**ACCELERATED SCREENING METHODS FOR DETERMINING CHEMICAL
AND THERMAL STABILITY OF REFRIGERANT-LUBRICANT MIXTURES
PART II: EXPERIMENTAL COMPARISON AND
VERIFICATION OF METHODS**

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ABSTRACT

The research reported herein continued to concentrate on *in situ* conductivity measurements for development of an accelerated screening method for determining the chemical and thermal stabilities of refrigerant/lubricant mixtures. Tungsten rods were sealed into the round bottoms of the sealed tubes to provide electrical connections for the *in situ* conductivity measurements. The *in situ* conductivity measurements were used to monitor the degradation of HFC-134a/ester oil mixtures heated at 175°C (347°F) for two days. The preliminary results indicate that the *in situ* conductivity measurements correlate with H-134a/oil degradation as determined by color measurements.

A short study to evaluate the potential of *in situ* color measurements for development into an accelerated screening test was also performed. The initial results indicate that the *in situ* color measurements are not well suited for long-term, *in situ* degradation measurements.

SCOPE

This report describes the research performed during Part II of the MCLR Project Number 655-51500 entitled, "Accelerated Screening Methods for Determining Chemical and Thermal Stability of Refrigerant-Lubricant Mixtures." The research was performed from July 1, 1993 to September 30, 1993. The research described in this report was performed to evaluate analytical techniques for development into accelerated compatibility tests. The candidate techniques were identified in Part I of the MCLR Project Number 655-51500 performed from October 15, 1992 to January 15, 1993.

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SIGNIFICANT RESULTS

Introduction

During the past three months, research has continued to focus on modifying the ANSI/ASHRAE Standard 97-1989 [1] for development into an accelerated screening method for determining the chemical and thermal stabilities of refrigerant/lubricant mixtures. The sealed glass tube specified in ANSI/ASHRAE Standard 97-1989 [1] has been modified to include two tungsten wire posts (Figure 1) for performing *in situ* conductivity measurements. Previous research [2] has demonstrated that the conductivity measurements performed with the modified sealed glass tubes (Figure 1) rank the thermal and chemical stabilities of CFC and HCFC refrigerant/lubricant mixtures in the same order as the ANSI/ASHRAE Standard 97-1989 [1]. Previous research [2] also indicated that the *in situ* conductivity measurements accelerated the degradation rates of the refrigerant/lubricant mixtures shortening the analysis times of the developed screening test in relation to ANSI/ASHRAE Standard 97-1989 [1].

The research reported herein further evaluates the screening capabilities of the *in situ* conductivity measurements by analyzing various HFC-134a refrigerant/ester oil mixtures heated at 175°C (347°F) for two days. Research was also performed to assess the potential of continuous, *in situ* color measurements for development into accelerated screening methods. All of the oils to be used in the evaluation of the accelerated screening test were analyzed thoroughly and their corresponding analytical results are listed herein. The commercial sources and brand names of the oils tested in this study are listed in Appendix A. The commercial source for the refrigerants is also listed in Appendix A.

In Situ Color Measurements

Since the refrigerant/oil mixtures are heated in glass tubes and color is one of the degradation evaluation techniques most often used by ANSI/ASHRAE Standard 97-1989 [1], a short study was performed to evaluate *in situ* color measurements for development into an accelerated screening method. An aluminum block used to hold the glass tubes during heating was modified by drilling a 6.3 millimeter (0.25 inch) diameter bore perpendicular to, and intersecting with one of the wells used to hold the sealed glass tubes. To protect the light source and detector from thermal stressing, the aluminum block was placed on a hot plate instead of inside an oven. A sealed glass tube containing a CFC-11/naphthenic mineral oil mixture was

MODIFIED SEALED GLASS TUBE

Figure 1. Schematic of Modified Sealed Glass Tube. Tube Dimensions [150 mm (ℓ) x 9 mm (O.D.)] According to ANSI/ASHRAE Standard 97-1989.

placed into the modified well of the heated aluminum block. The modified aluminum block was then placed onto a hot plate and heated to 175°C (347°F) [block temperature reached 175°C (347°F) in 30 minutes]. The percent transmission measured by the detector was plotted versus temperature during heat up to 175°C (347°F) as shown in Figure 2.

The percent transmission plot versus block temperature in Figure 2 indicates that the amount of light reaching the detector decreases rapidly as the temperature increases to 150°C (302°F). The sealed tube was removed and the refrigerant/oil mixture was inspected for color change. No color change was perceptible indicating the decrease in light transmission was most likely due to a change in the refractive index of the refrigerant/oil mixture caused by the increased temperature. The tube was reinserted into the block and heated at 175°C for 1 hour. The light transmission remained constant (~70%) for the heating period indicating that the color of the refrigerant/oil mixture was unchanged. After 1 hour the tube was removed and reinspected for a color change. A perceptible color change had occurred (increased from below 0.5 to above 1.0), i.e., refrigerant/oil mixture degradation increased. Consequently, the *in situ* color measurement was insensitive to the initial refrigerant/oil degradation.

For direct comparison of techniques, the experiment was repeated with the modified sealed tube (Figure 1) to allow simultaneous *in situ* color and conductivity measurements [tube temperature 175°C (347°F) in 10 minutes]. The conductivity and percent transmission plots versus heating time in Figure 3 indicate the conductivity of the heated refrigerant/oil mixture increases with heating time (degradation increases) and the percent transmission is constant with heating time (no degradation). The room temperature color measurement again detected a color change (increase from 0.5 to 1.5) indicating degradation of the refrigerant/oil mixture. Consequently, the *in situ* conductivity measurement was more sensitive to refrigerant/oil degradation than the *in situ* color measurement.

The experiment was repeated several times with different interference filters placed in front of the detector to select wavelength regions (400 to 450 nanometers: yellow) more susceptible to refrigerant/oil color changes. In all cases, the transmission was more dependent on temperature than on refrigerant/oil mixture color changes.

In addition to temperature dependence, the transmission of the tungsten light changed between experiments. Although double beam (sample beam and reference beam) set ups can be constructed to negate output fluctuation of light sources (and possibly refractive index changes),

Figure 2. Plot of Percent Transmission Versus Temperature for a CFC-11/Naphthenic Mineral Oil Mixture Heated to 175°C in a Sealed Glass Tube.

Figure 3. Plots of Percent Transmission and Conductivity Versus Heating Time at 175°C (347°F) for a CFC-11/Naphthenic Mineral Oil Mixture Heated in a Modified Sealed Glass Tube (Figure 1).

the associated electronics greatly increase the complexity of operation and the cost of the test equipment.

Consequently, this initial study has shown that the *in situ* conductivity measurements are inherently more reliable and easier to perform than *in situ* color measurements. Consequently, *in situ* conductivity tests are better suited for performing chemical and thermal stability measurements of heated refrigerant/lubricant mixtures than *in situ* color measurements.

In Situ Conductivity Measurements of HFC-134a/Oil Mixtures

To further evaluate the potential of the *in situ* conductivity measurements for development into an accelerated screening method for determining the chemical and thermal stabilities of any refrigerant/oil mixture, modified sealed tubes (Figure 1) were prepared containing HFC-134a mixtures with three different ester based oils (branched acids 1 and 2 and mixed acid 2 in Appendix A). The oils were used as received (without prior drying or other purification). The oils were used as received since the research described herein was more concerned with test development than oil evaluation. The oils will be analyzed thoroughly and purified prior to the final refrigerant/oil evaluations. One of the oils (branched acid 1) was allowed to sit on a window sill in a closed glass bottle for 24 hours prior to testing. The oil changed color (light yellow to orange) and the hydroperoxide content increased (0.05 to 0.8 mmoles of hydroperoxide/liter of oil) upon exposure to sunlight and is referred to as "branched acid 1 exposed" in Figure 4. The increase in color and hydroperoxide content indicate that the oil is easily oxidized by dissolved air (i.e., oil does not contain antioxidants as specified by the program work statement). The prepared tubes were placed into the wells of an aluminum block which was placed into an oven and heated at 175°C (347°F) for two days.

The *in situ* conductivity measurements of the four tubes were made continuously during the test using a different electronics board and data logger input/output pair for each heated tube. A triangular waveform (oscillating between $\pm 15\text{V}$) was applied to the tungsten posts (Figure 1) at a rate of 1V/second to make the *in situ* conductivity measurements. The current readings of each tube were averaged over one hour of heating by the data logger and the resulting conductivity (average current) measurements versus heating time at 175°C (347°F) plots for the different HFC-134a/oil mixtures are shown in Figure 4. Raw data for Figure 4 is listed in Appendix B.

The conductivity measurement versus heating time at 175°C plots in Figure 4 indicate that the HFC-134a/fresh oil mixtures are stable at 175°C (in agreement with literature [3]). After

Figure 4. Plots of Conductivity Measurements (Current in Arbitrary Units) Versus Heating Time at 175°C (347°F) for HFC-134a/Ester Oil Mixtures Heated in Modified Sealed Glass Tubes (Figure 1).

rapid changes in the first ten hours of heating (block reaches 175°C after two hours of heating), the conductivity measurements of the aged HFC-134a/fresh oil mixtures decrease or increase 76 to 312 (arbitrary current units) during the remaining 40 hours of heating at 175°C (347°F). Increases in conductivity measurements indicate that the HFC-134a/oil mixture is undergoing increased degradation. Decreases in conductivity measurements indicate that the concentration of polar species in the HFC-134a/oil mixture is decreasing or that the surfaces of the electrodes are being coated by degradation species or other reactive species present in the HFC-134a/oil mixtures.

In contrast to the unexposed branched acid 1 ester oil, the conductivity of the HFC-134a/exposed branched acid 1 oil mixture (Figure 4) increases dramatically during the first three hours of heating, decreases during the next seven hours of heating, and then increases again during the remaining forty hours of heating at 175°C (347°F). Since the exposed and unexposed oils contain the same water and acid contents [conductivity similar after two hours of heating - tube temperatures at 175°C (347°F)], the large conductivity changes in Figure 4 indicate that the exposed oil is less thermally stable (contains hydroperoxides which are free radical initiators) than the unexposed oil.

To better interpret the relationships between the conductivity changes and the degradation of the HFC-134a/oil mixtures, ASTM color and infrared spectrophotometric analyses of the aged oils were performed and gas chromatographic analyses of the aged HFC-134a were performed. The results of the analytical tests for the aged HFC-134a and oils were compared with those of the fresh fluids to quantitate the degradation of the aged HFC-134a and oils.

The gas chromatograms of the fresh and aged (representative) R-134a are presented in Appendix C and indicate that volatile degradation products of the R-134a are below detection limits (below 0.005 percent) in full agreement with the literature [3]. The infrared spectra of the fresh and aged (representative) oils (also presented in Appendix C) are identical (i.e., differences are smaller than experimental error) indicating that the nonvolatile degradation products are below the detection capabilities of the infrared spectrophotometer (in agreement with literature [3]).

Of the analytical tests performed, only the ASTM color measurements detected degradation products in the aged oils with respect to the fresh oils (Table 1). The increase in color was greatest for the branched acid 1 oil and least for the branched acid 2 oil. For the

branched acid 1 oil, the exposed oil showed greater increases in color during aging than the unexposed oil.

Table 1
Analytical Results for Aged HFC-134a/Oil Mixtures Aged at 175°C (347°F) for 50 Hours

<u>Oil</u>	<u>Fresh Oil Color *</u>	<u>Aged Oil Color *</u>	<u>Infrared Spectrun</u>	<u>Aged R-134a Gas Chromatograph</u>	<u>Conductivity * Change</u>
Branched Acid 1					
Unexposed	< 0.5	0.5 < 1.0	No Change	No Change	+312
Exposed	0.5	3.5	No Change	No Change	-163
Branched Acid 2					
	< 0.5	< 0.5	No Change	No Change	+107
Mixed Acid 2					
	< 0.5	0.5	No Change	No Change	-76

* by ASTM Standard Method D1500

** Change in conductivity (arbitrary current units) between 10 and 50 hours

Comparison of the conductivity versus heating time plots in Figure 4 with the analytical results listed in Table 2 indicate that the conductivity changes that occur after the first ten hours of aging at 175°C (347°F) are related to the degradation evaluations made by the ASTM color measurements. Since the gas chromatographic analyses indicate that the HFC-134a had not undergone degradation, the conductivity increases are most likely related to degradation of the aged oils as detected by the color measurements. The dramatic conductivity changes that occur during the first ten hours of aging are most likely related to the metal surface-refrigerant-oil interactions that occur during the initial heating of the modified sealed tubes (Figure 1).

Consequently, the relationship between degradation evaluation and the conductivity changes for the HFC-134a/ester oil mixtures (Figure 4) are not as straight forward as for the CFC-11, CFC-12, and HCFC-22 mixtures with naphthenic mineral oil (refrigerant and oil degradations occur) [2]. Also, mixed acid 2 ester oil which after the first six hours of heating

continually decreased in conductivity (Figure 4) contained phosphorous (Table 2) indicating additives may affect the direction of the conductivity changes measured for refrigerant/lubricant mixtures. Increasing the heating time to seven days (current test time 14 days for ANSI/ASHRAE Standard 97-1989) and using data reduction techniques (derivative, percent change, etc.) to evaluate the conductivity versus heating time plots are expected to improve the *in situ* degradation determinations of heated HFC refrigerant/ester oil mixtures.

Summary

The initial results reported herein and previously [2] indicate that the *in situ* conductivity measurements have the best potential for development into an accelerated screening method for determining the chemical and thermal stabilities of CFC, HCFC, and HFC refrigerant mixtures with different lubricating oils. The *in situ* color measurement techniques would require square tubes (to reduce light scattering improving light transmission), complicated electronics, and other test modifications to be suitable for development into an accelerated screening method, and consequently, were considered impractical for this study.

REFRIGERANT AND OIL ANALYSES

Prior to performing the final evaluation of the *in situ* conductivity measuring technique for development into an accelerated screening method for different type refrigerant/lubricant mixtures, the oils to be used in the final evaluation study were analyzed for water, acids, additive, and trace metal concentrations. The analytical results are presented in Table 2.

The results in Table 2 indicate that the majority of the oils received from the manufacturers contained water concentrations in excess of 50 ppm (30 ppm allowed in mineral oils and 50 ppm allowed in ester and polyglycol oils). Therefore, the oils were stored in amber bottles over molecular sieves to obtain the required water concentrations. The polyglycol oils were heated under vacuum to obtain the required water concentrations.

All of the oils produced acid numbers below the required 0.05 mg of KOH/g of oil using ASTM Method D974. Some of the oils gave slightly higher acid numbers using ASTM Method D664 (Table 2) which titrates weaker acids than ASTM Method D974.

Table 2
Analytical Results of Oils to be Used in the Evaluation of the Accelerated Screening Test

Oil Sample	Fe ppm	Cu ppm	Dried H ₂ O(ppm)	As Received H ₂ O(ppm)	Acid Numbers mg of KOH/g of oil		Hydro- peroxide ^a	Phosphorus ^b (ppm)
					D974	D664		
Naphthenic:	0.1	<0.1	11	78	<0.01	0.04	No	<0.1
Paraffinic: #1	<0.1	<0.1	14	33	<0.01	0.04	No	<0.1
#2	<0.1	<0.1	23	32	<0.01	<0.01	No	<0.1
Alkylbenzene:	<0.1	<0.1	29	85	<0.01	<0.01	No	<0.1
Polyglycol: #1	0.1	<0.1	42	637	0.04	0.22	Yes	<0.1
#2	0.1	<0.1	36	134	0.04	<0.01	No	903 ^c
Polyolesters: Mixed Acid #1	0.5	<0.1	33	50	0.02	0.04	No	<0.1
Mixed Acid #2	0.1	<0.1	26	95	0.03	0.04	No	407 ^c
Branched Acid #2	0.5	<0.1	38	162	0.01	<0.01	No	<0.1
Branched Acid #1	0.2	<0.1	42	176	0.05	0.30	Yes ^c	<0.1
REQUIREMENT	<1.0	<1.0	<30 ^d , <50 ^e	--	<0.01 ^d , <0.05 ^e	--	--	<0.1

^a Detection limit - 0.5 mmol of hydroperoxide / liter of oil

^b Indicates oil contains antiwear additive

^c Exposed to sunlight for 24 hours

^d Naphthenic, Paraffinic, and Alkylbenzene oils

^e Polyglycol and Polyolester oils

All of the oils contained less than 1 ppm of copper and iron as required. However, two of the oils (polyglycol 2 and mixed acid 2 oils in Table 1) contained high concentrations of phosphorus which is indicative of the antiwear additive, tricresyl phosphate.

In addition to the required tests, the oils were checked for organic hydroperoxide concentrations using ASTM Method 3703 (solvent soluble) and hydroperoxide strips (water soluble). Polyglycol 1 oil as received and mixed acid ester 1 oil after standing in sunlight for 24 hours contained detectable levels of hydroperoxide (Table 2). Vacuum distillation to remove water from the polyglycol oil did not reduce the concentration of hydroperoxides in the polyglycol oil prior to use.

PROPOSED DESIGN OF HEATING BLOCK FOR ACCELERATED TEST

To provide the developed accelerated screening test with variable heating capabilities and to improve operational safety, the modified aluminum block in Figure 5 was designed. The number of wells drilled into the aluminum block are limited only by the number of channels available on the selected data logger. For this study, the block was designed with three wells (Figure 5) to allow duplicate and triplicate aging tests and to minimize the mass to be heated during testing to increase potential heating rates.

To enable the aluminum block to stand alone and perform heating ramps, a heating cartridge (Figure 5) will be inserted into the aluminum block (perpendicular but not intersecting the wells). A programmable temperature controller will be used to control the temperature, isothermal versus ramped (or a combination of heating programs), of the block. Electrical feed throughs and sockets will be placed into the bottoms of the wells to allow the *in situ* conductivity measurements to be performed. A pressurizable top plate will be attached to the heating block to allow the aging tests to be run under pressure (air or nitrogen) minimizing tube explosions at higher temperatures [greater than 200°C (392°F)]. A pressure gauge with a pressure relief valve will also be located in the top plate to monitor the pressurization of the top plate and to ensure pressure is released if extreme pressures occur.

FUTURE WORK

The work to be performed during the next three to six months will be performed in two phases. In the first phase, sealed tubes will be prepared with steel catalysts and mixtures of CFC-12, HCFC-22, HFC-134a, and HFC-32/HFC-134a (zeotrope 30:70) with the oils listed in Table 2

Figure 5. Schematic of Modified Aluminum Block Proposed for Use in Accelerated Screening Method.

as described in ANSI/ASHRAE Method 97-1989 [1]. The sealed tubes will be heated in aluminum blocks in an oven for 14 days at 175°C (347°F) for the CFC-12/oil mixtures and for 28 days at 175°C (347°F) for the HCFC-22, HFC-134a, and HFC-32/HFC-134a refrigerant/oil mixtures. Aging tests will be repeated with higher temperatures of 200°C (392°F) for the refrigerant/oil mixtures stable at 175°C (347°F), i.e., no degradation products detectable by color (mixture), gas chromatographic (gas phase), or trace metal analyses (residue).

In the second phase of work, the modified sealed tubes (Figure 1), with and without steel catalysts present, will be used to perform *in situ* conductivity measurements on mixtures of CFC-12, HCFC-22, HFC-134a, and HFC-32/HFC-134a with the oils listed in Table 2 under various heating conditions, isothermal versus ramped, using the modified aluminum block. Sets of tests will be run under isothermal conditions at 175°C (347°F) to 200°C (392°F) for less than two weeks (ANSI/ASHRAE Method 97-1989 uses two weeks) to evaluate the capabilities of the *in situ* conductivity tests to measure degradation (conductivity increases) of the selected refrigerant/oil mixtures. The oils containing additives in Table 2 will be tested to determine if additives have detrimental effects (e.g., coat wires, reduce conductivity measurements) on the degradation monitoring capabilities of the *in situ* conductivity measuring technique. The degradation detected by the *in situ* conductivity measurements will be verified by conventional tests, e.g., color, gas chromatography, trace metals, etc. Other sets of tests will be performed using ramped temperature conditions from 150°C (302°F) to 250°C (482°F) to evaluate the capabilities of the *in situ* conductivity measurements to detect the onset of rapid degradation.

The chemical and thermal stability rankings of the *in situ* conductivity measurements for aged mixtures using the isothermal and ramped temperature tests (with and without steel catalysts) will be compared to the rankings of the color, gas chromatographic, and trace metal analyses obtained for aged mixtures using the ANSI/ASHRAE Method 97-1989 [1] aging procedures (with steel catalysts). The temperature and catalyst conditions which produce chemical and thermal stability rankings in good agreement with ANSI/ASHRAE Method 97-1989 [1] in less time than ANSI/ASHRAE Method 97-1989 (usually two weeks for CFC-12/oil mixtures and four weeks for HCFC-22, HFC-134a, and HFC-32/HFC-134a/oil mixtures) will be chosen for final development into an accelerated screening method for determining the chemical and thermal stabilities of refrigerant/lubricant mixtures.

References

1. ANSI/ASHRAE Standard 97-1989, "Sealed Glass Tube Method to Test the Chemical Stability of Material for Use Within Refrigerant Systems," ASHRAE, Atlanta, GA (1989).

2. Kauffman, R. E., "Accelerated Screening Methods for Determining Chemical and Thermal Stability of Refrigerant-Lubricant Mixtures, Part II: Experimental Comparison and Verification of Methods," Progress Report No. DOE/CE/23810-20D, Air-Conditioning and Refrigeration Technology Institute, October 1993.
3. Huttenlocher, D. F., "Chemical and Thermal Stability of Refrigerant-Lubricant Mixtures with Metals," Final Report No. DOE/CE/23810-5, Air-Conditioning and Refrigeration Technology Institute, October 1992.

COMPLIANCE WITH AGREEMENT

The University of Dayton Research Institute has complied with all aspects of the agreement.

PRINCIPAL INVESTIGATOR EFFORT

Mr. Robert Kauffman was the principal investigator for Part II of this research effort. Mr. Kauffman devoted 25% of his available work hours on the project.

APPENDIX A

CHEMICALS USED IN THIS STUDY

Oil Samples

Naphthenic: Suniso 3GS
Paraffinic: Sontex 160LT (#1)
 Sontex 200LT (#2)
Alkylbenzene: Zerol 150
Polyglycol: P425 (#1)
 Emkarox RL118D (#2)
Polyesters: Emkarate RL22H (Mixed Acid #1)
 EAL 22A (Mixed Acid #2)
 2928 (Branched Acid #2)
 Icematic SW32 (Branched Acid #1)

Refrigerant Samples

CFC-11 and HFC-134a

Manufacturers

Witco, New York, New York
Penreco, Dickinson, Texas
Penreco, Dickinson, Texas
Shrieve Chemical Products, Woodlands, Texas
Dow Chemical, Midland, Michigan
ICI Americas, Wilmington, Delaware
ICI Americas, Wilmington, Delaware
Mobil Chemical, Fairfax, Virginia
Henkel/Emery, Cincinnati, Ohio
Castrol, Irvine, California

PCR Incorporated, Gainesville, Florida

APPENDIX B

RAW DATA FOR FIGURE 4

Table B-1

Raw Data for Figure 4

- Conducting Measurements

Heating Time (Hours)	Mixed Acid 2	Branched Acid 2	Branched Acid 1 Exposed	Branched Acid 1 Unexposed
1	495.72	337.09	260	114
2	55.315	493.68	816	225
3	110.5	629.36	1249	334
4	178.32	690.89	1134	379
5	197.58	730.05	1004	393
6	200.87	752.56	900	407
7	200.2	773.84	820	415
8	198.66	783.48	773	420
9	195.72	801.22	732	429
10	192.25	814.05	721	431
11	190.69	818.14	710	438
12	186.67	828.36	707	438
13	183.66	840.63	717	439
14	181.25	839.08	723	438
15	179.57	837.27	721	427
16	176.84	843.75	734	420
17	174.77	854.13	746	407
18	171.23	865.61	760	396
19	169.73	866.19	765	379
20	167	867.34	779	367
21	165.18	871.73	799	356
22	162.12	863.16	815	341
23	160	868.98	830	328
24	158.68	881.41	834	314
25	155.7	891.11	843	300
26	153.93	877.22	858	294
27	151.45	900.13	867	281
28	148.73	894.73	889	274
29	147.68	892.44	889	265
30	144.41	913.91	902	259
31	142.99	879.72	909	254
32	142.98	917.14	929	249
33	138.32	889.97	932	247
34	137.42	913.41	949	248
35	136.21	895.33	949	246
36	134.45	909.09	955	245
37	132.93	929.58	957	246
38	131.35	909.66	977	250
39	129.37	908.28	993	250
40	127.78	928.3	971	248
41	126.22	917.27	960	249
42	124.87	911.22	974	251
43	123.13	917.27	982	252
44	121.98	914.13	994	257
45	120.89	931	1014	262
46	118.88	927.52	1025	265
47	117.62	917.22	1024	268
48	116.36	921.61	1033	268

APPENDIX C

REPRESENTATIVE INFRARED SPECTRA AND GAS CHROMATOGRAPHIC RESULTS FOR AGED HFC-134A/OIL MIXTURES

Figure C-1 Infrared Spectra of Fresh (Top Spectrum) and Aged at 175°C (347°F) in Figure 4 (Bottom) Branched Acid 1 Unexposed.

RUN# 213 APR 16, 1982 00:56:07

RT	AREA	TYPE	WIDTH	AREA%
3.023	40183	PH	.102	.05346
3.395	74957696	SBB	.158	99.73043
9.250	162440	PV	.177	.21612

RUN# 187 MAR 7, 1982 02:03:11

RT	AREA	TYPE	WIDTH	AREA%
2.949	10242	PB	.097	.03392
3.325	30139632	SBB	.105	99.80781
9.115	47798	PB	.177	.15828

Figure C-2 Gas Chromatographic Results for Fresh (As Received)
and Aged at 175°C (347°F) in Figure 4 HFC-134a.

DATE

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END