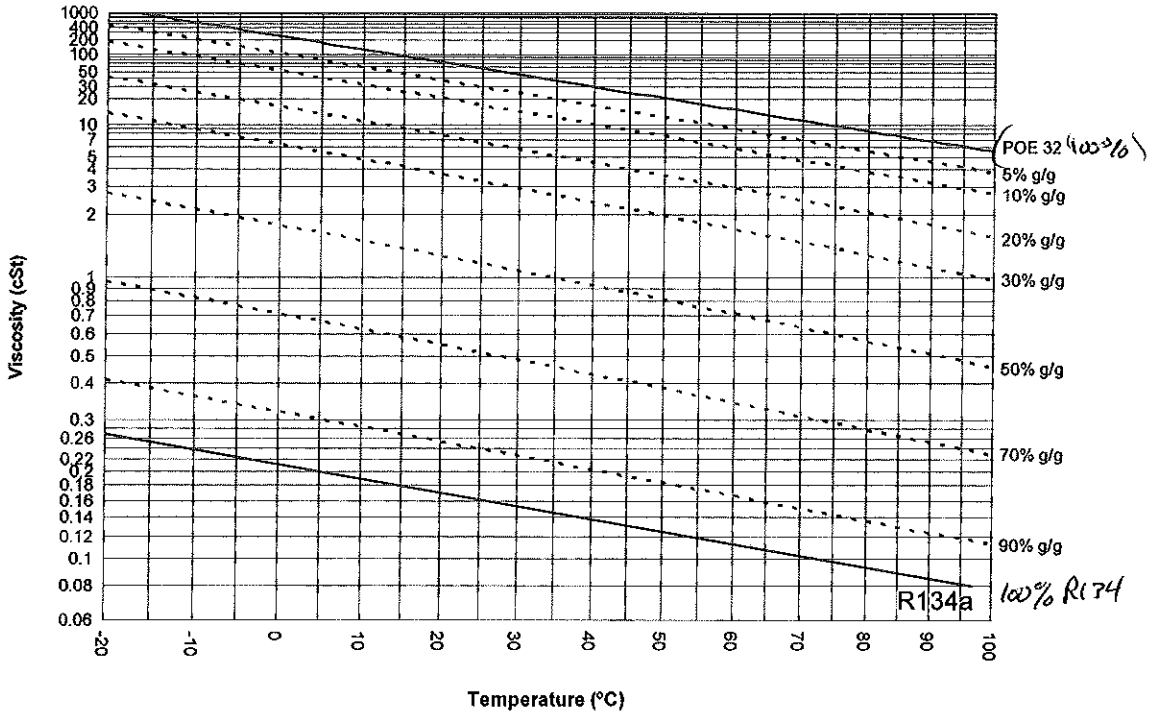
Daniel Chart - Viscosity



problem with high side shell is large dissolved refrigerant

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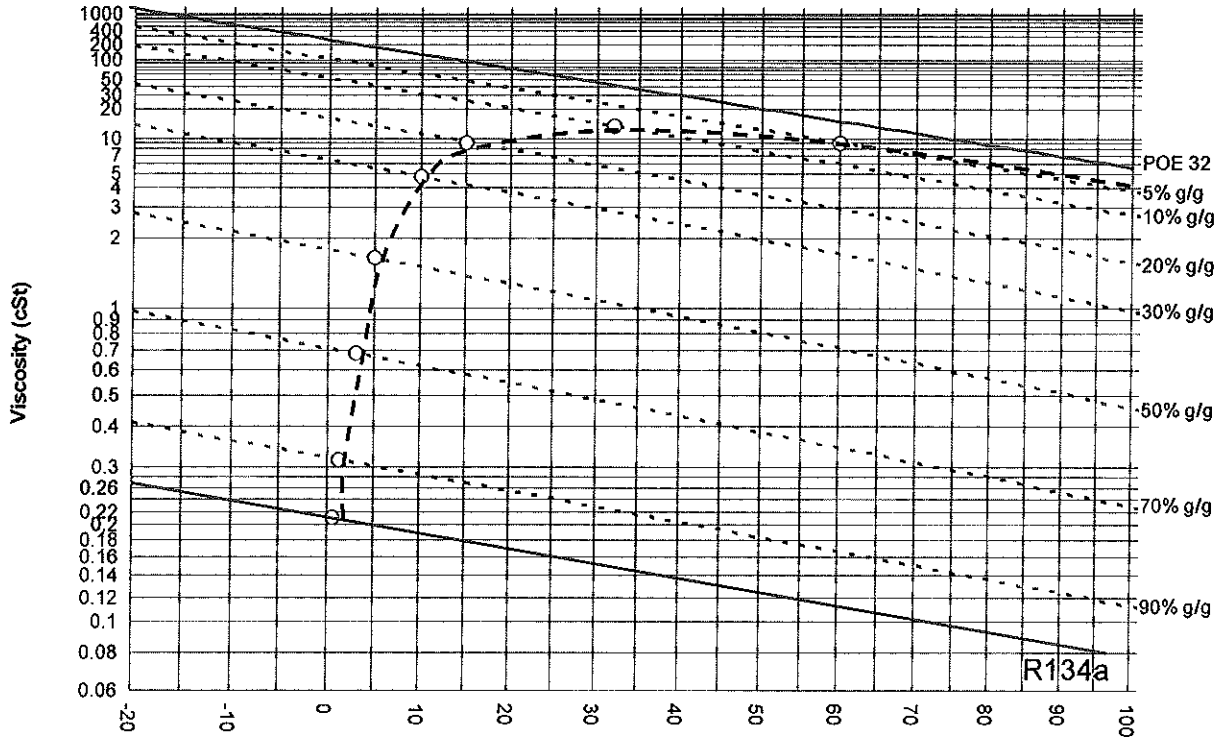
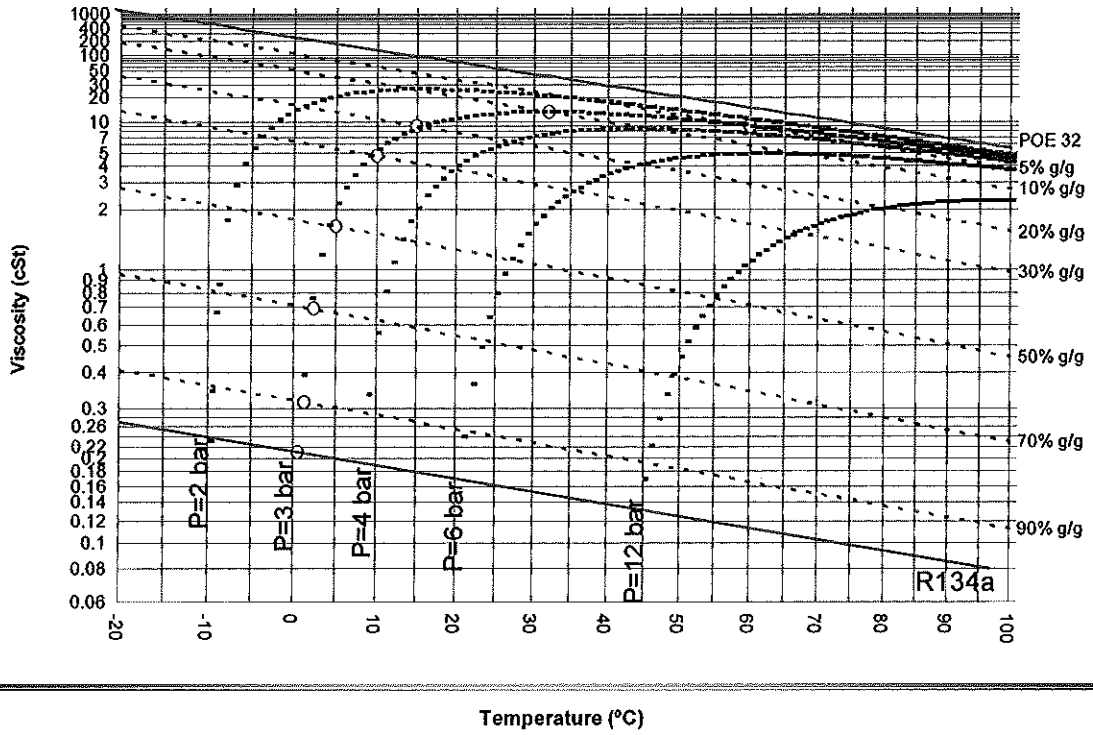
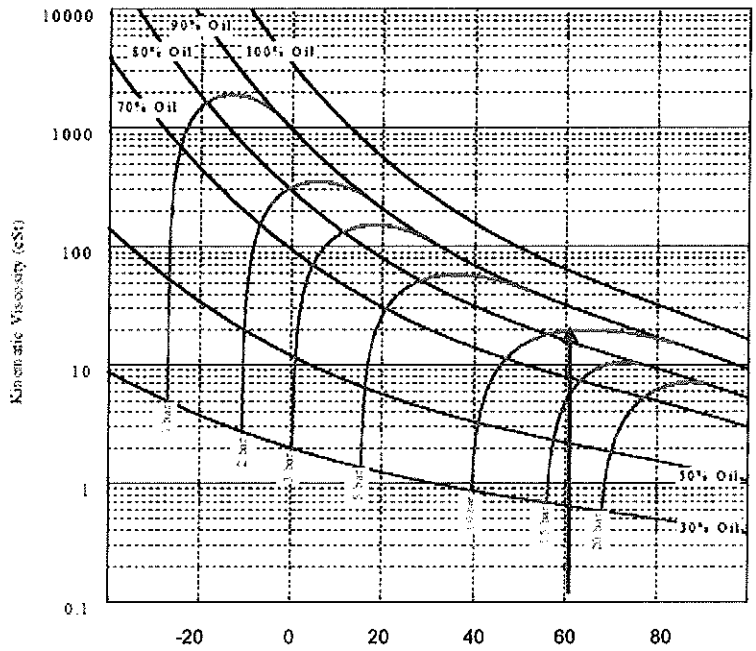
Daniel Chart – Pressure/Solubility



Daniel Chart
Pressure-Viscosity-Temperature



Lubricant Chemistry and Viscosity Options



60°C and 10 bar

18% Dilution and 20 cSt

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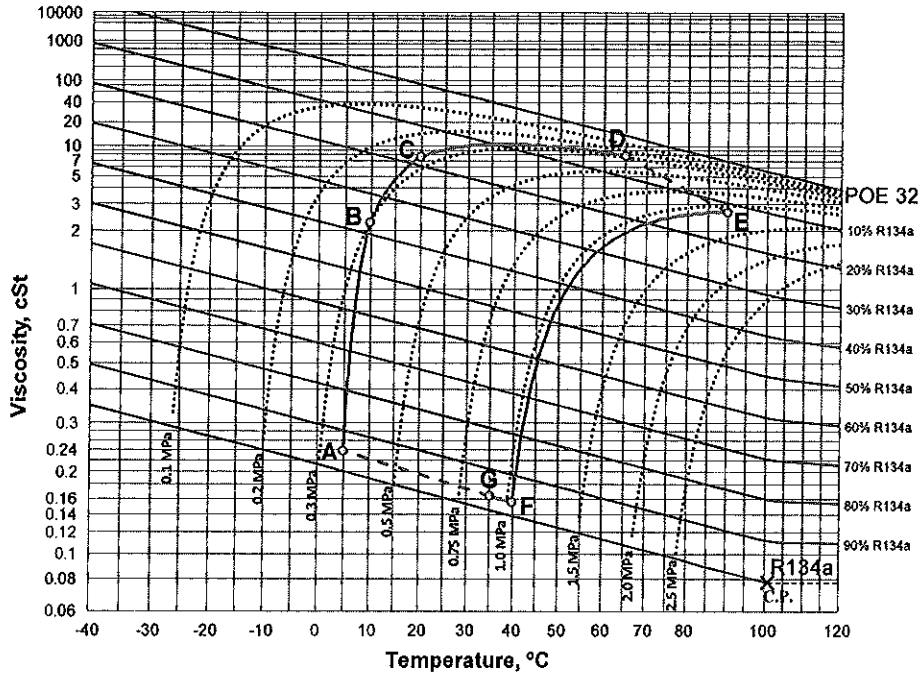
Daniel Chart
AC Cycle Overlay



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Daniel Chart
Refrigeration Cycle Overlay

A evap inlet low P & T

B evap outlet

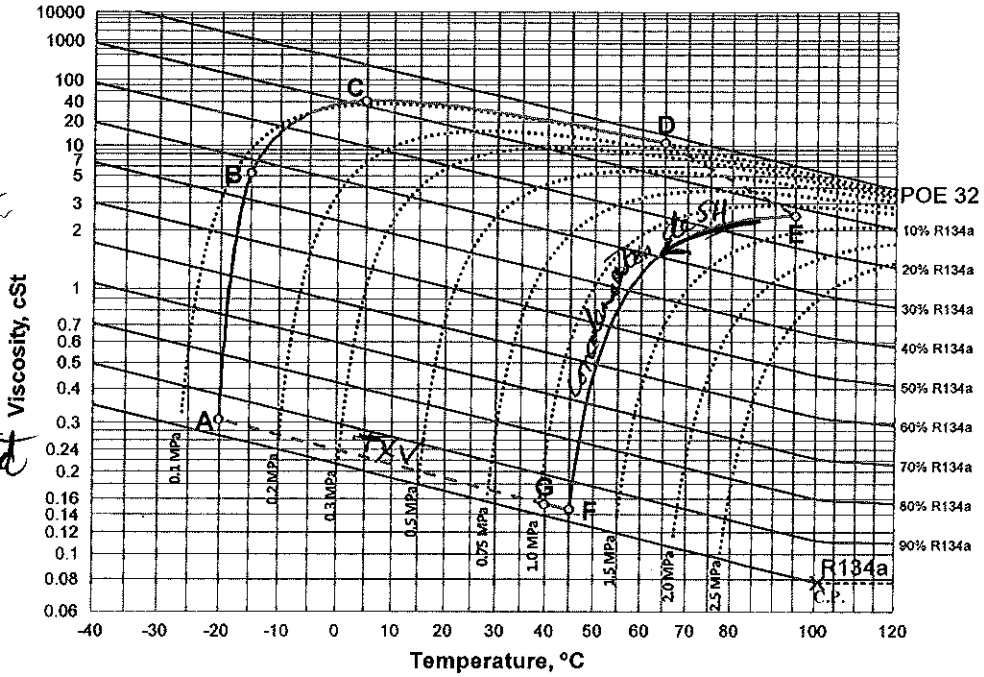
C compressor suction

D

E cond inlet

G subcool outlet

---- TXV



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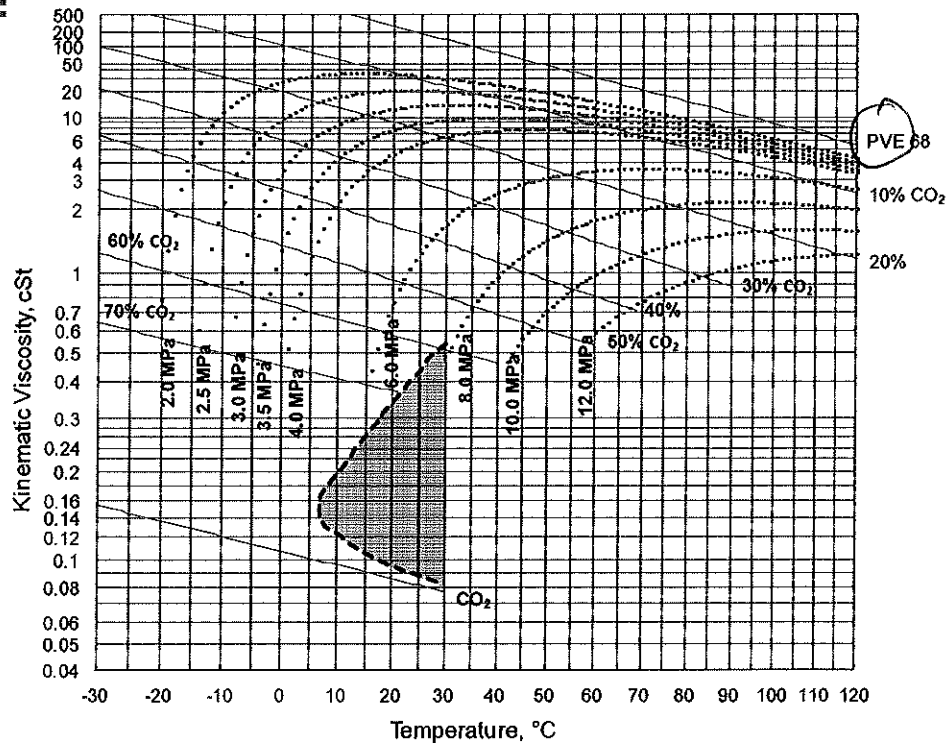
PVT – Miscibility Lubricant 1 PVE



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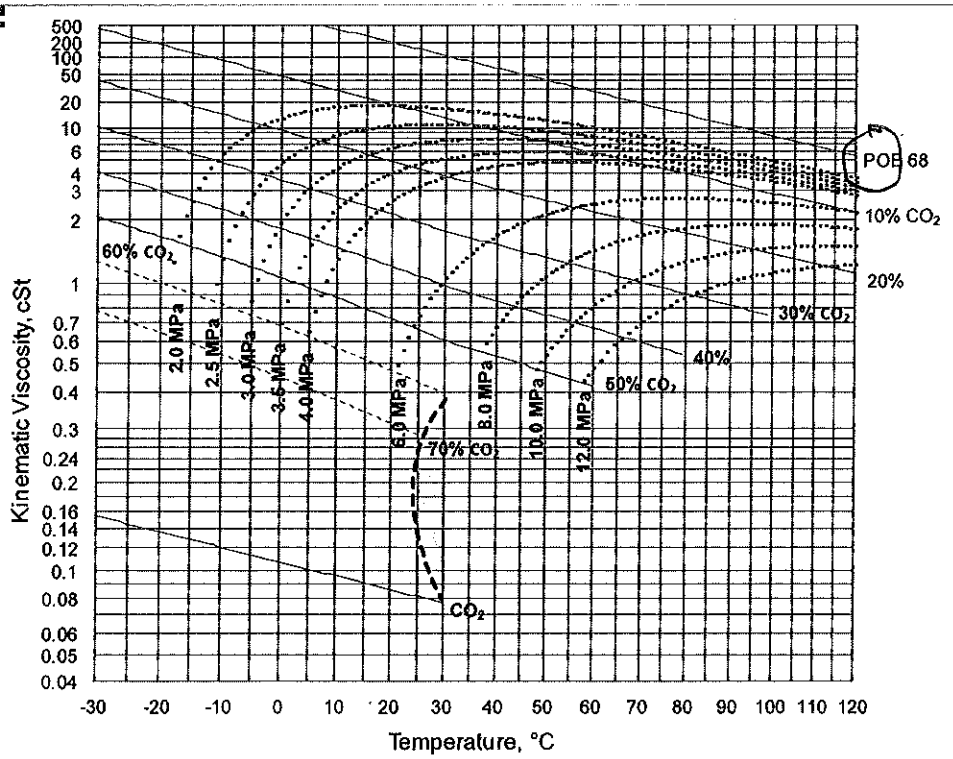
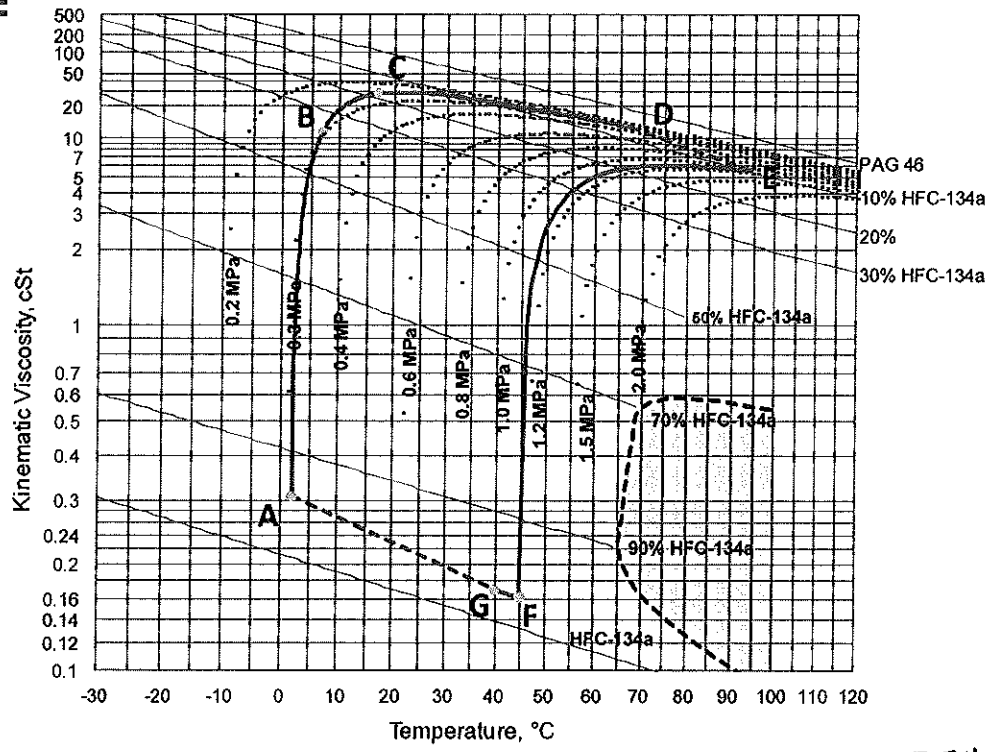
PVT – Miscibility Lubricant 2 POE



PVT – Miscibility - Cycle Overlay



1234YF

modified PAG composition

Questions