



ART-3

Suva® 134a in Chillers

Introduction

Because of the phaseout of chlorofluorocarbon (CFC) refrigerants, environmentally acceptable replacements have been commercialized for use in new chillers and in chillers originally designed for use with CFCs. The "alternative" refrigerants have operating characteristics similar to those of CFCs, both to limit the design changes involved in manufacturing new chillers which use these new refrigerants and to reduce the cost of converting existing chillers from CFCs to them.

DuPont is now producing HFC-134a (Suva® 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. DuPont has converted most of its own CFC-12 and R-500 chillers to HFC-134a and has replaced its other CFC-12 and R-500 chillers with new chillers operating on HCFC-123, HFC-134a, or HCFC-22.

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 develops 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.

General Considerations

In general, alternative refrigerants cannot be simply "dropped into" a system designed to use CFCs.

Table 1
Property Comparisons

| | CFC-12 | HFC-134a |
|---------------------------|-----------------|-------------------|
| Boiling Point, °C (°F) | -30°C (-21.6°F) | -26.1°C (-14.9°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 | 8,500 | 1,300 |

*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 DuPont for compounds that do not have a TLV.

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 that 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 will need to be changed and the impeller speed increased 10–15% or replaced with impellers suitable for HFC-134a. Experience to date with retrofit of CFC-12 and R-500 chillers to HFC-134a is discussed later in this bulletin.

Table 2
Typical Retrofit Performance Ranges of HFC-134a versus CFC-12

| | |
|----------------------------------|----------------------------------|
| Capacity | +2% to -10% |
| Coefficient of Performance | +2 to -8% |
| Evaporator Pressure Difference | 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.

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 nonreactive with CFC refrigerants. Lubricants have now been developed which have acceptable stability with HFC-134a.

Common construction materials, such as copper, steel, and aluminum, are suitable for CFC refrigerants. However, in some circumstances, catalysts for the lubricant/refrigerant reaction such as AlCl_3 and AlF_3 , can be formed. The chemical stabilities of copper, steel, and aluminum have been tested and confirmed as acceptable for use with HFC-134a and lubricants.

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®

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 (AlCl_3, AlF_3) |
| 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 |

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 versus HFC-134a.

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.

**Table 4
Elastomer Compatibility of HFC-134a**

| | Ratings | | | | | |
|-------------------|----------------|-----------------|------------------|----------------|-----------------|------------------|
| | CFC-12 | | | HFC-134a | | |
| | 25°C (77°F) | 80°C (176°F) | 141°C (285°F) | 25°C (77°F) | 80°C (176°F) | 141°C (285°F) |
| Adiprene® L | 1 | 5 | | 2 | 5 | |
| Buna N | 1* | 0* | 2* | 1 | 0* | 1 |
| Buna S | 3 | 4 | | 3 | 2 | |
| Butyl Rubber | 2 | 4 | | 0 | 3 | |
| Hypalon® 48 | 1 | 0 | 0 | 1* | 0 | 0 |
| Natural Rubber | 4 | 5 | | 0 | 2 | |
| Neoprene W | 0* | 1* | | 0 | 2 | |
| Nordel® Elastomer | 2* | 2* | | 1 | 1 | |
| Silicone | 5 | 5 | | 2 | 2 | |
| Thiokol® FA | 1 | 1 | | 1* | 0 | |
| Viton® A | 5 | 5 | | 5 | 5 | |

*Recommend elastomer replacement after equipment teardown.
Hypalon, Nordel, and Viton are DuPont registered trademarks.
Adiprene is a Uniroyal registered trademark.
Thiokol FA is a Morton Thiokol registered trademark.

Codes: 0 = No change.
1 = Acceptable change.
2 = Borderline change.
3 = Slightly unacceptable change.
4 = Moderately unacceptable change.
5 = Severely unacceptable change.

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.

Initially, polyalkylene glycol (PAG) lubricants were used for chiller retrofits. PAG lubricants may be susceptible to chemical attack by chloride residue in a refrigeration system that previously contained CFC-12. The PAG or its moisture content may also affect hermetic motor materials. As a result, extensive cleaning of retrofits was required.

Polyol Ester Lubricants

Due to PAG lubricant concerns, the focus shifted to polyol ester lubricants that offer many of the same properties as PAGs. There are many types of polyol ester lubricants available today, and compressor original equipment manufacturers (OEMs) have specified different products based on individual testing. Contact the compressor or equipment OEM for more information on specific polyol ester lubricant recommendations.

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 10% for chilled water applications and

less than 5% for low temperature applications, following a retrofit to an ester, primarily to prevent formation of a second lubricant phase when the refrigerant is changed to HFC-134a. Contact your equipment OEM for more information concerning lubricant handling procedures.

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

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 versus 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.

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

| Oil Type | Percent Refrigerant in Mixture | | |
|------------------------|--------------------------------|------------|------------|
| | 30% | 60% | 90% |
| 500 SUS Naphthenic | 2 phase | 2 phase | 2 phase |
| 500 SUS Paraffinic | 2 phase | 2 phase | 2 phase |
| 125 SUS Dialkylbenzene | 2 phase | 2 phase | 2 phase |
| 300 SUS Alkylbenzene | 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 |

*One phase in this temperature range, °C.

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 OEM must be made to ensure that the system will perform correctly and efficiently.

DuPont Retrofit Program

Working with major chiller manufacturers, DuPont has retrofitted its extensive inventory of CFC chillers to alternative refrigerants.

As a first step in this effort, the Company retrofitted open-drive and hermetic chillers in DuPont 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 was then expanded, and led to the conversion of essentially all DuPont CFC chillers of 20-ton (70-kW) capacity or higher to alternative refrigerants.

Field Experience

Case History #1

The first conversion of a CFC-12 chiller to HFC-134a was conducted at DuPont Sabine River Works in Orange, Texas in November 1989 on a 700-ton (2,460-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% versus 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 32 to 34°C (90 to 93°F). 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 1990 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 start-up in CFC-12 service. The gear set was replaced with one having an 8% higher rpm and the compressor was returned to service. Follow-up performance testing in May 1990 showed a 1 to 9% increase in capacity versus CFC-12 and a 1 to 8% increase in power consumption versus 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 1990. 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 1991, 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 in (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 that 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 DuPont 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 lb (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.

Case History #4

In April 1991, a 3,000-ton (10,560-kW) open-drive Carrier 17DA chiller with naphthenic oil was converted to HFC-134a and a polyol ester oil on a DuPont fibers plant in Camden, South Carolina. The unit provides chilled water for air conditioning and product cooling. After R-12 and oil draining, the compressor and lubrication oil system were flushed three times with polyol ester oil. The compressor rotor was removed and inspected prior to increasing the speed by 13%. During the inspection, a defective shaft was found and replaced. The new compressor rotor assembly was then overspeed tested and reinstalled in the case. The external gear box was refitted with a higher ratio gear set to increase compressor speed by 13%. The system was then charged with 10,900 lb (4,955 kg) of HFC-134a and polyol ester oil. Initially a lower viscosity oil was installed in this unit. Unsatisfactory operating pressures were noted and the oil was replaced with a higher viscosity oil. Preliminary testing found that the capacity was regained but that energy consumption increased at full design capacity. Later experience has shown that the unit capacity has increased to 3,200 tons with energy consumption per ton better than the previous experience with CFC-12.

Oil and refrigerant monitoring are continuing with no problems encountered to date.

Case History #5

In July 1992, a 2,000-ton (7,040-kW) open-drive Worthington 52EH CFC-12 chiller with naphthenic oil was converted to HFC-134a and a polyol ester oil on a DuPont chemical plant in Nashville, Tennessee. The unit provides chilled water for air conditioning and product cooling. The unit is unique because Worthington no longer produces chillers. The unit was installed in 1965 and had operated without overhaul for that entire period. The Worthington units in general are fitted with condensers that have design pressure ratings of 150 psig. In most retrofits, the pressure rating on the condenser will be inadequate for HFC-134a and the condenser may have to be replaced. This application did not require condenser replacement. Initial computer evaluations indicated that a 4% speed increase would be required to achieve full capacity. The CFC-12 and mineral oil were removed from the system. The unit was opened and an overhaul was conducted. The compressor rotor was overspeed tested and reinstalled. A single oil flush was performed with polyol ester oil. The unit was charged with 7,000 lb (3,181 kg) of HFC-134a and a polyol ester oil. Initially a lower viscosity oil was installed in this unit. Unsatisfactory operating pressures were noted and the oil was replaced with a higher viscosity oil. Also, during the performance evaluation it was necessary to add 5 gal of oil to the evaporator to improve performance of the heat exchanger. Testing indicated that the unit capacity increased 2% versus the CFC-12 and energy efficiency increased 10% versus CFC-12. This is a unique case and the reader is cautioned to properly evaluate the pressure rating requirement and modify the condenser accordingly before retrofitting to HFC-134a. Oil and refrigerant monitoring are continuing with no problems encountered to date.

Summary

Major chiller manufacturers now have HFC-134a chillers in commercial production. The retrofit technology developed over the past decade is now routinely used to retrofit CFC-12 and R-500 chillers to HFC-134a.

In conjunction with the chiller OEMs, DuPont continues to assist in educating 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 DuPont at 1-800-235-SUVA.

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