



Suva[®]

alternative refrigerants

ART-3

SUVA[®] 134a* (SUVA Cold MP*, HFC-134a) IN CHILLERS

INTRODUCTION

As production of chlorofluorocarbon (CFC) refrigerants is reduced and ultimately eliminated, environmentally acceptable replacement compounds are needed for use in chillers. These "alternative" refrigerants should have operating characteristics similar to those of the CFCs, both to reduce the cost of converting existing chillers to alternatives and to limit the design changes involved in manufacturing new chillers which can use the alternative refrigerants.

Du Pont is now producing HFC-134a refrigerant as a replacement for CFC-12 in chillers, and is providing this new refrigerant to chiller manufacturers for use in new and existing chillers. Du Pont is also converting its own CFC-12 and R-500 chillers to HFC-134a.

Property comparisons of HFC-134a with CFC-12 are outlined in *Table 1*. The boiling point of the new refrigerant is close to that of CFC-12. This means that HFC-134a will develop system operating pressures similar to CFC-12.

The environmental advantages of HFC-134a over CFC-12 are clearly shown by the Ozone Depletion Potential (ODP) and Global Warming Potential (GWP) values of the two compounds. Neither compound is flammable. The 1000 ppm Allowable Exposure Limit (AEL) of HFC-134a means that this refrigerant is expected to have similar toxicity characteristics as CFC-12 and the other CFC refrigerants.

* SUVA[®] Cold MP and SUVA[®] 134a are Du Pont's registered trademarks for HFC-134a.

TABLE 1
Property Comparisons

	CFC-12	HFC-134a
Boiling Point °C (°F)	-30°C (-21.6°F)	-26°C (-15.7°F)
Flammability	None	None
Exposure Limit, PPM (V/V)	1,000 TLV*	1,000 AEL**
Ozone Depletion Potential	1.0	0.0
Global Warming Potential	3.0	0.26

* A Threshold Limit Value (TLV), established for industrial chemicals by the American Conference of Governmental Hygienists, is the time-weighted average concentration of an airborne chemical to which workers may be exposed during an 8-hour workday 40 hours per week for a working lifetime.

** An Acceptable Exposure Limit (AEL) is the recommended time-weighted average concentration of an airborne chemical to which nearly all workers may be exposed during an 8-hour workday 40 hours per week for a working lifetime without adverse effect, as determined by the Du Pont Company for compounds that do not have a TLV.

GENERAL CONSIDERATIONS

In general, alternative refrigerants cannot be simply "dropped into" a system designed to use CFCs. Depending on the specifics of the machine, materials may need to be replaced, and the compressor will in many cases need to be modified. When converting a chiller from a CFC to HFC-134a, the lubricant will need to be replaced. Maintenance records should list any modifications that have been made to original system components. Also, the equipment manufacturer should be consulted regarding compatibility of system parts with the new refrigerant.

PERFORMANCE COMPARISONS

As shown in *Table 2*, the performance characteristics of HFC-134a are similar to those of CFC-12. HFC-134a was initially thought to be slightly less efficient than CFC-12, based on models which did not take into account differences in heat transfer coefficients between the two refrigerants. Chillers converted to HFC-134a are performing about the same as they did on CFC-12.

Although a new chiller can be designed for HFC-134a, an existing chiller operating on CFC-12 will have to undergo some modifications to operate on the new refrigerant. The lubricant may need to be changed and the impeller speed increased. Experience to date with retrofit of CFC-12 and R-500 chillers to HFC-134a is discussed later in this bulletin.

TABLE 2
Typical Performance Ranges of
HFC-134a vs. CFC-12

Capacity	+2% to -10%
Coefficient of Performance	+2 to -8%
Evaporator Pressure Difference	0 to -3 psi 0 to -0.2 Bar
Condenser Pressure Difference	+15 to +25 psi +1 to +1.7 Bar
Discharge Temperature Difference	0 to -10 F 0 to -5.6 C

Note: Actual performance will depend on the specific equipment and operating conditions used.

MATERIALS COMPATIBILITY

When converting from CFC-12 to HFC-134a, there are several factors that must be considered, most notably chemical compatibility. *Table 3* lists the prominent considerations that must be addressed.

TABLE 3
Chemical Compatibility Considerations

Lubricants	<ul style="list-style-type: none"> • Chemical reactivity with HFC-134a • HCl, carbon compounds
Metals	<ul style="list-style-type: none"> • Chemical reactivity with HFC-134a • Catalyst formation at high temperatures (AlF₃, AlCl₃)
Elastomers	<ul style="list-style-type: none"> • Swelling • Mechanical property changes due to refrigerant/lubricant exposure • Permeation of HFC-134a
Plastics	<ul style="list-style-type: none"> • Mechanical property changes due to refrigerant/lubricant exposure

A primary consideration in chemical compatibility is finding a stable lubricant. In conventional refrigeration and air conditioning applications, there is a very slow reaction between the lubricant and refrigerant, which generates HCl and carbon compounds. Over the past 50 years, lubricants have been developed that are practically non-reactive with CFC refrigerants. Lubricants are now being evaluated for similar stability with HFC-134a.

Common construction materials, such as copper, steel and aluminum, are suitable for the current CFC refrigerants. However, in some circumstances, catalysts for the lubricant/refrigerant reaction such as AlCl₃ and AlF₃, can be formed. To confirm the chemical stability of HFC-134a, these metals are being tested with the candidate refrigerant and lubricant.

Acceptable plastics and elastomers have been found for use with existing CFC refrigerants. However, an elastomer or plastic that is acceptable with one refrigerant may not perform well with another. For this reason, elastomers should be qualified on an application by application basis. Testing with SUVA® refrigerants shows that there will be no one family of elastomers or plastics that will work with all the alternative refrigerants. The results of using improper materials may include swelling, extraction of plasticizers and fillers, and changes in mechanical properties due to extraction and exposure to refrigerants. *Table 4* provides a comparison of elastomer compatibility for CFC-12 vs. HFC-134a.

TABLE 4
Elastomer Compatibility of
CFC-12 vs. HFC-134a

	CFC-12		HFC-134a	
	25°C (77°F)	80°C (176°F)	25°C (77°F)	80°C (176°F)
ADIPRENE® C** Urethane	1	5	2	5
Buna N	1	0	1	0
Buna S	3	4	3	2
Butyl Rubber	2	4	0	3
HYPALON® 48* Chlorosulfonate Polyethylene	1	0	1	0
Natural Rubber	4	5	0	2
Neoprene W	0	1	0	2
NORDEL®* Hydrocarbon Rubber	2	2	1	1
Silicone	5	5	2	2
THIOLKOL® FA*** Polysulfide	1	1	1	0
VITON® A* Fluoroelastomer	5	5	5	5

Codes: 0 = No change

1 = Acceptable change

2 = Borderline change

3 = Slightly unacceptable change

4 = Moderately unacceptable change

5 = Severely unacceptable change

* HYPALON, NORDEL and VITON are Du Pont registered trademarks.

** ADIPRENE is a Uniroyal registered trademark.

*** THIOLKOL FA is a Morton Thiokol registered trademark.

LUBRICANT/REFRIGERANT RELATIONSHIPS

In many refrigeration and air conditioning systems, some lubricant escapes from the compressor discharge area and circulates through the system with the refrigerant.

Current lubricants used with CFC-12 are fully miscible over the range of expected operating conditions, easing the problem of getting the lubricant to flow back to the compressor. Refrigeration systems using CFC-12 take advantage of this full miscibility when considering lubricant return. Refrigerants with little or no chlorine may exhibit less miscibility with many lubricants. When such refrigerants are tested with lubricants, critical miscibility curves show that the refrigerant and lubricant tend to separate at lower temperatures.

Another consideration of refrigerant/lubricant solutions is lubricity. Once a combination with acceptable solubility is found, the lubricant's ability to perform its primary function of lubricating compressor components must be established. If a miscible lubricant is found that has inadequate lubricity, additives can be included to improve lubrication. However, these lubricity enhancers can create solubility problems or introduce chemical reactions between the refrigerant and lubricant.

POLYALKYLENE GLYCOL (PAG) LUBRICANTS

HFC-134a has a very limited solubility with existing refrigeration lubricants, although candidate lubricant families, such as the polyalkylene glycols have been known for the past decade. One peculiarity of some PAG/HFC-134a solutions is that they have an "inverse" solubility curve. This means that instead of becoming insoluble at low temperatures, these solutions tend to separate at high temperatures. Thus, instead of having a tendency to congeal in the evaporator, the lubricant is more likely to separate out in the condenser or liquid line receiver.

The initial search for a candidate lubricant started with commercially available products. Table 5 shows solubilities of various refrigerant/lubricant combinations. Current naphthenic, paraffinic and alkylbenzene lubricants have very poor solubility with HFC-134a.

PAG lubricants may be susceptible to chemical attack by chloride residue in a refrigeration system which previously contained CFC-12. The PAG or its moisture content may also affect hermetic motor materials.

POLYOL ESTER LUBRICANTS

Due to PAG lubricant concerns, polyol ester lubricants that offer many of the same properties as the PAGs are being developed. There are many types of polyol ester lubricants available today, and compressor OEMs will be specifying different products based on individual testing. Contact the compressor or equipment OEM or Du Pont for more information on specific polyol ester lubricants.

In general, esters offer excellent solubility with HFC-134a, as shown in Table 5. In addition many of the esters are not highly sensitive to residual mineral oil concentration, an issue that made retrofits using PAGs difficult.

It is recommended that the mineral oil concentration be less than 1 to 2%, following a retrofit to an ester, primarily to prevent formation of a second lubricant phase when the refrigerant is changed to HFC-134a. A series of successive lubricant changes using esters can normally reduce the mineral oil concentration to low levels. Contact your equipment OEM for more information concerning lubricant handling procedures.

Du Pont has screened many elastomers and plastics for compatibility with HFC-134a and polyol ester lubricants. Contact Du Pont or your equipment OEM for more information.

TABLE 5
Solubility Tests—HFC-134a
Temperature Range -50°C TO 93°C (-58°F to 200°F)

Oil Type	Percentage Refrigerant In Solution		
	30%	60%	90%
500 SUS Naphthenic	2 phase	2 phase	2 phase
500 SUS Paraffinic	2 phase	2 phase	2 phase
125 SUS Dialkyl Benzene	2 phase	2 phase	2 phase
300 SUS Alkyl Benzene	2 phase	2 phase	2 phase
165 SUS PAG	-50 to >93	-50 to >93	-50 to +73
525 SUS PAG	-50 to >93	-40 to +35	-23 to -7
100 SUS Ester	-40 to >93	-35 to >93	-35 to >93
150 SUS Ester	-50 to >93	-50 to >93	-50 to >93
300 SUS Ester	-50 to >93	-50 to >93	-50 to >93
500 SUS Ester	-40 to >93	-35 to >93	-35 to >93

RETROFITTING EXISTING CFC-12 AND R-500 CHILLERS

BACKGROUND

The decision to retrofit CFC equipment with alternative refrigerants must be made based on the cost to retrofit vs. the expected life of the equipment and the anticipated efficiency of the system after the retrofit. As discussed earlier, alternative refrigerants are similar to but not identical to the CFCs they are targeted to replace. The differences in properties must be considered carefully because systems designed for CFCs may perform inefficiently or completely fail if improperly retrofitted with an alternative refrigerant.

Retrofit requirements can range from a minimum effort, such as replacing the lubricant, to significant equipment changes, such as replacing gears, impellers or materials of construction located throughout the system.

The main point to remember is that a service technician cannot simply put an alternative refrigerant into a CFC system. The property data must be compared and the materials of construction reviewed. Then, changes recommended by the original equipment manufacturer (OEM) must be made to ensure that the system will perform correctly and efficiently.

DU PONT'S RETROFIT PROGRAM

Working with major chiller manufacturers, Du Pont has begun an extensive equipment retrofit program to convert all of its large CFC chillers to use alternative refrigerants.

As a first step in this effort, the Company has retrofitted open-drive and hermetic chillers in Du Pont facilities, developing a general understanding of what is required to convert each manufacturer's various models from CFC-12 or R-500 to HFC-134a. This program has now been expanded, with a goal of converting all Du Pont CFC chillers of 20-ton (70 kW) capacity or higher to alternative refrigerants by the end of 1995.

FIELD EXPERIENCE

CASE HISTORY #1

The first conversion of a CFC-12 chiller to HFC-134a was conducted at Du Pont's Sabine River Works in Orange, Texas in November 1989. This was a 700-ton (3,460 kW) open-drive York unit with a 3,200 lb (1,455 kg) refrigerant charge. The compressor lubrication system and evaporator were flushed with CFC-11 to remove residual chlorinated oil before the system was charged with HFC-134a and a 300 SUS PAG lubricant. No modifications were made to the chiller before initial conversion to HFC-134a. The CFC-11 with residual oil was recovered and re-used in CFC-11 chillers on-site.

Initial performance testing showed a capacity loss of 13 to 17% vs. CFC-12, along with an equivalent reduction of power requirement. It was also found that the compressor could not deliver sufficient discharge head to operate during summer when temperatures in the cooling water reach 90 to 93°F (32 to 34°C). The compressor did provide enough lift to operate during winter, and was placed into service with HFC-134a while plans were made to change out the gear set in the Spring of 1990 to increase impeller rpm.

The chiller operated without incident over the Winter of 1989-90 and the compressor was removed in March '90 for disassembly inspection and gear replacement. The internal condition of the compressor was excellent, with virtually no bearing wear except for some marking on the thrust bearing, which sometimes occurs during startup in CFC-12 service. The gear set was replaced with one having an 8% higher rpm and the compressor was returned to service. Followup performance testing in May showed a 1 to 9% increase in capacity vs. CFC-12 and a 1 to 8% increase in power consumption vs. CFC-12. In short, the compressor performed better on HFC-134a and PAG oil than it had on CFC-12 and naphthenic oil. Also, the increase in impeller speed provided sufficient lift to permit summertime operation and the chiller has been in service on HFC-134a ever since.

CASE HISTORY #2

A second CFC-12/naphthenic oil chiller at Sabine, a Carrier open-drive unit, was converted to HFC-134a/PAG oil in December, '90. This was a 1,200 ton (4,224 kW) unit with an 8,000 lb (3,636 kg) charge of CFC-12. The gear set was changed out in Spring '91, anticipating a need for higher RPM for summertime operation with HFC-134a. In this case the CFC-11 flushing was not as extensive, consisting of only flushing the compressor and lubrication system. The intent was to determine how little flushing could be done and still get suitable performance with the PAG oil. As in the previous chiller, frequent refrigerant and oil samples were taken to look for any evidence of chemical degradation. More trace contaminants were found in the oil than were seen in the previous conversion, but their levels were not considered a cause for concern. The only maintenance problem that was encountered since conversion involved the lubrication oil pump. The pump shaft showed some "hourglass" wear, and metal fines were found in the oil. Clearances in the compressor journal bearings had opened up 0.001 to 0.015 inches (0.025 to 0.38 mm). The cause of this lube oil pump problem could not be

ascertained, but the PAG lubricant was replaced with a polyol ester, which doesn't have the sensitivity to residual chlorides which PAG lubricants have.

CASE HISTORY #3

In April 1991, a 3000-ton (10,560 kW) open-drive York R-500 chiller with naphthenic oil was converted to HFC-134a and a polyol ester oil on a Du Pont chemical plant in La Porte, Texas. After R-500 removal and oil draining, the compressor and lubrication oil system were flushed with new polyol ester lubricant. The system was then charged with polyol ester oil and 5,000 lbs (2,272 kg) of HFC-134a refrigerant and started up. Preliminary testing confirmed the earlier expectation that no impeller speed increase would be needed to provide adequate discharge pressure during Summer months, because this chiller was originally used with R-500 instead of CFC-12. Oil and refrigerant monitoring are continuing, with no problems encountered to date.

SUMMARY

At this time, major chiller manufacturers offer chillers for HFC-134a. Du Pont is continuing to work with chiller OEMs to develop retrofit technology and expertise. This program has been in progress for several years, both to determine retrofit needs and to qualify materials for use in new chillers specifically designed for HFC-134a.

In conjunction with the chiller OEMs, Du Pont is working to educate the industry about how to handle this alternative refrigerant. This effort includes making people aware of the handling requirements of new refrigerants, the chemical compatibility requirements of oils and materials of construction, and the effects of conversion on chiller operating characteristics.

For more information about retrofitting CFC equipment for use with SUVA® refrigerants, contact the OEM or Du Pont at 1-800-441-9442.