7th BEAMA International Electrical Insulation Conference, Brighton 1994

INSULATION SYSTEMS FOR THE NEW ENVIRONMENTALLY FRIENDLY REFRIGERANTS

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Todays most widespread refrigerants CFC-11, CFC-12 and HCFC-22 used in refrigeration, chilling and air conditioning are being replaced by new systems to protect the ozone layer. Refrigerants with no or very low ozone depletion potential have been evaluated and tested together with new motor lubricants. With the transition from traditional to new refrigerant systems, it is essential to ensure that the electrical insulating materials used in compressor motors are compatible with the new fluids. A range of electrical insulating materials for low and high voltage motors has been examined for compatibility with the new refrigerants. Detailed results are given in this paper.

INTRODUCTION

Chlorofluorocarbons (CFCs) used as refrigerants, blowing agents for polymer foams, aerosols and cleaning agents for more than 50 years are now being phased out to protect the ozone layer. It is the stability of these compounds coupled with their chlorine content which has linked them to the depletion of the earth's protective ozone layer. Hydrofluorocarbons (HFCs) and hydrochloro-fluorocarbons (HCFCs) have been evaluated as alternatives to meet CFC user needs and protect the environment. HFCs do not contain chlorine, and therefore have zero ozone depletion potential. In HCFCs, the addition of hydrogen to the CFC structure allows the dissipation of most of the chlorine in the lower atmosphere, before it reaches the ozone layer. The world consumption of CFCs in 1991 was estimated to 680'000 tons, about one third of which was used for refrigeration, chilling and air conditioning.

Regulatory activities began in 1978, when the U.S. Environmental Protection Agency banned all non-essential aerosol uses of CFCs. In 1987 the Montreal Protocol on Substances that Deplete the Ozone was established. Shortly after the Montreal Protocol was signed, calls for its strengthening followed. In 1992 the parties to the Montreal Protocol agreed in Copenhagen to move the phase-out of CFCs forward towards January 1, 1996. In this revision to the Protocol, HCFCs were also scheduled for eventual phase-out. The production levels of HCFCs will be frozen in 1996 and a complete phase-out is scheduled for 2030. Even so the HCFCs (i.e. HCFC-123) are still seen as transitional substances to move away from the CFCs, these are now designated for phase-out (1).

This paper focuses on the liquids used in refrigeration, chilling and air conditioning. Several alternatives have been proposed and introduced in the market. With the transition from traditional to new refrigerant systems, it is essential to ensure that the electrical insulating materials used in compressor motors are compatible with the new fluids. Therefore a range of electrical insulating materials for low and high voltage motors has been examined for compatibility with the new refrigerants. The most important of the common refrigerants subject to phase-out and the alternatives to them which have been used in the tests are as follows:

New refrigerant:	Replacement for:	Applications:
HCFC-123	CFC-11	Centrifugal chillers
HFC-134a	CFC-12	Domestic, automotive and commercial refrigeration systems, medium temperature food cases and chillers, air conditioning
Blend of HFC-32, HFC-125 and HFC-134a	HCFC-22	Low and medium temperature applications, domestic and commercial refrigeration, air conditioning
Blend of HFC-32, HFC-125 and HFC-134a	CFC-502	Commercial refrigeration (supermarkets, ice machines, transport)

In nearly all the cases where HFCs are used as replacements, the lubricant used in the system is different than used with CFCs or HCFCs. The new synthetic lubricants which replace the mineral oils traditionally used with CFCs are from two main classes: polyalkylene glycol and polyol ester. A broad range of the new lubricants was included in the examinations together with the new refrigerants.

EXPERIMENTAL

Various electrical insulating materials manufactured by Von Roll Isola were selected for the test, see table 1. Compatibility of the materials was assessed by exposure to either refrigerant or refrigerant-lubricant mixtures at elevated temperatures and pressures. The testing procedure complies to the ASHRAE standard (ANSI/ASHRAE 97-1983, Sealed glass tube method to test the chemical stability of material for use within refrigerant systems). The materials were placed in an autoclave and measured weights of refrigerant - and lubricant if required - were added. The autoclave was then heated to 130 °C (90 °C in the case of HCFC-123) for a period of 14 days at autogenous pressure (approximately 600 psig). On completion, the autoclave was allowed to cool down to ambient temperature. The samples were removed and visual changes (appearance of bubbles or blisters, changes in colour etc.) as well as changes in weight and volume were determined within a few minutes. Where appropriate, changes in other properties such as hardness, tensile strength, flexural strength and bond strength were measured. Weight change determined is the sum of any weight loss due to material dissolution or extraction and any absorption of refrigerant by the sample.

The compatibility of winding wire lubricants with HFC-134a / ester lubricant systems was examined in a separate test. Solubility of various winding wire lubricants was tested in the ester lubricants at 0.3 % by weight and in 15 % ester / 85 % HFC-134a at 0.05 % by weight in the temperature range of -40 °C to +80 °C.

The tests with HFC-134a and the HCFC-22 and CFC-502 replacement refrigerants were done by ICI Klea, Widnes, Cheshire, UK and those with HCFC-123 by DuPont, Wilmington, Delaware, USA.

RESULTS AND DISCUSSION

The performance of the electrical insulating materials in the new refrigerants and refrigerant-lubricant mixtures is compiled in table 2.

HFC-134a / ester lubricant systems, HCFC-22 and CFC-502 replacement refrigerants: All of the materials selected for low and high voltage motors performed in general as well as, or better in the new refrigerants and refrigerant / lubricant mixtures than they did in CFC-12, HCFC-22 and their mixtures with mineral oil. The visual inspection of the insulating materials showed no appearance of bubbles or blisters in any case (2, 3).

HFC-134a is now generally accepted as being the most appropriate ozone-benign refrige-rant to replace CFC-12 in most application areas. Replacement of CFC-502 and HCFC-22 is more complicated by the fact, that unlike the CFC-12 / HFC-134a situation, at present there is no single refrigerant molecule capable of closely matching the physical and thermodynamic properties of the threatened materials. For lack of a single component solution, refrigerant blends are proposed.

The traditional mineral oil lubricants used with CFC-12, HCFC-22 and CFC-502 are not compatible with HFCs. HFCs require the use of polyalkyleneglycols (PAGs) and polyolesters as lubricants. Because of their relatively high water affinity the PAG lubricants have been essentially displaced by the polyolesters in these applications. Of great importance is also the choice of the suitable winding wire lubricant. Conventional paraffinic motor winding lubricants have been found to block capillary tubes in domestic fridge/freezer systems when used with polyolester lubricants. Selection of winding lubricants for use in such systems requires careful consideration.

HCFC-123: Current oils used with CFC-11 are fully soluble in HCFC-123 over the range of expected operating conditions. This means that mineral oil will generally be used as lubricant together with HCFC-123. The same hydrogen atom which makes HCFC-123 desirable from an environmental standpoint makes it a stronger solvent than CFC-11. Because of this, HCFC-123 is more aggressive towards polymers, which was confirmed by the test results. Several electrical insulating materials which are compatible with other refrigerants fail in HCFC-123. Careful selection of materials is necessary when designing equipments using HCFC-123.

REFERENCES

1. Dekleva T.W. and Yost R.W., 1993, Responding to the CFC Challenge, Proc. Electrical/Electronics Insulation Conference, Chicago, 495

2. Brütsch R., Allison J. and Tompsett G., 1992, Insulation Systems and the New Refrigerants, Proc. Int. Coil Winding Assoc., Cincinnati, 219

3. Corr S., Dekleva T.W., Dowdle P., Tompsett G., Allison J. and Brütsch R., 1993, Compatibility of Non-Metallic Motor Components with R-22 and R-502 Replacement Refrigerants, Proc. Electrical/Electronics Insulation Conference, Chicago, 507

TABLE 1: Details of Materials, Structure and Application

No.	Material Name	Composition	Application
1	Myoflex PVS	Composite of PET between two polyester felts impregnated with resin	Slot lining insulation (class F)
2	Myoflex N	Composite of PET between two polyamide papers impregnated with resin	Slot lining insulation (class F)
3	Vetroflex 253.13	Glass fibre tape impregnated with epoxy resin	Field coil and slot lining insulation (class F)
4	Vetroflex 253.10	Glass fibre tape impregnated with polyurethane resin	Field coil and slot lining insulation (class F)
5	Samicatherm 366.28	Composite of mica paper and glass fabric impregnated with epoxy resin	Insulation for high voltage motors (class H)
6	Epoflex 215.01	Polyester fleece tape impregnated with pigments and flexible epoxy resin	Insulation at coil ends (class F)
7	Filosam 326.52 - 11	Composite of mica, glass threads and polyester film impregnated with acrylic resin	Flexible insulation for h.v. motors (class F)
8	Filosam 326.52 - 30	Composite of mica, glass threads and polyester film impregnated with epoxy resin	Flexible insulation for h.v. motors (class F)
9	Resin 3308 + 366.58	Composite of mica/glass fabric impregnated with polyesterimide resin	Insulation for high voltage motors (class H)
10	Isomica 326.04	Mica - glass fabric - polyester film impregnated with polybutadiene resin	Conductor and ground insulation (class F)
11	Isomica 326.12	Mica - glass fabric - polycarbonate film impregnated with polybutadiene resin	Conductor and ground insulation (class F)
12	Resin 3316	Unsaturated polyesterimide resin containing styrene as thinner	Motor winding resin for rotors and stators (class F)
13	Resin 3305	Solventless unsaturated polyesterimide resin	Motor winding resin, final dip (class F)
14	Resin 3405	Modified epoxy resin with little solvent	Motor winding resin for rotors and stators (class F)
15	Resin 3360	Modified unsaturated polyesterimide resin without styrene	Motor winding resin for rotors and stators (class F)
16	Exar - 500	Modified crosslinked polyolefin	Motor lead wire (class F)
17	2MN - 180	Diacetate fibres, PET film and polyamide paper with polyester/polyurethane coat	Motor lead wire (class H)
18	2PM-700	Polyester yarn and tape	Motor lead wire (class F)
19	Samicaflex	Micapaper and glass fabric impregnated with a silicone binder	Armature winding insulation (class C)
20	Siwo - Kul	Silicone rubber and synthetic yarn braid impregnated with polyurethane resin	Cables for h.v. motors (class H)
21	RT8 Tying Tape	Stabilised rayon impregnated with resin	Tape for lacing and binding coils
22	Siligaine Sleeve	Impregnated polyester braid	Compressor cable insulation (class B)
23	Polyglas H200	Glass yarns impregnated with polyester resin	Banding tape (class C)
24	Conductive Tape 215.55	Polyester non - woven fleece impregnated with carbon particles/epoxy resin	Control of corona discharges in h.v. motors (class F)
25	Semiconductive Tape 217.31	Polyester fabric impregnated with silicone carbide/epoxy resin	With conductive tape, dissipates corona charge (class F)
26	G11 Laminate	Woven glass cloth impregnated with epoxy resin	Dielectric APPS with high mechanical stresses
27	GP03 Laminate	Woven glass cloth impregnated with polyester resin	Terminal boards and switch gear
28	Thermex 180 PZ/2	THEIC modified Polyesterimide	Enamelled motor winding wire (class H)
29	Thermex 200 PZ/2	Polyesterimide with polyamideimide overcoat	Enamelled motor winding wire (class C)
30	Thermex 305	Modified polyesterimide	Enamelled motor winding wire (class H)
31	Thermex 306	Modified polyesterimide with polyamideimide overcoat	Enamelled motor winding wire (class C)
32	Thermibond 158	Modified polyesterimide, self bonding	Enamelled motor winding wire (class H)
33	Thermibond 164	Modified polyesterimide, self bonding	Enamelled motor winding wire (class C)
34	Varnish 2004 HFP	Hard phenolic resin	Motor winding varnish, final dip (class B)
35	Varnish 2005 HFP	Modified alkyd polyester resin	Motor winding varnish, final dip (class F)
36	Varnish 2053 HFP	Modified polyesterimide resin	Motor winding varnish, final dip (class H)
37	Daglas	Glass filament fused with synthetic yarn	Used with enamelled wire (class F)

Materials supplied by Von Roll Isola

TABLE 2: Compatibility of Electrical Insulating Materials for Low and High Voltage Applications with the New Refrigerant and Refrigerant / Lubricant Systems

No.	MATERIAL CONDITION	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p
1	Myoflex PVS	X	X	X	X	X	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
2	Myoflex N	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	X
3	Vetroflex 253.13	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	-	-	-	-	-
4	Vetroflex 253.10	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	-	-	-	-	-
5	Samicatherm 366.28	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	-	-	-	-	OK
6	Epoflex 215.01	X	OK	OK	X	X	X	X	OK	OK	X	OK	-	-	-	-	-
7	Filosam 326.52 - 11	OK	OK	OK	X	X	OK	OK	OK	OK	OK	OK	-	-	-	-	-
8	Filosam 326.52 - 30	X	X	OK	X	OK	OK	X	X	X	X	X	-	-	-	-	X
9	Resin 3308 + 366.58	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	-	-	-	-	-
10	Isomica 326.04	OK	OK	OK	X	OK	OK	OK	OK	OK	OK	OK	-	-	-	-	-
11	Isomica 326.12	X	X	OK	X	X	X	X	OK	X	OK	X	-	-	-	-	-
12	Resin 3316	-	-	-	-	-	-	-	-	-	-	-	OK	OK	OK	OK	X
13	Resin 3305	-	-	-	-	-	-	-	-	-	-	-	OK	OK	OK	OK	OK
14	Resin 3405	OK	OK	OK	OK	OK	X	OK	OK	OK	OK	X	-	-	-	-	-
15	Resin 3360	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	-	-	-	-	-
16	Exar - 500	OK	OK	OK	X	OK	OK	OK	OK	OK	OK	OK	-	-	-	-	-
17	2MN - 180	X	X	X	X	X	X	X	X	X	X	X	OK	OK	OK	OK	X
18	2PM - 700	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	OK
19	Samicaflex	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	-	-	-	-	OK
20	Siwo - Kul	X	X	X	X	X	X	X	X	X	X	X	-	-	-	-	X
21	RT8 Tying Tape	X	X	X	X	X	X	X	X	X	X	X	OK	OK	OK	OK	X
22	Siligaine Sleeve	X	X	X	X	X	X	X	X	X	X	X	-	-	-	-	-
23	Polyglas H 200	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	OK
24	Conductive Tape 215.55	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	-	-	-	-	OK
25	Semiconductive Tape 217.31	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	X
27	GP03 Laminate	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	-	-	-	-	-
28	Thermex 180 PZ/2	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	-
29	Thermex 200 PZ/2	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	-
30	Thermex 305	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	-	-	-	-	X
31	Thermex 306	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	-	-	-	-	OK
32	Thermibond 158	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	-	-	-	-	OK
33	Thermibond 164	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	-	-	-	-	OK
34	Varnish 2004 HFP	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
35	Varnish 2005 HFP	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	X
36	Varnish 2053 HFP	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	X
37	Daglas	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	-	-	-	-	OK

Key:

a: R 22
b: R 32
c: R 134a
d: R 32 / R 134a (30 : 70)
e: R 22 / SUNISO 3 GS
f: R 32 / EMKARATE RL 68S
g: R 32 / EMKARATE RL 32S
h: R 32 / R 134a / EMKARATE RL 68S
i: R 32 / R 134a / EMKARATE RL 32S
j: R 22 / EMKARATE RL 68S
k: R 22 / EMKARATE RL 32S
l: R 134a / EMKARATE RL 15S
m: R 134a / EMKARATE RL 32S
n: R 134a / EMKARATE RL 68S
o: R 12 / SHELL CLAVUS 32
p: R 123

OK: Visually no change
X: Change occurred
-: Not tested

Electrical insulating materials supplied by Von Roll Isola
EMKARATE lubricants supplied by ICI