DuPont™ Suva®
refrigerants

ART-21

Using HFC-23 for Very Low Temperature (VLT) Refrigeration

Introduction

HFC-23 refrigerant (also known as Freon® 23) is a commercially available, CFC-free alternative to R-503 and R-13. Because R-503 and R-13 are ozone depleters (both contain chlorine), they will be phased out as part of the Montreal Protocol and U.S. Clean Air Act. HFC-23 does not contain chlorine and therefore has a zero Ozone Depletion Potential (ODP).

This bulletin will discuss the physical/environmental properties of HFC-23, safety considerations during use, materials compatibility, and tips for retrofitting R-503 and R-13 systems with HFC-23.

Physical/Environmental Properties

General physical and environmental properties of HFC-23, R-503, and R-13 are compared in **Table 1**. In addition to **Table 1**, the vapor pressure curves for R-503, R-13, and HFC-23 are shown in **Figure 1**. Complete thermodynamic tables are available from DuPont.

As can be seen from **Table 1** and **Figure 1**, HFC-23 has physical properties similar to R-503 and R-13, but with the improved environmental properties of no ozone depletion and reduced global warming potential.

Safety Considerations

HFC-23 refrigerant poses no acute or chronic hazard when handled in accordance with DuPont recommendations and when exposure is maintained below recommended exposure limits. The current exposure limit for HFC-23 is DuPont's Acceptable Exposure Limit (AEL) of 1,000 ppm for an 8- and 12-hour time weighted average (TWA). An AEL is an airborne concentration to which nearly all workers may be repeatedly exposed without adverse effects during an 8-hour day or 40-hour week. The AEL for HFC-23 is the same level as the Threshold Limit Value (TLV) determined for R-503 (1000 ppm for an 8- and 12-hour time weighted average). No exposure limit has been established for R-13.

Users should obtain and understand the MSDS for HFC-23 before handling.

Materials Compatibility

Materials commonly used with R-503 and R-13 are compatible with HFC-23.

Tips for Retrofitting R-503 and R-13 Systems with HFC-23

There are several key items to consider when retrofitting from R-503 and R-13 to HFC-23; namely, system capacity, coefficient of performance (C.O.P.), operating pressure, static pressure, lubrication and expansion valve adjustments. In this section, we will discuss how HFC-23 compares with R-503 and R-13 in these areas. The information presented here is meant only to serve as a guide in the transition away from R-503 and R-13. It is recommended that the equipment manufacturer be contacted before a retrofit is started.

Laboratory Data

The experimental data discussed here, unless otherwise noted, are based upon a laboratory cascade unit operating at a condensing temperature of –29°C (–20°F). The evaporator temperature was varied from –96°C to –73°C (–140°F to –100°F). An open drive compressor was used on both the high and low side.

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System Capacity

A comparison of system capacity when using either HFC-23, R-503, and R-13 is shown in **Table 2** for the same equipment operating at roughly the same evaporator (–84.4°C/–120°F) and condenser (–29°C/–20°F) temperatures. As can be seen, HFC-23 gives superior capacity when compared with R-13, but when compared with R-503, a capacity reduction can be expected. This reduction is a result of the higher suction pressure and molecular weight of R-503 vs HFC-23. HFC-23, because of its higher net refriger-ation effect, has greater capacity than R-13.

A comparison of the three refrigerants is shown in **Figure 2** over a range of evaporator temperatures.

Coefficient of Performance (COP)

A comparison of COPs is illustrated in **Figure 3** and **Table 2**. At the same temperature (–84.4°C/–120°F evaporator and –29°C/–20°F condenser), HFC-23 uses slightly less energy to obtain the same amount of cooling as R-13. However, when compared to R-503, roughly 10% more energy is required.

Operating Pressure

A comparison of operating pressures and compression ratios is shown in **Table 2** and **Figure 4**. **Figure 4** looks at the compression ratio as a function of evaporator temperature. Because of the lower vapor pressure of HFC-23 vs R-503 at commonly desired evaporator temperatures (–120°F), it would be typical to find the suction pressure of a HFC-23 system to be lower than R-503 but comparable to R-13. This coupled with the higher vapor pressure at typical condenser temperatures (–29°C/–20°F) vs R-13 results in HFC-23 having a higher compression ratio than R-503 and R-13. These factors need to be considered in system design, and certainly must be understood in any retrofit to HFC-23.

Static Pressure

Because of HFC-23's lower saturated vapor density vs R-13 and R-503, retrofits with HFC-23 may result in higher static pressures. This lower saturated vapor density causes HFC-23 to have liquid present at higher temperatures than R-13 and R-503 as the unit is warmed to ambient during a shutdown, assuming equal charge size. Since liquid vapor pressure rises faster with temperature than pressure exerted by gas expansion, the static pressure of HFC-23 will be greater than R-13 and R-503 assuming equal charge size and system volume. Retrofits to HFC-23 may, therefore, require a larger expansion tank than R-13 and R-503. It is recommended that HFC-23 be initially charged by static pressure, and that the same static pressure for R-13 and R-503 be used. This will ensure that the maximum static pressure will be no greater than the static pressure of R-13 and R-503. Charge size optimization can then take place by adjusting the static pressure above or below the R-13/503 static pressure.

At typical operating conditions (–29°C/–20°F condenser/–84.4°C/120°F evaporator), HFC-23 has not only a lower vapor density, but a lower liquid density than R-13 and R-503. Consequently, it is anticipated that the optimum charge size will be 10–20% lower by weight.

Lubrication

It is anticipated that mineral oil and alkylbenzenes will not be suitable lubricants for HFC-23 because HFCs have very low miscibility (solubility) with these lubricants. Polyol esters have been tested with HFC-23 down to –120°F in small laboratory bench top cascade units using capillary tubes for expansion devices. Testing continues to establish long term performance. To date, no adverse effects have been seen with polyol esters.

For any retrofit to HFC-23, it is recommended that polyol esters be considered as possible lubricants.

Expansion Valve Adjustments

After retrofitting to HFC-23, the system superheat should be carefully monitored, and the expansion valve adjusted if needed. Retrofits from R-13 to HFC-23 should not require adjustments to the expansion valve because the vapor pressures of the two gases are almost identical at typical operating temperatures (–84.4°C/–120°F). However, R-503 has a higher vapor pressure at this temperature so expansion valve adjustments may be necessary to maintain proper superheat settings based on theoretical calculations.

Other Considerations

Filter/Drier

At this time, no specific tests have been done with HFC-23 and filter/drier elements. However, because HFC-23 is a component of R-503, it is anticipated that filter/driers used in R-503 service should be compatible.

Baseline Data

It is usually good practice to obtain as much baseline data as possible before conversion. This will allow the user to quickly determine how the system is running with HFC-23. A suggested baseline data guide is attached.

Table 1
General Property Information

Physical Property	Units	HFC-23	R-503	R-13
Molecular Wt	(Avg.)	70.01	87.28	104.47
Boiling Point @ 1 atm	°C °F	–82.1 –115.7	–88.7 –127.6	–81.4 –114.6
Critical Temperature	°C °F	25.8 78.5	19.4 67.0	28.8 83.9
Critical Pressure	kPa psia	4820 701.4	4330.9 627.4	3872.6 561
Sat'd Liquid Density @ –29°C (–20°F)	kg/cu m lb/cu ft	1217 75.98	1228 76.68	1293.3 80.71
Sat'd Vapor Density @ –29°C (–20°F)	kg/cu m lb/cu ft	44.1 2.75	68.7 4.29	53.4 3.33
Specific Heat Liquid @ –29°C (–20°F)	kJ/kg K Btu/lb °F	1.46 0.35	1.55 0.37	1.09 0.26
Vapor Pressure @ 25°C (77°F)	kPa psia	4728.6 685	NA NA	3603.4 522
Heat of Vaporization at B.P.	kJ/kg Btu/lb	240 103	179.8 77.15	148.8 63.85
Flammability Limit in Air (1 atm)	vol%	None	None	None
Ozone Depletion Potential	CFC-12 = 1	0	0.599	1
Halocarbon Global Warming Potential	CFC-11 = 1	5.7	8–10	>10

Table 2
Experimental Comparison of Low Temperature Refrigerants*

Refrigerant	Pressure (psia/kPa) Evaporator	Pressure (psia/kPa) Condenser	Comp. Ratio	C.O.P.	Capacity (% R-13)
HFC-23	12.8/88.3	152.5/1052.7	12.0	0.486	106
R-13	12.5/86.3	126.4/872.5	10.1	0.472	100
R-503	18.5/127.7	174.8/1206.6	9.5	0.542	157

–84.4°C (–120°F) Evaporator; –29°C (–20°F) Condenser.

*Please see "Laboratory Data" Section for complete experimental conditions

Figure 1. Vapor Pressure

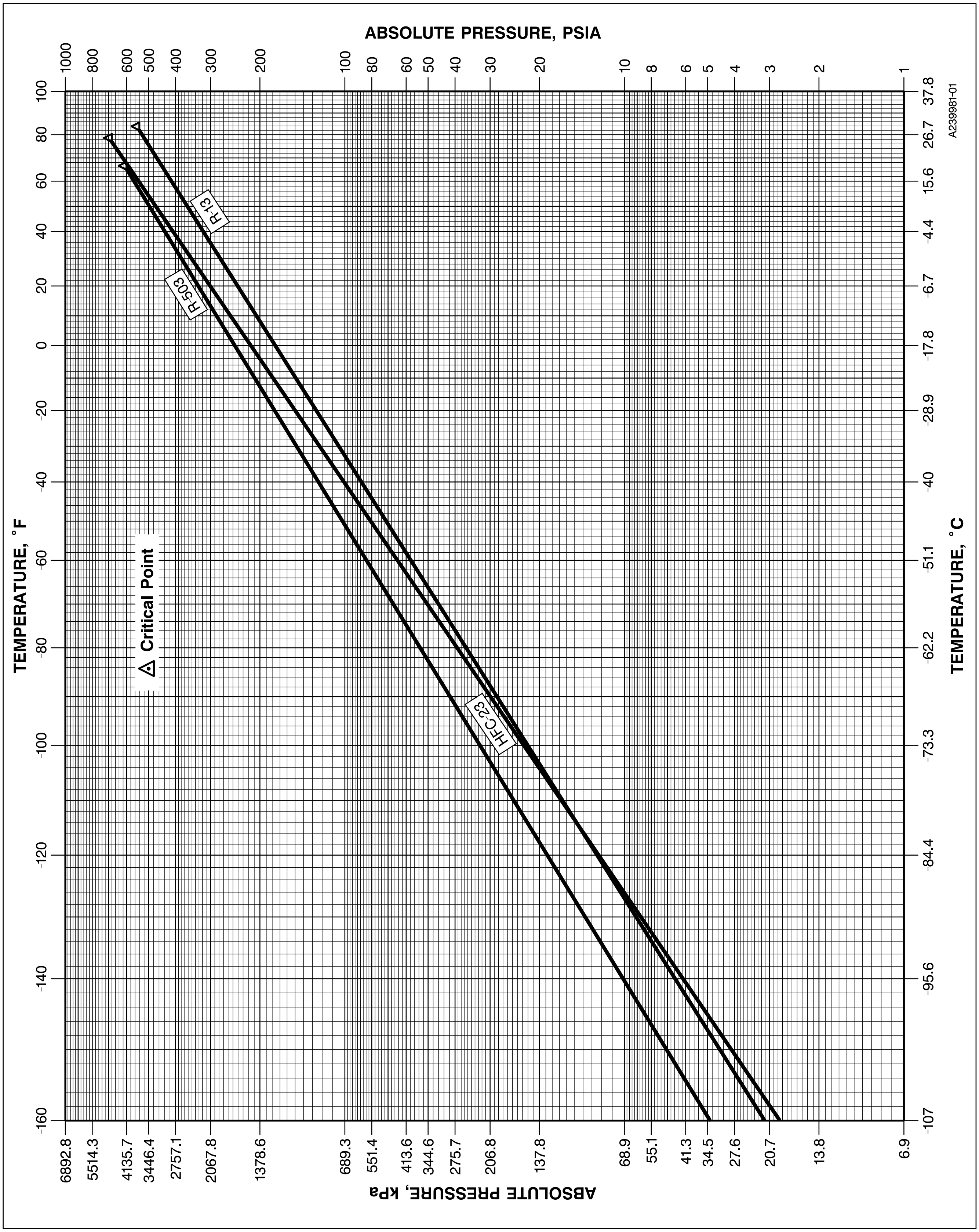


Figure 2. Experimental Comparison of Capacity (Condensing Temperature –20°F [–29°C])

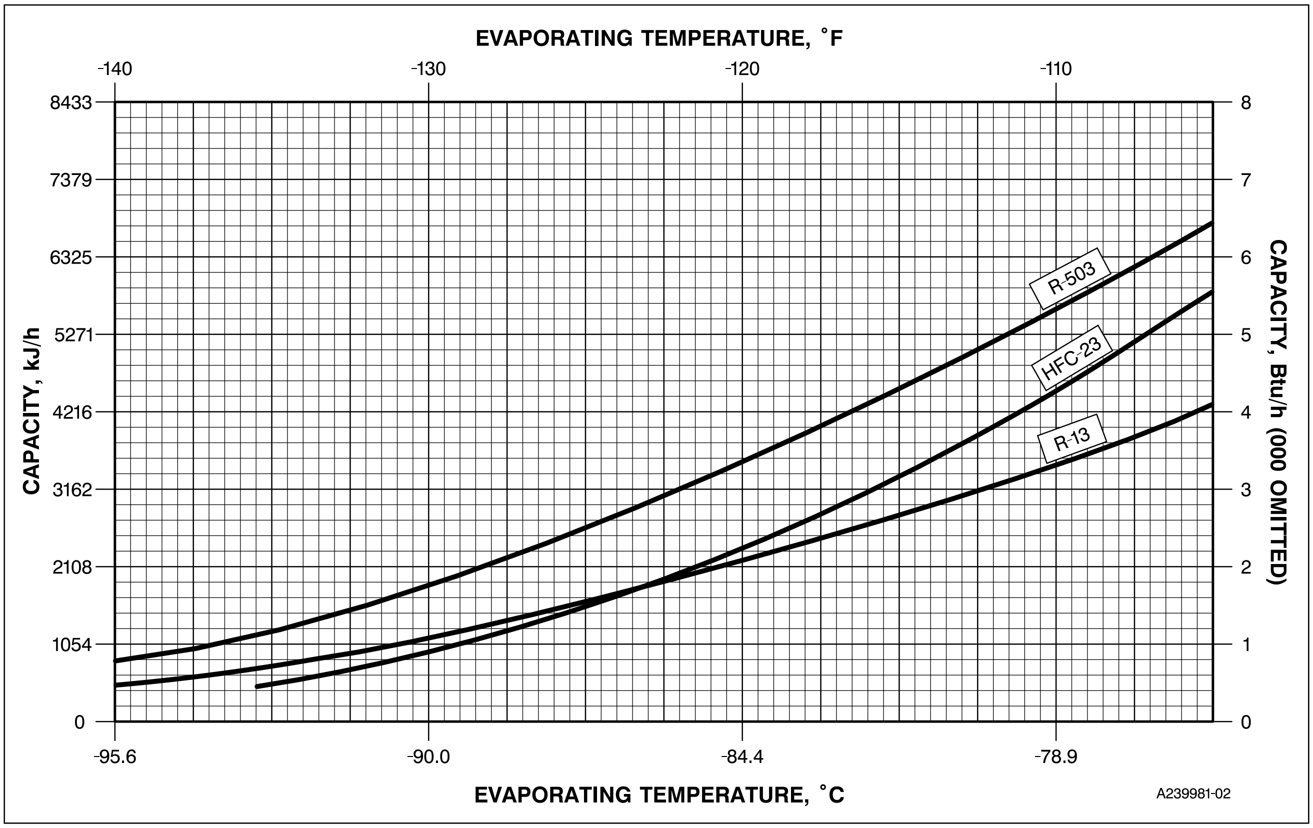


Figure 3. Measured Coefficient of Performance

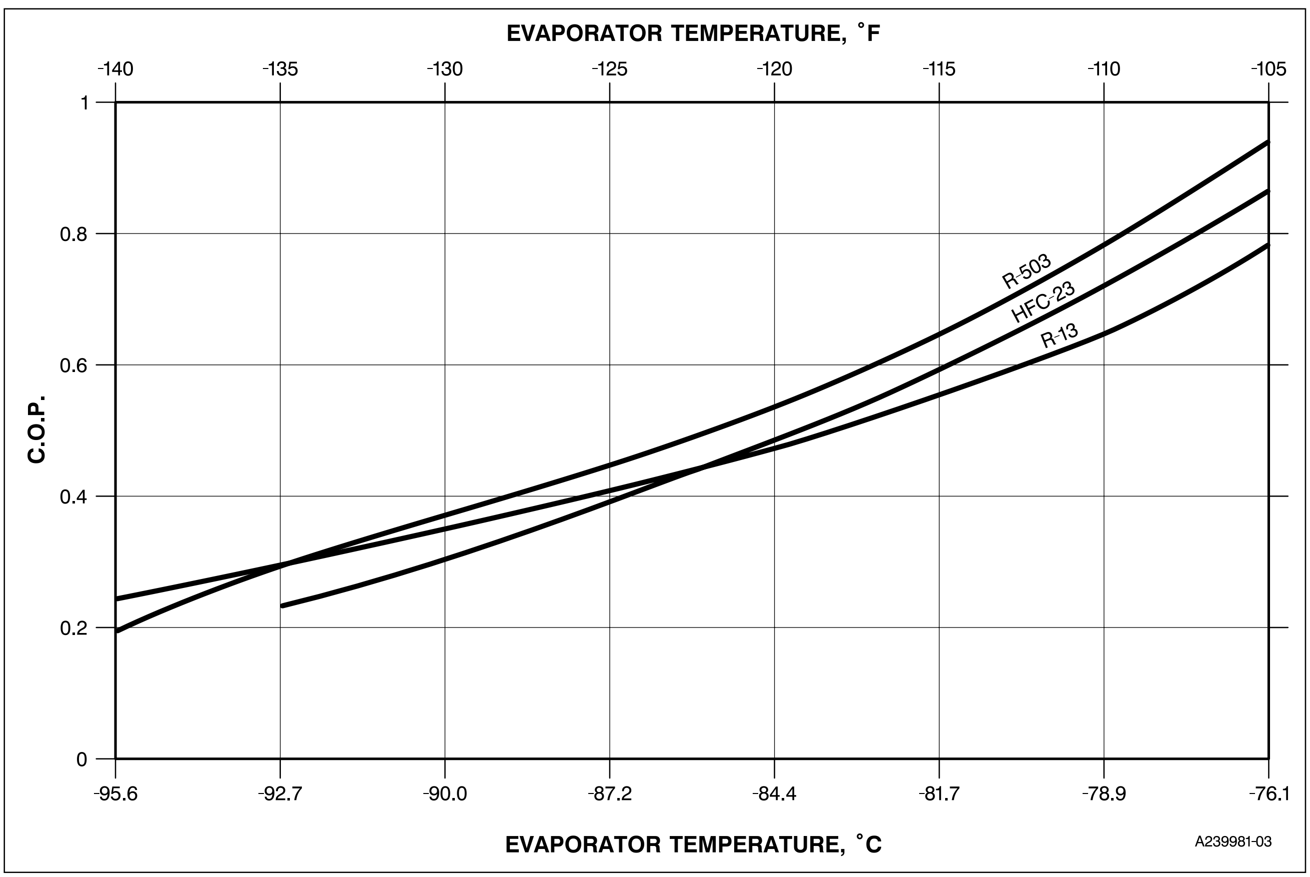
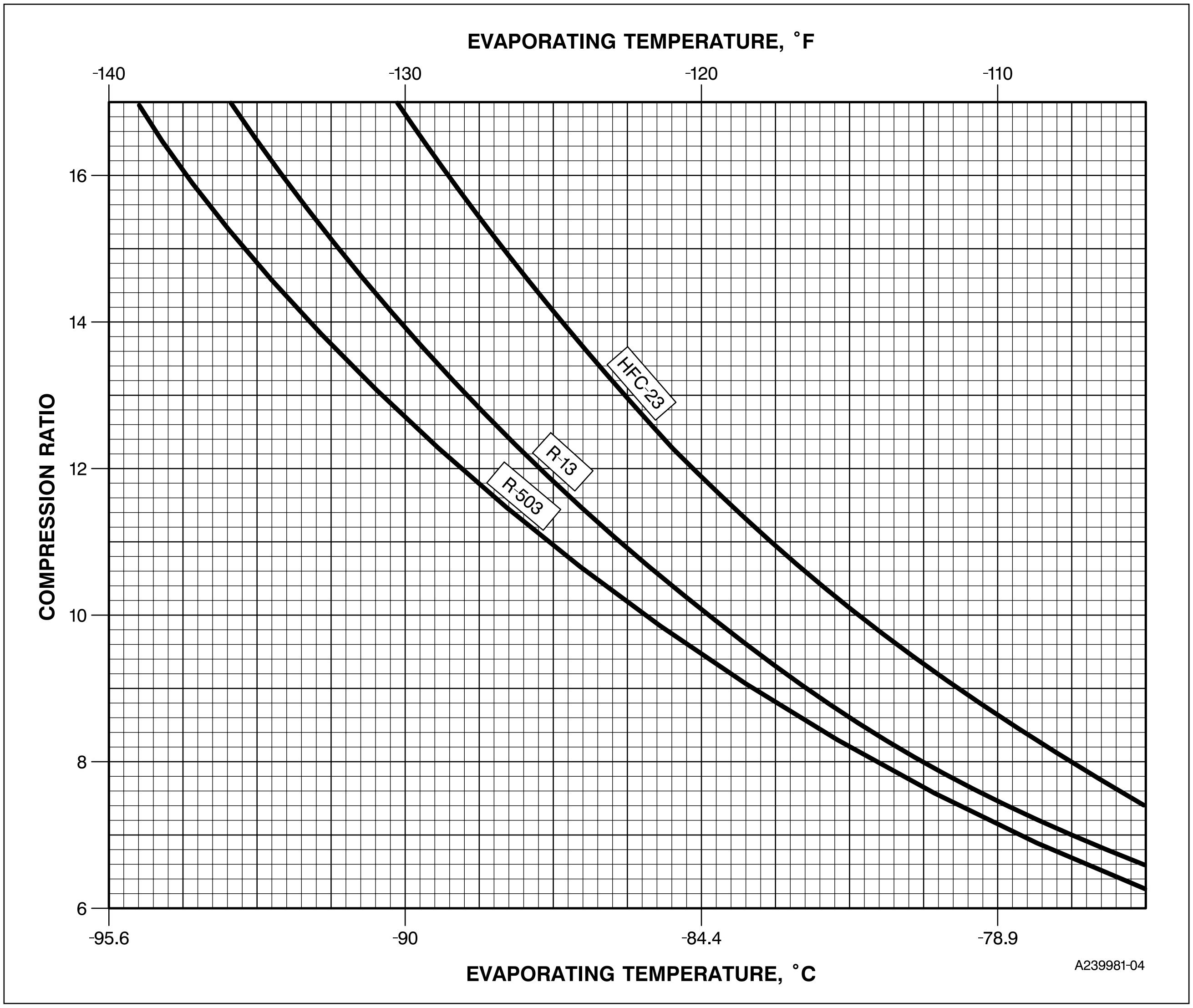


Figure 4. Experimental Compression Ratio (Condensing Temperature –20°F [–29°C])



SYSTEM DATA SHEET

Type of System/Location: ____________________

Equipment Mfg.: ____________________ Compressor Mfg.: ____________________

Model No.: ____________________ Model No.: ____________________

Serial No.: ____________________ Serial No.: ____________________

R-503 or R-13 charge size: ____________________ Lubricant type: ____________________

R-503 or R-13 static pressure: ____________________ Charge size: ____________________

Drier Mfg.: ____________________ Drier type (check one):

Model No.: ____________________ Loose fill: ____________________

Solid core: ____________________

High Stage Refrigerant: ____________________

Expansion Device (check one): Capillary tube: ____________________

Expansion valve: ____________________

If Expansion valve:

Manufacturer ____________________

Model No.: ____________________

Control/set point: ____________________

Location of sensor: ____________________

Other System Controls (ex.: head press control), Describe: ____________________

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(circle units used where applicable)

Date/Time					
Refrigerant					
Charge Size (lbs/grams)					
Static Pressure (psig, psia/kPa, bar)					
Ambient Temp. (°F/°C)					
Relative Humidity					
Compressor:					
Suction T (°F/°C)					
Suction P (psig, psia/kPa, bar)					
Discharge T (°F/°C)					
Discharge P (psig, psia/kPa, bar)					
Box/Fixture T (°F/°C)					
Evaporator:					
Refrigerant Inlet T (°F/°C)					
Refrigerant Outlet T (°F/°C)					
Coil Air/H_2O In T (°F/°C)					
Coil Air/H_2O Out T (°F/°C)					
Refrigerant T @ Superht. Ctl. Pt. (°F/°C)					
Interstage Condenser:					
Refrigerant Inlet T (°F/°C)					
Refrigerant Outlet T (°F/°C)					
High Side Refrigerant In T (°F/°C)					
High Side Refrigerant Out T (°F/°C)					
Exp. Device Inlet T (°F/°C)					
Motor Amps					
Run/Cycle Time					

Comments: ____________________

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