AHRI 8003

Thermal Stability and Chemical Compatibility of R-22 Replacement Refrigerants

Final Technical Report

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ABSTRACT

Five (5) potential R-22 service replacement refrigerant blends (R-417A, R-422D, R-424A, R-434A and R-438A) were tested following ASHRAE 97-2007 in sealed glass tubes in the presence of materials of construction. The five refrigerants were aged in the presence of aluminum, copper and steel coupons with Suniso ISO 32 3GS mineral oil (3GS) and with blended 200 white mineral oil with 2% BTPP (BWMO), after which reacted coupons and oils were subsequently analyzed for chemical and physical changes if corrosion was present. Control tests were performed using R-22 as the refrigerant on all materials evaluated.

In addition to the sealed glass tube testing, the five alternative refrigerants were analyzed with refrigeration system materials of construction using ASTM and UOP exposure methods. The tests were structured to obtain compatibility aging data from like new conditions which simulated introduction of the alternative refrigerants into new, unused systems, as well as from conditions simulating a retrofit of R-22 systems to the alternative refrigerants.

Standard sealed glass tube materials were aged with anhydrous mineral oils for fourteen (14) days and charged with refrigerant at 1:1 weight ratio. Observations were made at three (3), seven (7) and fourteen (14) days. Notable, although outside the scope of this project, is that the R-22 service replacements refrigerant blends are immiscible with the mineral oils at room temperature while R-22 is miscible.

The non-metallic materials of construction used in this project (i.e., elastomers, sealants, plastics) were aged with dried mineral oils (15-20ppm water) and the alternative refrigerants for thirty (30) days to simulate a "like new" compressor condition; parallel tests to simulate the retrofit condition were done by exposure which consisted of thirty (30) days with R-22 followed by the alternative refrigerants for an additional thirty (30) days at 127°C (260°F).

Remarkable material changes found with the R-22 alternative refrigerants are noted herein. This study shows that retrofit with the R-22 alternative refrigerants should require the application of current production 4AXH6 desiccant material (or other equivalent desiccant that is similarly unreactive toward HFC refrigerants) to ensure compatibility. Also shown is that retrofit with the Valox 325 (PBT) was found to be embrittled, whereas nylon 6,6 was found to soften, with all of the alternative refrigerants under experimental conditions. Significant changes were repeatedly shown with PTFE/lead composite bearing material in all of the HFC alternative refrigerants, but less so with R-22 at all sealed tube conditions. All of the negative performance changes occurred within seventy-two (72) hours at glass sealed tube conditions with BWMO, showing the more significant changes in the DU bearing material and the appearance of the aluminum coupons.

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EXECUTIVE SUMMARY

A general, overall statement can be made that material changes for the R-22 alternative refrigerants investigated in this study do not have statistically significant differences compared to R-22 exposure in both time and temperature. Notable, although outside the scope of this project, is the fact the five (5) alternative refrigerant blends are immiscible (1:1 w/w) with the mineral oils at room temperature while R-22 is miscible.

Retrofit with the R-22 alternatives must meet compatibility with new, current production 4AXH6 desiccant material. It doesn't have to be specifically 4AXH6 but there needs to be a filter drier assembly containing desiccant that is unreactive toward HFC refrigerant blends. It will be very important to make sure it will function efficiently with existing R-22 HVAC applications.

This study also evaluated the chemical and thermal stability of engineering plastics. Of note, Valox 325 (PBT) was found to be embrittled with all of the refrigerants under experimental conditions. A time study with Valox 325 found it to embrittle within 15 days of the exposure and definitely embrittled (highly weakened) for the 30 day test used throughout this study.

It was found that the extended 60 day heat aging of the water borne motor varnishes normalized the bond strength of helical coils compared to solvent based varnish. Possibly, motor varnish may inhibit the loss in tensile strength exhibited by the Mylar, Melinex and DMD sheet insulation. There was a trend that BWMO, more than 3GS, reduces tensile and elongation properties for all three insulation materials with less of an observed impact on the DMD.

The R-22 alternative refrigerants had effects of softening nylon and reducing tensile properties of the engineering plastics evaluated. There was little evidence that the alternative refrigerants had a negative effect on rubber elastomers; however, there was measureable softening of PTFE o-rings, more so than when exposed with R-22.

Significant changes were repeatedly shown with PTFE/lead composite bearing material in all of the HFC alternative refrigerants, but less so with R-22 at all sealed tube conditions. All of the negative performance changes occurred within seventy-two (72) hours at glass sealed tube conditions with BWMO, showing the more significant changes in the DU bearing material and the appearance of the aluminum coupons.

1. INTRODUCTION

Implementation under the Clean Air Act of the ban on production and importation of R-22 and manufactured equipment utilizing R-22 intensifies the need to identify alternative refrigerants to retrofit R-22 systems. Many of the R-22 alternative blends contain hydrocarbons to help mineral oil circulate throughout the system (Lavelle, 2009). For long-term reliability of air-conditioning and refrigerating systems, these alternative refrigerants must be compatible with the lubricants and materials of construction in the refrigerant system.

Use of replacement refrigerants in existing R-22 systems that have unknown compatibility with the compressor lubricant, electrical insulation and system construction materials might result in premature failure of the system. This project addresses thermal stability, chemical compatibility and physical compatibility of R-22 system components after retrofit with five non-ozone depleting alternative refrigerants promoted as R-22 replacements.

The five alternative refrigerant blends selected by the Air-Conditioning, Heating and Refrigeration Institute (AHRI) for this project are listed in Table 1with their compositions by weight percentages. Control tests were performed using R-22 as the refrigerant.

Table 1

ASHRAE NUMBER	**R-32**	**R-125**	**R-134a**	**R-143a**	**R-600** n-butane	**R-600a** isobutane	**R-601a** isopentane
R-417A		46.6	50.0		3.4		
R-422D		65.1	31.5			3.4	
R-424A		50.5	47.0		1.0	0.9	0.6
R-434A		63.2	16.0	18.0		2.8	
R-438A	8.5	45.0	44.2		1.7		0.6

The first task of this project was a literature survey conducted in search of information related to the above alternative refrigerants that would impact their use as R-22 replacement refrigerants. Focused interest was on compatibility of these alternative refrigerants with compressor lubricants and typical system construction materials. The results of the search are included as Appendix U.

Each of the alternative refrigerants was used with Suniso 3GS (“3GS”) and with blended white mineral oil with 2% BTPP (“BWMO”) to test compatibility with system materials of construction. The samples were aged and analyzed for chemical and physical changes using ASTM methods drawn from the DOE sponsored Materials Compatibility and Lubricant Research Program ("ARTI MCLR"), UOP procedures and ASHRAE 97.

In addition to thermal compatibility tests with glass sealed tubes simulating "like new" (LN) compressor conditions, parallel tests (PT) were conducted simulating retrofit conditions. In these parallel tests, the materials of construction were first heat-aged in evacuated R-22/lubricant mixes for thirty (30) days, after which the R-22 was released and the cylinders evacuated to approximately 200 to 300 micron. The samples were then recharged with the alternative refrigerants and heat-aged for a second thirty (30) day period. The PT tests provide data that can be compared with the LN data and provide the best confidence level for a service retrofit.

2. MOTOR INSULATION - MAGNET WIRE

18 gauge Class H Essex Ultrashield Plus magnet wire was used to fulfill the stipulated polyester imide overcoated with polyamide imide wire requirement for this project. The wire was tested in three configurations: 1) unvarnished twisted pairs; 2) helical coils varnished with EM59; and 3) helical coils varnished with Elantas 923.

2.1 Unvarnished Twisted Pairs

Twisted pair samples of the magnet wire were created with a twisted pair fabricator in accordance with ASTM D 1676-03. Two types of twisted pairs were created: one type with 8 turns (designated as "A" samples in the appendices) and one with 9 turns (designated as "B" samples in the appendices) under the same tensile loads. Duplicate sets of six unaged pairs were used to determine the control base average dielectric strengths. Stainless steel pressure vessels were used to submerge two sets of six LN samples in each of the refrigerant/lubricant mixes. The samples were then heat aged at 127°C (260°F) under 275-300psig for 30 days. At the end of the 30 day period, the LN samples were removed from the pressure vessels and sent for dielectric testing.

Duplicate sets of six PT samples were submerged in dry R-22/lubricant mixes and heat aged at 127°C (260°F) under 275-300 psig for 30 days. The R-22 was then released and the cylinders evacuated to approximately 200 micron, after which the samples were recharged with the alternative refrigerants. The PT samples were then heat-aged for an additional 30 day period, after which they were removed from the stainless steel pressure vessels and forwarded for dielectric testing.

All after-exposure to refrigerant and lubricant mixtures dielectric testing was performed by the Chemistry and Materials Technology Lab at Ingersoll Rand in La Crosse WI. The reported dielectric strengths for the LN and PT twisted pairs are provided in Appendices A and B.

2.1.2 Twisted Pairs Results and Observations

Dielectric twisted pairs were formed using ASTM D 1676-03 protocol. Dielectric properties improved with heat and refrigerant exposure time. Basically, there is nothing that is remarkable other than the fact that R-22 pre-exposure improved the dielectric breakdown response. The BWMO exposure showed a minor negative response that is well within experimental error.

2.2 Varnished Helical Coil Samples

Following ASTM D 2519-07, the Ultrashield Plus magnet wire was first formed into helical coils. The coils were then preheated to 175°C (347°F) for two hours prior to varnishing, after which they were cooled to approximately 93°C (199°F).

The varnishes were used as received. No attempt was made to adjust solids content as referenced by the supplier. Sets of coil samples were dipped into Elantas EM 59 25MR, batch #1163523, and sets of samples were dipped into Elantas PED 923-35, batch #001165678. They were removed at a rate of 4” per minute and allowed to drip until no further dripping was noticed. The sets were suspended in a forced convection oven to step cure at 100°C (212°F) for two hours, after which they were inverted and heated to 163°C (325°F). The coils were then cooled to approximately 93°C (199°F) and dipped a second time into the respective varnishes. The samples were removed at a rate of 4” per minute and allowed to drip until no further dripping was noticed. The sets of coils were then step cured in an oven for two hours at 100°C (212°F) after which the oven temperature was increased to 163°C (325°F) and the samples were cured an additional ten hours. A set of five (5) cured Elantas EM 59 coil samples and a set of five (5) cured Elantas PED 93-35 coil samples were used as the unexposed controls for testing bond strength.

After curing, the LN coil samples were immersed in the alternative refrigerant/lubricant mixes and heat-aged at 127°C (260°F) under 275-300psig for 30 days. At the end of the aging period, the LN samples were tested for bond strength using an Instron 1122 equipped with a V-block fixture as detailed in ASTM D 2519-07.

After curing, the PT coil samples were immersed in R-22/lubricant mixes and heat-aged at 127°C (260°F) under 275-300psig for 30 days. The R-22 was then released, and the cylinders were evacuated to 200 micron and recharged with the alternative refrigerants. Heat-aging was performed at 127°C (260°F) under 275-300psig for an additional 30 days, after which the PT samples were tested for bond strength using the Instron 1122 and the V-block fixture.

The data results are reported in Appendix C.

2.2.1 Helical Coil Results and Observations

Varnished helical coils results were essentially unremarkable in the LN data. However what is remarkable is that after the sixty (60) day aging in the parallel test, the heat aging normalized the results for both the Elantas EM 59 and the Elantas PED 923, suggesting that heat aging improves the varnish bond regardless of what refrigerant or mineral oil lubricant is used. More research work is needed to clarify if extended heat aging before refrigerant exposure provides improvement.

3. POLYESTER FILM GROUND AND PHASE INSULATION

3.1 Test Materials and Methods

Following ARTI MCLR and ASTM D 6287-09, Melinex 228, Mylar 10 and DMD samples were cut using a rotary cutter into 0.5” x 6” test specimens. Prior to aging, all of the plastic strips were heat-aged for four hours at 125°C (257°F) to remove water.

LN specimens were submersed in refrigerant/lubricant mixes and heat-aged at 127°C (260°F) under 275-300psig for thirty (30) days. At the end of the aging period, they were checked against unaged control samples for elongation and tensile per ASTM D 882-09 using an Instron tensile tester, Model 1122, equipped with flat faced serrated pneumatic grips.

PT specimens were submersed in dry R-22/lubricant mix and heat-aged for thirty (30) days, after which the R-22 was released and the cylinders evacuated to approximately 200 micron and recharged with the alternative refrigerants. Heat aging was performed for an additional thirty (30) days at 127°C (260°F) under 275-300psig, after which the samples were also tested for tensile and elongation.

The data results are reported in Appendices D1 to E2.

3.2 Results and Observations

Mylar, Melinex and Dacron/Mylar/Dacron (DMD) are excellent insulation materials used with or without motor varnish in hermetic motor construction. All three products are polyester film products that have a wide operating temperature range of -70°C to 150°C (-94°F to 302°F) in ambient air motors.

Hermetic use motors are subjected to an oil/refrigerant environment that is susceptible to hydrolysis at elevated temperatures when water is present. Therefore, after being rotary cut, the insulation materials were conditioned for 4 hours at 125°C (257°F) before being placed into the refrigerant/lubricant mixes. It is reported that Mylar can be heated to 160°C (320°F) for four (4) hours to remove water. The 125°C (257°F) temperature was chosen since motors are not normally heated to 160°C (320°F) prior to varnishing. In an assembled compressor, dehydration rarely removes sufficient water to make the insulation materials drier than if exposed to 125°C (257°F) or 160°C (320°F). During motor manufacture, dehydration of the sheet insulation material may occur if the motor was preheated prior to varnishing.

The alternative refrigerants in the LN aging conditions yielded no significant evidence of producing lesser physical qualities, but DMD due to its fibrous nature did adsorb more weight. There is a trend that BWMO, more than 3GS, reduces tensile and elongation properties for all three insulation materials with less of an observed impact on the DMD. We need to keep in mind that BWMO does contain a butylated triphenyl phosphate ester as the wear additive.

After the PT extended aging of sixty (60) days, all of the sheet insulation gained more weight and yielded test strips that were highly brittle. Appendix E2 shows the number of samples that were brittle failures. On the other hand, the DMD yielded physical properties of survival with no trend toward any specific lubricant or refrigerant type.

Aging times of 30 and 60 days is a unique aspect of this report. Typically materials are aged for 14 to 20 days at specific conditions, but practically materials are in hermetic systems for years. The 30 day aging conditions were to get close to typical performance issues. The 60 day aging physical property behavior confirms reported data in Mylar Product Information of extended heating in air at 150°C. The data in Appendix D2, which was from the 30 day aging, also follows the temperature physical property trend reported. The physical properties for the 30 and 60 day aging tests are consistent. The resulting loss of physical properties is anticipated. (DuPont, 2003).

Like with the polyester linkage in Valox and the polyamide linkage in Nylon 6,6 (see 7. Engineered Plastics), the PT extended aging temperature seems excessive. For Mylar and Melinex, the aging temperature is below the service temperature of the polyester film. (Sepe, 2007). Conditioning at 160°C (320°F) should be explored with oils that are below 5ppm moisture with aging for the same time period. However, sheet insulation is generally used in a retained fashion and at motor service temperatures that are lower.

4. SEALS – O-RINGS

4.1 Test Materials and Methods

In accordance with ASTM D 1414-94 and ASTM D 2240-05, physical measurements were taken and Shore A hardness determined of standard size 1”OD x 0.125” PTFE O-rings, along with neoprene C0873-70 and Viton V-0747 Parker O-rings. Five control samples of each of the three types of O-rings were heat aged in nitrogen only.

LN test samples of each type O-ring were submerged in dry refrigerant/lubricant mixes and heat-aged in stainless steel pressure vessels at 127°C (260°F) under 275-300 psig for 30 days. At the end of the 30 day aging period, the LN samples were removed from the vessels and tested for elongation, tensile and physical dimensional changes.

PT test samples of each type O-ring were submerged in dry R-22/lubricant mixes and heat-aged in stainless steel vessels at 127°C (260°F) under 275-300 psig for 30 days. After the 30 day aging period was completed, the R-22 was released and the cylinders were evacuated to approximately 200 micron, charged with the alternative refrigerants and the samples were then heat-aged under the same conditions for an additional 30 days before being tested.

Elongation and tensile strength of all samples were determined following ASTM D 1414-94 and are reported with the after aging physical change data in Appendices F and G.

4.2 Results and Observations

After examining all of the exposure responses of the oils and refrigerants, there are very little remarkable concerns for the LN exposure with the CO 873-70 neoprene O-rings. However, there is definitely a trend that shows which O-ring material performs better than the others as a material group. The 3GS lubricant seems to promote good flexibility whereas the BWMO seems to embrittle the rubber with increased tensile. This trend follows through all refrigerants except for R-438A, wherein the lack of change is within experimental error.

The Viton (V0747) O-ring results are equally as unremarkable as the neoprene data but trends toward an increased loss of tensile without a significant change in elongation when exposed to BWMO. This is probably due to the wear additive (BTPP).

The PTFE O-ring data is clearly unremarkable in response to refrigerant exposures under LN conditions and are within experimental error.

The PT evaluation of elastomers for sixty (60) days at accelerated conditions of temperature and pressure with R-22 and the alternative refrigerants gave the same trend as with the LN exposure. Therefore, little remarkable response is noteworthy other than the BWMO promoted embrittlement. Both neoprene and Viton still maintain their seal worthiness. The PTFE O-rings did show significant softening, but displayed better elongation and tensile over the rubber counterparts.

5. 4AXH6 DESICCANT

5.1 Test Materials and Method

Freshly obtained current (2010) production 4AXH6 desiccant beads, 4x8 mesh, were acquired from UOP for this evaluation. Compatibility aging evaluations were done on samples consisting of: a) 100g of desiccant as received of 100% 4AXH6 desiccant; and b) 100g made up of 75% 4AXH6 desiccant as received and 25% activated alumina(AN/V 801), weight/weight %. Fresh and dry samples were exposed to the alternative refrigerant/lubricant mixes (95%/5% w/w) in dried 316 stainless steel cylinders for accelerated aging at 180°F for a period of 14 days.

The stainless steel reaction cylinder had 2” ID and 500ml volume. With 100g of each desiccant, the volume of 140g liquid refrigerant covered all of the desiccant bead volume in the cylinder. After exposure, the desiccant was removed from the test cylinders and allowed to hydrate from atmospheric moisture to constant weight. An aliquot of 10g desiccant was finely ground using a porcelain mortar and pestle and stored in vials for analysis by following UOP Test Method 3662 to liberate fluoride and chloride into water distillate. The alumina was separated from the desiccant beads using a VWR Scientific sieve number 14 and was analyzed as is. The test data is reported in Appendix H.

5.2 Results and Observations

The pyrohydrolytic analyses were calibrated with NBS (National Bureau of Standards) standard 120c phosphate rock (Florida) and found to yield the correct amount of fluoride ion determined by liquid ion chromatography. R-22 refrigerant control was the only HCFC that yielded detectable amounts of both fluoride and chloride ion on the new, current production 4AXH6 desiccant.

R-22 alternatives were essentially nonreactive and, therefore, are deemed compatible with the exceptions of R-422D and R-424D, which had trace reactivity with the desiccant/alumina combination, whereas R-438A had trace reactivity with all combinations of desiccant.

Please be mindful the desiccant used in this study does not reflect the potential reactivity of old desiccant that has not been modified to prevent breakdown of new alternative HFC refrigerants. When recharging old equipment, it is anticipated that a new filter drier will be recommended. Therefore, the data in this report for desiccant compatibility is only from current 4AXH6 production.

Although ambient air hydration of the used desiccants was about 15 to 16% water weight gain, we have no idea how this new material stacks up for liquid refrigerant dehydration.

TAN analysis of the lubricants as received is reported in Appendix H but after aging TAN analysis was not possible due to the total adsorption of the oils by the desiccant.

6. ANAEROBIC THREAD LOCKERS

6.1 Test Materials and Methods

Following the procedure developed for Loctite, 5/16” x 18 threaded steel nut and bolt assemblies were washed with solvent, followed by water. They were then washed with a phosphoric acid solution (Prep & Etch) for thirty minutes, rinsed with water and heat dried. The assemblies were then hand-coated with Loctite 620 and with Loctite 272 to fill the thread, after which the coated threads were run into the nuts so the threads were fully coated with anaerobic material. The parts were allowed to react and crosslink at room temperature and were then heat-treated at 60°C (140°F) for two hours. Enough assemblies were made to accommodate both the LN and PT aging.

The LN assembled parts were submerged in the alternative refrigerant/lubricant mixes and heat-aged for 30 days at 127°C (260°F) under 275-300 psig. At the end of the thirty (30) day period, the LN parts were tested for breaking and prevailing torque.

The PT assembled parts were submerged in R-22/lubricant mixes and heat aged for 30 days at 127°C (260°F) under 275-300 psig. The R-22 was then released and the sample cylinders were evacuated to approximately 200 micron and recharged with the alternative refrigerants, followed by heat aging for an additional thirty (30) days at 127°C (260°F) under 275-300psig. Upon completion of the second thirty (30) day aging period, the PT parts were tested for breaking and prevailing torque.

Control assemblies were heat-aged in nitrogen without lubricant. Comparison was made between the breaking torque followed by one revolution (prevailing) of the aged assemblies and the breaking torque followed by one revolution as recorded for the control assemblies. The torque wrench used was a calibrated CDI 2502 LDIN dial wrench. Only one finger was used to pull the wrench due to the low torque requirements.

The experimental data for the LN and PT assemblies are reported in Appendix I.

6.2 Results and Observations

The nut and bolt assemblies were unaffected by the refrigerant/lubricant mixtures. The resultant torque values, when compared to R-22 results were not remarkably different. No one single refrigerant was substantially worse than the R-22 control values.

7. ENGINEERING PLASTICS

7.1 Test Materials and Methods

LN modified ASTM type 5 tensile bars of polyaryletheretherketone (PEEK), Nylon 6/6 polyamide and poly(butylene-terephthalate) (PBT) were heat aged in refrigerant/lubricant mixes at 127°C (260°F) under 275-300psig for thirty (30) days. At the conclusion of the aging period, the samples were tested for elongation and tensile in accordance with ASTM D638-08 using an Instron tensile tester, Model 1122, equipped with pneumatic grips.

PT samples were heat aged in R-22/lubricant at 127°C (260°F) under 275-300psig for thirty (30) days. At the end of this aging period, the R-22 was released and the vessels were evacuated to approximately 200 micron and recharged with the alternative refrigerants, after which they were aged for an additional 30 days under 275-300psig at 127°C (260°F). Following this additional aging, the samples were tested for elongation and tensile following ASTM 638-08 using an Instron tensile tester, Model 1122.

The experimental data for both the LN and PT samples are reported with the after aging physical change data in Appendices J and K.

7.2 Results and Observations

Aging times of 30 and 60 days is a unique aspect of this report. Typically materials are aged for 14 days at specific conditions, but practically materials are in hermetic systems for years. The 30 day aging conditions were to get close to typical performance issues.

When evaluating the elevated temperature conditions, the glass transition temperature (Tg) of each plastic becomes an important property to keep in mind when analyzing the outcome of long term thermal conditions. Valox 325 is a PBT polyester semi-crystalline material that displayed a room temperature tensile of 9.7 kpsi and 404% elongation. With heat aging, its crystallinity improves brittleness and produces a reduction in elongation and tensile. When aging is extended to sixty (60) days in the presence of refrigerants and oils, there are dramatic failures of the Valox test samples for both the R-22 baseline and the alternative refrigerants.

Further evaluation of Valox 325 in a time and temperature study was conducted for this research to verify the tensile bar failure mode. Samples of 3GS and BWMO as received were used along with samples of the lubricants that were degassed to extract out the potential influences of water. Valox samples were then aged with R-22 and the lubricant samples to determine the amount of time required to cause the brittle failure mode. The results are seen in Appendix L. The aging was conducted for seven (7), fifteen (15) and thirty (30) days. Brittleness was clear and evident to occur at or before fifteen days, and was definite by thirty days. The influence of water is not seen. Hence, we find Valox 325 has notable failure performance that after sixty days of aging, the internal stress and crystalline process confirms the embrittlement failure mode. (Sepe, 2007).

Nylon 6,6 is also a semi-crystalline polyamide material with a reported Tg of at least 65°C (149°F), which is substantially lower than our aging temperatures in this study and the Tg where the amorphous region of the plastic becomes mobile. Nylon has strength due to internal hydrogen bonding by water. Therefore, when the amorphous region is altered and there is water loss, the tensile bar should embrittle. The positive result is that none of the alternative refrigerants yielded lesser physical properties than R-22 on the LN 30 day aging evaluation. Although the tensile property was less, embrittlement is a very negative property for any polymer. However, the nylon shows better elongation and lower tensile, suggesting that the nylon became more flexible due to the softening by the highly fluorinated refrigerants under both aging conditions. When evaluated for the 60 day PT aging, there was a remarkable trend to reduced physical tensile properties with the alternative refrigerants, but still with acceptable tolerance when compared to R-22 results.

8. GLASS SEALED TUBES

8.1 Test Materials and Methods

Standard ASHRAE 97 glass sealed tube protocol was followed for aging the refrigerant/lubricant mixtures. The glass sealed tubes were made to be oxygen free and were analyzed under a 25 micron equilibrium pressure condition at approximately 60°C (140°F) for 35-40 minutes with agitation.

The alloys in this project were tested in sealed tube reactions with standard metal coupons of copper CDA 120, valve steel Sandvick 100 and aluminum AA1100, in either wire or strip form. The metal coupons were cleaned in acetone, followed by hexane, and allowed to air dry. The DU bearing material was only washed with hexane. After filling the tubes with a 1:1 lubricant/refrigerant weight/weight ratio, the glass sealed tubes were sealed under 35 micron vacuum and aged for 14 days at 175°C (347°F). Visual observations were made at 3, 7 and 14 days, finalized with digital photographs and is reported in Appendices M through R.

The analytical procedure for the glass sealed tubes that displayed corrosion employed an all glass pressure apparatus to remove the refrigerant, oil and metal coupons from the glass sealed tubes to avoid any possibility of metal contamination. The TAN values of the oils were determined, following ASTM D 974-07. Absorption spectroscopy was performed using a Varian atomic absorption spectrometer, Model Spectra AA 220FS, to determine, copper, iron, lead and aluminum content by normal methods using either air/acetylene or nitrous oxide/acetylene for aluminum (Burrows, et. al., 1965)(Skujins, S., 1970)(Yawar, Y., 2010). The metals solution was formed by washing the glass pressure apparatus, the glass sealed tube, metal coupons with a 60:40 mixture of methylisobutylketone (MIBK) and ethanol into a 100 ml volumetric flask. The sample was then analyzed using the Spectra AA 220FS. The glass sealed tubes that showed any kind of corrosion after the fourteen day aging period were analyzed by gas chromatograph for refrigerant decomposition, TAN values and by atomic absorption spectrometry (AA) for metal content. The TAN and AA data is reported in Appendix S.

8.2 Results and Observations

For the most part, the R-22 alternative refrigerants yielded essentially no corrosive or particulate formation of any kind with the exceptions noted. The most significant observation was a consistent decay of the DU bearing surface and dissolution of the PTFE/lead bearing matrix. After three days of aging, the glass sealed tube became cloudy with a precipitate in all of the HFC containing refrigerants, unlike the tubes with R-22 which remained clear in both 3GS and BWMO even at fourteen days at 175°C (347°F).

Since HFC refrigerants are very much alike the physical properties of PTFE are reduced, which is consistent with the visual observations seen in the glass sealed tubes. Gas chromatography of the glass sealed tube reaction gas shows essentially no reaction of the refrigerants over the contents of the refrigerants as received (see Appendix T).

With R-22, two metals, brass UNC 26000 and UNS 37700, gave a corrosive indication of tarnish (dulling) of the metal surfaces only in BWMO. The metal analysis is seen in Appendix S.

Reported are results of the DU bearing material response to a highly fluorinated solvent system exposed to 175°C (347°F). Everything observed in this study clearly suggests the aging temperature was too high for the fluorinated chemistry. References show that interhalogenated compounds reduce the operating temperature of pure Teflon® to 204°C (399°F). Considering that, the PTFE/lead matrix squeezed onto the bearing surface may possibly operate at a lower temperature closer to the glass sealed tube temperature of 175°C (347°F).

With this in mind, it is possible the DU bearing was incorrectly evaluated. The exposure temperature should probably be made lower, possibly 150°C (302°F) with a twenty-eight (28) day exposure to properly evaluate 20+year life expectancy with the alternative refrigerants present. DU bearings have been used for 20+ years in the HVAC industry with various refrigerants and oils (R-22 and BWMO and 3GS or HFCs with POEs) at less than 175°C without a chemical or thermal degradation problem in operating equipment.

The most striking evidence of consistent incompatibility is the swelling and dissolution of the PTFE/lead matrices with purely HFC refrigerants. Since the metal analysis and observations, the R-22 evaluation shows the PTFE matrix stays more intact whereas the PTFE/lead matrix dissolves without significant acid formation, an indicator of a non-ionic and strictly polar fluorine solvent function. The observation occurred within three days at 175°C (347°F). This same effect would be evident with the same result if a system operated continuously for 1536 days at 85°C (185°F).

All of the gases removed from the glass sealed tubes containing the DU bearing materials had additional trace gases that remain unidentified at this time and require further study.

Using Appendix S as our reference point, tubes associated with the BWMO all showed an increased acid number with increased lead in solution. Glass sealed tubes made with only BWMO and no HFC refrigerant demonstrated to a lesser degree the same PTFE dissolution effect. The evidence does indeed show that together with HFC refrigerants and BWMO, there is a predominant dissolution effect of the PTFE/lead matrix compared with the HCFC R-22.

9. SUMMARY OF SIGNIFICANT RESULTS

All of the aging temperatures were above the critical liquid temperatures of the refrigerants. The effects observed are, therefore, due to temperature and gas interactions and not the liquid refrigerant, albeit the samples were in liquid hot oil saturated with refrigerant gas.

With the BWMO, there is the added concern of BTPP additive, while not part of this work project, which is known to have variable difficulties with plastics and elastomers. This study was done to evaluate the bulk properties of materials used in hermetic compressor construction that can date back to the 1990's or farther. The current BWMO is not the same material as the material used then. The original BWMO was formulated with an acid treated, dry filtered naphthenic oil with a low pour point and adequate R-22 miscibility, whereas the current BWMO has a high pour point and less than adequate miscibility.

Also, due to current oil production, the BWMO is somewhat more polar and less compatible with the BTPP additive but remains adequate in production compressors. Consequently, R-22 use is acceptable, there are immiscibility and gas solubility consequences which cause the interaction of HFC refrigerants to act primarily like gases rather than in a refrigerant/oil solution. The refrigerants containing R-32 along with other HFC's will have substantially negative effects compared to those that do not contain R-32.

A general, overall statement can be made that the R-22 alternative refrigerants investigated in this study are marginally compatible with existing R-22 HVAC units working in the field. Notable, although outside the scope of this project, is the fact the five (5) alternative refrigerant blends are immiscible (1:1 w/w) with the mineral oils at room temperature while R-22 is miscible.

Retrofit with the R-22 alternatives must meet compatibility with new, current production 4AXH6 desiccant material. It doesn't have to be specifically 4AXH6 but there needs to be a filter drier assembly containing desiccant that is unreactive toward HFC refrigerant blends. It will be very important to make sure it will function efficiently with existing R-22 HVAC applications.

This study also evaluated the chemical and thermal stability of engineering plastics. Of note, Valox 325 (PBT) was found to be embrittled with all of the refrigerants under experimental conditions. A time study with Valox 325 found it to embrittle within 15 days of the exposure and definitely embrittled (highly weakened) for the 30 day test used throughout this study.

Unvarnished magnet wire aged with the R-22 alternative refrigerants and the lubricants were found completely compatible with no negative effects on its dielectric properties.

It was found that the extended 60 day heat aging of the water borne motor varnishes normalized the bond strength of helical coils compared to solvent based varnish. Possibly, motor varnish may inhibit the loss in tensile strength exhibited by the Mylar, Melinex and DMD sheet insulation. There was a trend that BWMO, more than 3GS, reduces tensile and elongation properties for all three insulation materials with less of an observed impact on the DMD.

The R-22 alternative refrigerants had effects of softening nylon and reducing tensile properties of the engineering plastics evaluated. There was little evidence that the alternative refrigerants had a negative effect on rubber elastomers; however, there was measureable softening of PTFE o-rings, more so than when exposed with R-22.

Significant changes were repeatedly shown with PTFE/lead composite bearing material in all of the HFC alternative refrigerants, but less so with R-22 at all sealed tube conditions. All of the negative performance changes occurred within seventy-two (72) hours at glass sealed tube conditions with BWMO, showing the more significant changes in the DU bearing material and the appearance of the aluminum coupons. The glass sealed tube observations were consistent with results from this study that demonstrated softening of the PTFE o-ring materials, which is similar to the PTFE used in the bonded DU bearing and the release of lead metal.

REFERENCES

ASTM Standards:

D638-08, *Standard Test Method for Tensile Properties of Plastics*

D882-09, *Standard Test Method for Tensile Properties of Thin Plastic Sheeting*

D974-07, *Standard Test Method for Acid and Base Number by Color-Indicator Titration*

D1414-94 (Reapproved 2008), *Standard Test Method for Rubber O-Rings*

D1676-03, *Standard Test Methods for Film-Insulated Magnet Wire*

D2240-05, *Standard Test Method for Rubber Property – Durometer Hardness*

D2519-07, *Standard Test Method for Bond Strength of Electrical Insulating Varnishes by the Helical Coil Test*

D6287-09, *Standard Practice for Cutting Film and Sheeting Test Specimens*

ARTI MCLR Project Reports:

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DOE/CE/23810-54, *Sealed Tube Comparisons of the Compatibility of Desiccants with Refrigerants and Lubricants.*

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LIST OF ACRONYMS
(as used in this report)

3GS	Suniso ISO 32 3GS mineral oil
AA	Atomic Absorption Spectrometry
AHRI	Air-Conditioning Heating and Refrigeration Institute
ASTM	ASTM International (formerly American Society for Testing and Materials)
BTPP	(tert-Butylimino)tris(pyrrolidino)phosphorane
BWMO	blended 200 white mineral oil with 2% BTPP
DMD	Dacron/Mylar/Dacron
GC	Gas Chromatography
LN	“Like New” 30 day test conditions
PT	Parallel 60 day test conditions simulating retrofit
PTFE	Teflon® polytetrafluoroethylene
UOP	A Honeywell Specialty Materials Company

APPENDICES

Appendix A Like New (LN) 30 Day Aged Twisted Pairs Dielectric Strength

Appendix B Parallel (PT) R-22/Alternative Refrigerant 60 Day Aged Twisted Pairs Dielectric Strength

Appendix C Bond Strength Varnish Coated Magnet Wire

Appendix D1 Like New (LN) 30 Day Aged Sheet Insulation % Change in Weight

Appendix D2 Like New (LN) 30 Day Aged Sheet Insulation % Elongation and Tensile

Appendix E1 Parallel (PT) R-22/Alternative Refrigerant 60 Day Aged Sheet Insulation % Change in Weight

Appendix E2 Parallel (PT) R-22/Alternative Refrigerant 60 Day Aged Sheet Insulation % Elongation and Tensile

Appendix F Like New (LN) 30 Day Aged Elastomer Seal Materials

Appendix G Parallel (PT) R-22/Alternative Refrigerant 60 Day Aged Elastomer Seal Materials

Appendix H Pyrohydrolytic Testing of 4AXH6 Desiccant Aged 14 Days at 180°F

Appendix I Aged Thread Locker and Sealants

Appendix J Like New (LN) Tensile Properties 30 Day Aged Engineering Plastics

Appendix K Parallel (PT) R-22/Alternative Refrigerant Tensile Properties of 60 Day Aged Engineering Plastics

Appendix L Valox 7, 15 and 30 Day Aging with R-22

Appendix M R-22 Thermal Stability Tube Observations

Appendix N R-417A Thermal Stability Tube Observations

Appendix O R-422D Thermal Stability Tube Observations

Appendix P R-424A Thermal Stability Tube Observations

Appendix Q R-434A Thermal Stability Tube Observations

Appendix R R-438A Thermal Stability Tube Observations

Appendix S Atomic Absorption Spectroscopy and TAN Results of Glass Sealed Tubes Displaying Corrosion

Appendix T Gas Chromatographic Area Counts of Refrigerants After Glass Sealed Tube Aging of DU Bearing Material at 175° for 14 Days

Appendix U Literature Survey

APPENDIX A

Like New (LN) 30 Day Aged Twisted Pairs Dielectric Strength

Sample ID	Visual Obs	Dielectric Strength Base Avg (kV)	Dielectric Strength Aged (kV)	Dielectric Strength ± % Change	Sample ID	Visual Obs	Dielectric Strength Base Avg (kV)	Dielectric Strength Aged (kV)	Dielectric Strength ± % Change	Sample ID	Visual Obs	Dielectric Strength Base Avg (kV)	Dielectric Strength Aged (kV)	Dielectric Strength ± % Change	Sample ID	Visual Obs	Dielectric Strength Base Avg (kV)	Dielectric Strength Aged (kV)	Dielectric Strength ± % Change
	Control R-22 3GS - #1A					Control R-22 3GS - #1B					Control R-22 BWMO 2% BTPP - #2A					Control R-22 BWMO 2% BTPP - #2B			
1	No Change	9.45	8.99	6.4%	1	No Change	9.59	8.87	-0.6%	1	No Change	9.45	9.61	4.7%	1	No Change	9.59	9.11	0.4%
2		9.45	11.14		2		9.59	10.51		2		9.45	11.13		2		9.59	9.81	
3		9.45	8.03		3		9.59	9.73		3		9.45	10.22		3		9.59	9.1	
4		9.45	10.98		4		9.59	9.31		4		9.45	8.5		4		9.59	9.24	
5		9.45	11.15		5		9.59	8.6		5		9.45	11.3		5		9.59	10.89	
6		9.45	lost		6		9.59	10.16		6		9.45	8.58		6		9.59	9.62	
	R-417A 3GS - #3A					R-417A 3GS - #3B					R-417A BWMO 2% BTPP - #4A					R-417A BWMO 2% BTPP - #4B			
1	No Change	9.45	10.71	-1.9%	1	No Change	9.59	9.17	4.1%	1	No Change	9.45	12.1	7.6%	1	No Change	9.59	9.75	-0.1%
2		9.45	7.94		2		9.59	9.64		2		9.45	6.69		2		9.59	10.07	
3		9.45	9.42		3		9.59	10.26		3		9.45	11.95		3		9.59	9.21	
4		9.45	8.58		4		9.59	10.41		4		9.45	11.01		4		9.59	8.18	
5		9.45	8.08		5		9.59	10.89		5		9.45	8.65		5		9.59	9.55	
6		9.45	10.87		6		9.59	9.52		6		9.45	10.61		6		9.59	10.71	
	R-422D 3GS - #5A					R-422D 3GS - #5B					R-422D BWMO 2% BTPP - #6A					R-422D BWMO 2% BTPP - #6B			
1	No Change	9.45	10.09	11.5%	1	No Change	9.59	9.18	4.5%	1	No Change	9.45	9.5	5.9%	1	No Change	9.59	10.14	12.1%
2		9.45	11.49		2		9.59	7.73		2		9.45	10.89		2		9.59	11.09	
3		9.45	10.69		3		9.59	11.33		3		9.45	11.25		3		9.59	10.66	
4		9.45	9.42		4		9.59	11.73		4		9.45	10.24		4		9.59	11.26	
5		9.45	10.51		5		9.59	9.46		5		9.45	11.56		5		9.59	11.05	
6		9.45	11.04		6		9.59	10.68		6		9.45	6.6		6		9.59	10.31	
	R-424A 3GS - #7A					R-424A 3GS - #7B					R-424A BWMO 2% BTPP - #8A					R-424A BWMO 2% BTPP - #8B			
1	No Change	9.45	10.73	13.1%	1	No Change	9.59	10.52	4.9%	1	No Change	9.45	9.17	7.8%	1	No Change	9.59	lost	-3.6%
2		9.45	8.34		2		9.59	9.54		2		9.45	11.11		2		9.59	8.33	
3		9.45	10.78		3		9.59	9.55		3		9.45	11.53		3		9.59	10.58	
4		9.45	11.03		4		9.59	10.09		4		9.45	8.31		4		9.59	10.51	
5		9.45	12.37		5		9.59	10.73		5		9.45	9.95		5		9.59	7.66	
6		9.45	10.88		6		9.59	9.91		6		9.45	11.06		6		9.59	9.15	
	R-434A 3GS - #9A					R-434A 3GS - #9B					R-434A BWMO 2% BTPP - #10A					R-434A BWMO 2% BTPP - #10B			
1	No Change	9.45	8.46	-0.4%	1	No Change	9.59	10.19	6.0%	1	No Change	9.45	10.64	11.9%	1	No Change	9.59	8.98	2.3%
2		9.45	9.58		2		9.59	9.73		2		9.45	9.91		2		9.59	9.63	
3		9.45	10.71		3		9.59	10.09		3		9.45	11.54		3		9.59	10.44	
4		9.45	6.69		4		9.59	9.83		4		9.45	9.56		4		9.59	11.38	
5		9.45	9.65		5		9.59	10.11		5		9.45	10.21		5		9.59	7.17	
6		9.45	11.39		6		9.59	11.07		6		9.45	11.61		6		9.59	11.27	
	R-438A 3GS - #11A					R-438A 3GS - #11B					R-438A BWMO 2% BTPP - #12A					R-438A BWMO 2% BTPP - #12B			
1	No Change	9.45	7.96	6.1%	1	No Change	9.59	11.52	10.6%	1	No Change	9.45	8.36	-4.6%	1	No Change	9.59	9.53	3.4%
2		9.45	11.37		2		9.59	10.43		2		9.45	7.26		2		9.59	10.11	
3		9.45	10.7		3		9.59	11.06		3		9.45	11.06		3		9.59	10.22	
4		9.45	9.25		4		9.59	10.53		4		9.45	7.31		4		9.59	7.07	
5		9.45	10.85		5		9.59	9.37		5		9.45	10.56		5		9.59	11.2	
6		9.45	lost		6		9.59	10.73		6		9.45	9.55		6		9.59	11.39	

APPENDIX B

Parallel (PT) R-22/Alternative Refrigerant 60 Day Aged Twisted Pairs Dieletric Strength

Sample ID	Control R-22 3GS - #1A				Sample ID	Control R-22 3GS - #1B				Sample ID	Control R-22 BWMO 2% BTPP - #2A				Sample ID	Control R-22 BWMO 2% BTPP - #2B			
	Visual Obs	Dielectric Strength				Visual Obs	Dielectric Strength				Visual Obs	Dielectric Strength				Visual Obs	Dielectric Strength		
		Base Avg (kV)	Aged (kV)	± % Change			Base Avg (kV)	Aged (kV)	± % Change			Base Avg (kV)	Aged (kV)	± % Change			Base Avg (kV)	Aged (kV)	± % Change
1		9.45	9.36		1		9.59	9.26		1		9.45	8.79		1		9.59	11.73	
2		9.45	11.84		2		9.59	9.16		2		9.45	7.84		2		9.59	8.86	
3	No Change	9.45	11.59	14.2%	3	No Change	9.59	10.73	-0.2%	3	No Change	9.45	11.23	10.4%	3	No Change	9.59	9.05	5.6%
4		9.45	10.06		4		9.59	9.34		4		9.45	11.31		4		9.59	10.13	
5		9.45	10.99		5		9.59	8.98		5		9.45	11.41		5		9.59	11.35	
6		9.45	10.9		6		9.59	9.94		6		9.45	12.01		6		9.59	9.67	
	R-417A 3GS - #3A					R-417A 3GS - #3B					R-417A BWMO 2% BTPP - #4A					R-417A BWMO 2% BTPP - #4B			
1		9.45	12.26		1		9.59	10.04		1		9.45	11.01		1		9.59	10.24	
2		9.45	12.4		2		9.59	11.14		2		9.45	10.21		2		9.59	11.04	
3	No Change	9.45	11.86	24.4%	3	No Change	9.59	10.86	10.9%	3	No Change	9.45	11.64	17.2%	3	No Change	9.59	10.43	10.7%
4		9.45	11.91		4		9.59	11.24		4		9.45	11.89		4		9.59	9.94	
5		9.45	11.75		5		9.59	10.9		5		9.45	10.82		5		9.59	11.19	
6		9.45	10.34		6		9.59	9.64		6		9.45	10.87		6		9.59	10.86	
	R-422D 3GS - #5A					R-422D 3GS - #5B					R-422D BWMO 2% BTPP - #6A					R-422D BWMO 2% BTPP - #6B			
1		9.45	11.91		1		9.59	11.59		1		9.45	11.51		1		9.59	9.68	
2		9.45	10.56		2		9.59	8.6		2		9.45	11.62		2		9.59	9.73	
3	No Change	9.45	11.21	12.7%	3	No Change	9.59	8.74	4.7%	3	No Change	9.45	11.04	19.2%	3	No Change	9.59	10.91	1.5%
4		9.45	12.17		4		9.59	10.38		4		9.45	11.81		4		9.59	10.7	
5		9.45	7.11		5		9.59	10.24		5		9.45	10.09		5		9.59	7.15	
6		9.45	10.96		6		9.59	10.72		6		9.45	11.54		6		9.59	10.25	
	R-424A 3GS - #7A					R-424A 3GS - #7B					R-424A BWMO 2% BTPP - #8A					R-424A BWMO 2% BTPP - #8B			
1		9.45	11.35		1		9.59	10.84		1		9.45	11.84		1		9.59	10.71	
2		9.45	12.07		2		9.59	10.88		2		9.45	8.36		2		9.59	11.19	
3	No Change	9.45	8.3	9.8%	3	No Change	9.59	11.31	12.7%	3	No Change	9.45	12.64	13.6%	3	No Change	9.59	10.57	9.2%
4		9.45	7.84		4		9.59	11.27		4		9.45	11.8		4		9.59	9.79	
5		9.45	12.68		5		9.59	10.39		5		9.45	9.01		5		9.59	10.02	
6		9.45	10.02		6		9.59	10.16		6		9.45	10.77		6		9.59	10.56	
	R-434A 3GS - #9A					R-434A 3GS - #9B					R-434A BWMO 2% BTPP - #10A					R-434A BWMO 2% BTPP - #10B			
1		9.45	11.34		1		9.59	11.16		1		9.45	10.52		1		9.59	10.71	
2		9.45	11.3		2		9.59	11.65		2		9.45	11.37		2		9.59	11.08	
3	No Change	9.45	10.96	14.9%	3	No Change	9.59	9.89	14.7%	3	No Change	9.45	8.37	-0.9%	3	No Change	9.59	9.62	9.0%
4		9.45	8.37		4		9.59	10.43		4		9.45	8.74		4		9.59	10.49	
5		9.45	11.7		5		9.59	11.67		5		9.45	8.94		5		9.59	10.14	
6		9.45	11.5		6		9.59	11.17		6		9.45	8.26		6		9.59	10.69	
	R-438A 3GS - #11A					R-438A 3GS - #11B					R-438A BWMO 2% BTPP - #12A					R-438A BWMO 2% BTPP - #12B			
1		9.45	11.5		1		9.59	9.98		1		9.45	6.66		1		9.59	10.7	
2		9.45	8.61		2		9.59	6.69		2		9.45	11.47		2		9.59	10.62	
3	No Change	9.45	10.85	11.4%	3	No Change	9.59	10.28	0.7%	3	No Change	9.45	10.95	11.6%	3	No Change	9.59	10.21	0.4%
4		9.45	9.99		4		9.59	9.58		4		9.45	11.3		4		9.59	6.07	
5		9.45	12.35		5		9.59	10.4		5		9.45	11.29		5		9.59	10.32	
6		9.45	9.87		6		9.59	11.01		6		9.45	11.59		6		9.59	9.83	

Appendix C
Bond Strength
Varnish Coated Magnet Wire (ester imide overcoated with amide imide)

	Varnish	Break Force (lbs)
Unexposed	EM59	36.38
	Elanta 923	43.54

Like New (LN) 30 Day Aged Bond Strength				
Refrigerant/Lubricant Exposure	EM59		Elantas 923	
	Break Force (lbs)	± % Change from Unexposed	Break Force (lbs)	± % Change from Unexposed
R-22 3GS	29.76	-18.2	25.57	-41.3
R-22 BWMO 2%BTPP	35.27	-3.0	28.84	-33.8
R-417A 3GS	13.96	-61.6	23.52	-46.0
R-417A BWMO 2% BTPP	12.13	-66.7	23.33	-46.4
R-422D 3GS	16.35	-55.1	23.52	-46.0
R-422D BWMO 2% BTPP	13.78	-62.1	22.27	-48.9
R-424A 3GS	17.45	-52.0	22.05	-49.4
R-424A BWMO 2% BTPP	13.41	-63.1	25.13	-42.3
R-434A 3GS	15.80	-56.6	22.60	-48.1
R-434A BWMO 2% BTPP	15.43	-57.6	24.99	-42.6
R-438A 3GS	16.17	-55.6	23.33	-46.4
R-438A BWMO 2% BTPP	12.68	-65.2	22.60	-48.1

Data shown is the average of 5 samples of each varnish tested in each refrigerant/lubricant mixture

Parallel (PT) R-22/Alternative 60 Day Aged Bond Strength				
Refrigerant/Lubricant Exposure	EM59		Elantas 923	
	Break Force (lbs)	± % Change from Unexposed	Break Force (lbs)	± % Change from Unexposed
R-22 3GS	21.50	-40.9	24.25	-44.3
R-22 BWMO 2%BTPP	21.31	-41.4	21.86	-49.8
R-417A 3GS	22.78	-37.4	22.96	-47.3
R-417A BWMO 2% BTPP	17.64	-51.5	21.13	-51.5
R-422D 3GS	25.54	-29.8	26.01	-40.3
R-422D BWMO 2% BTPP	18.74	-48.5	23.52	-46.0
R-424A 3GS	18.37	-49.5	28.11	-35.4
R-424A BWMO 2% BTPP	18.37	-49.5	18.19	-58.2
R-434A 3GS	21.31	-41.4	22.60	-48.1
R-434A BWMO 2% BTPP	21.13	-41.9	24.80	-43.0
R-438A 3GS	18.30	-49.7	23.52	-46.0
R-438A BWMO 2% BTPP	19.66	-46.0	22.96	-47.3

Data shown is the average of 5 samples of each varnish tested in each refrigerant/lubricant mixture

Appendix D1

Like New (LN) 30 Day Aged Sheet Insulation % Change in Weight

Film/Phase Insulation	Refrigerant	Refrigerant/Lube	Initial Weight (g)	After Aging Weight (g)	% Change in Weight
Melinex	R-22	32 ISO 3GS	0.600	0.612	1.90
		BWMO 2% BTPP	0.575	0.599	4.21
	R-417A	32 ISO 3GS	0.601	0.609	1.43
		BWMO 2% BTPP	0.588	0.598	1.63
	R-422D	32 ISO 3GS	0.566	0.576	1.73
		BWMO 2% BTPP	0.583	0.592	1.61
	R-424A	32 ISO 3GS	0.584	0.596	1.92
		BWMO 2% BTPP	0.575	0.585	1.74
	R-434A	32 ISO 3GS	0.590	0.601	1.97
		BWMO 2% BTPP	0.587	0.598	1.91
	R-438A	32 ISO 3GS	0.580	0.595	2.52
		BWMO 2% BTPP	0.575	0.589	2.47
Mylar	R-22	32 ISO 3GS	0.593	0.591	-0.44
		BWMO 2% BTPP	0.590	0.604	2.27
	R-417A	32 ISO 3GS	0.600	0.610	1.70
		BWMO 2% BTPP	0.601	0.615	2.23
	R-422D	32 ISO 3GS	0.598	0.608	1.71
		BWMO 2% BTPP	0.590	0.600	1.63
	R-424A	32 ISO 3GS	0.599	0.609	1.67
		BWMO 2% BTPP	0.602	0.616	2.36
	R-434A	32 ISO 3GS	0.600	0.611	1.77
		BWMO 2% BTPP	0.598	0.606	1.41
	R-438A	32 ISO 3GS	0.599	0.611	1.94
		BWMO 2% BTPP	0.602	0.616	2.33
Dacron/Mylar/Dacron	R-22	32 ISO 3GS	1.150	1.190	3.46
		BWMO 2% BTPP	1.146	1.197	4.47
	R-417A	32 ISO 3GS	1.152	1.184	2.78
		BWMO 2% BTPP	1.137	1.184	4.17
	R-422D	32 ISO 3GS	1.165	1.216	4.34
		BWMO 2% BTPP	1.167	1.206	3.33
	R-424A	32 ISO 3GS	1.157	1.189	2.84
		BWMO 2% BTPP	1.135	1.197	5.43
	R-434A	32 ISO 3GS	1.153	1.202	4.23
		BWMO 2% BTPP	1.155	1.206	4.41
	R-438A	32 ISO 3GS	1.161	1.216	4.76
		BWMO 2% BTPP	1.167	1.221	4.64

Data shown is the average of 5 samples of each film tested in each refrigerant/lubricant mixture

Appendix D2
Like New (LN) 30 Day Aged Sheet Insulation % Elongation and Tensile

		Elongation %	Tensile lb/in^2	Tensile kg/mm^2
Unaged Controls	Melinex	215.47	22114.2	15.55
	Mylar	175.95	25571.9	17.98
	Dacron/Mylar/Dacron	209.53	13436.1	9.45

Aged Film/Phase Insulation	Refrigerant	Lubricant	Elongation %	Tensile lb/in^2	Tensile kg/mm^2	Tensile % (Loss)/Gain
Melinex	R-22	32 ISO 3GS	7.51	13858.2	9.74	-37.33
		BWMO 2% BTPP	38.22	18101.4	12.73	-18.15
	R-417A	32 ISO 3GS	26.85	18697.2	13.15	-15.45
		BWMO 2% BTPP	7.20	14206.3	9.99	-35.76
	R-422D	32 ISO 3GS	43.07	18098.3	12.72	-18.16
		BWMO 2% BTPP	45.63	17003.9	11.95	-23.11
	R-424A	32 ISO 3GS	49.56	17317.6	12.18	-21.69
		BWMO 2% BTPP	25.16	17499.0	12.30	-20.87
	R-434A	32 ISO 3GS	36.03	17565.4	12.35	-20.57
		BWMO 2% BTPP	7.51	15795.5	11.11	-28.57
	R-438A	32 ISO 3GS	49.14	16261.0	11.43	-26.47
		BWMO 2% BTPP	5.44	10297.4	7.24	-53.44
Mylar	R-22	32 ISO 3GS	5.13	11150.8	7.84	-56.39
		BWMO 2% BTPP	30.75	18739.2	13.17	-26.72
	R-417A	32 ISO 3GS	21.54	18709.8	13.15	-26.83
		BWMO 2% BTPP	11.81	17257.7	12.13	-32.51
	R-422D	32 ISO 3GS	66.77	20090.0	14.12	-21.44
		BWMO 2% BTPP	51.06	20320.4	14.29	-20.54
	R-424A	32 ISO 3GS	59.38	20037.1	14.09	-21.64
		BWMO 2% BTPP	21.41	19152.5	13.47	-25.10
	R-434A	32 ISO 3GS	19.41	19187.5	13.49	-24.97
		BWMO 2% BTPP	12.25	16497.7	11.60	-35.49
	R-438A	32 ISO 3GS	40.23	19660.0	13.82	-23.12
		BWMO 2% BTPP	14.61	18463.7	12.98	-27.80
Dacron/Mylar/Dacron	R-22	32 ISO 3GS	15.04	11409.0	8.02	-15.09
		BWMO 2% BTPP	17.17	11983.3	8.43	-10.81
	R-417A	32 ISO 3GS	22.48	12703.7	8.93	-5.45
		BWMO 2% BTPP	20.09	12336.4	8.67	-8.18
	R-422D	32 ISO 3GS	49.76	12398.3	8.72	-7.72
		BWMO 2% BTPP	62.36	12852.8	9.04	-4.34
	R-424A	32 ISO 3GS	44.00	13261.7	9.32	-1.30
		BWMO 2% BTPP	25.68	12668.8	8.91	-5.71
	R-434A	32 ISO 3GS	18.86	13175.3	9.26	-1.94
		BWMO 2% BTPP	27.94	12651.8	8.90	-5.84
	R-438A	32 ISO 3GS	47.40	13048.5	9.17	-2.89
		BWMO 2% BTPP	23.83	12232.0	8.60	-8.96

Data shown is the average of 5 samples of each film tested in each refrigerant/lubricant mixture

Appendix E1

Parallel (PT) R-22/Alternative Refrigerant 60 Day Aged Sheet Insulation % Change in Weight

Film/Phase Insulation	Refrigerant	Refrigerant/Lube	Initial Weight (g)	After Aging Weight (g)	% Change in Weight	Samples Lost
Melinex	R-22	32 ISO 3GS	0.577	0.591	2.50	4 of 5
		BWMO 2% BTPP	0.588	0.617	5.02	1 of 5
	R-417A	32 ISO 3GS	0.579	0.602	3.96	3 of 5
		BWMO 2% BTPP	0.578	0.608	5.19	3 of 5
	R-422D	32 ISO 3GS	0.584	0.616	5.41	4 of 5
		BWMO 2% BTPP	0.592	0.610	2.96	3 of 5
	R-424A	32 ISO 3GS	0.590	0.615	4.20	2 of 5
		BWMO 2% BTPP	0.587	0.606	3.21	1 of 5
	R-434A	32 ISO 3GS	0.584	0.602	2.99	2 of 5
		BWMO 2% BTPP	0.580			5 of 5
	R-438A	32 ISO 3GS	0.582	0.611	5.08	2 of 5
		BWMO 2% BTPP	0.584	0.589	0.79	4 of 5
Mylar	R-22	32 ISO 3GS	0.631	0.637	0.92	4 of 5
		BWMO 2% BTPP	0.627	0.667	6.50	2 of 5
	R-417A	32 ISO 3GS	0.603	0.614	1.89	4 of 5
		BWMO 2% BTPP	0.603	0.620	2.82	2 of 5
	R-422D	32 ISO 3GS	0.608			5 of 5
		BWMO 2% BTPP	0.620	0.627	1.06	3 of 5
	R-424A	32 ISO 3GS	0.607	0.625	2.90	3 of 5
		BWMO 2% BTPP	0.671	0.690	2.89	3 of 5
	R-434A	32 ISO 3GS	0.658	0.665	1.05	2 of 5
		BWMO 2% BTPP	0.664			5 of 5
	R-438A	32 ISO 3GS	0.638	0.653	2.38	3 of 5
		BWMO 2% BTPP	0.613	0.624	1.79	3 of 5
Dacron/Mylar/ Dacron	R-22	32 ISO 3GS	1.161	1.218	4.91	
		BWMO 2% BTPP	1.151	1.226	6.55	
	R-417A	32 ISO 3GS	1.164	1.219	4.73	
		BWMO 2% BTPP	1.158	1.212	4.63	
	R-422D	32 ISO 3GS	1.156	1.212	4.81	
		BWMO 2% BTPP	1.156	1.217	5.26	
	R-424A	32 ISO 3GS	1.153	1.178	2.19	
		BWMO 2% BTPP	1.149	1.157	0.73	
	R-434A	32 ISO 3GS	1.156	1.198	3.60	
		BWMO 2% BTPP	1.141	1.190	4.31	
	R-438A	32 ISO 3GS	1.153	1.200	4.15	
		BWMO 2% BTPP	1.157	1.207	4.34	

Data shown is the average of 5 samples of each film tested in each refrigerant/lubricant mixture, except where otherwise noted

Appendix E2

Parallel (PT) R-22/Alternative Refrigerant 60 Day Aged Sheet Insulation % Elongation and Tensile

		Elongation %	Tensile lb/in^2	Tensile kg/mm^2
Unaged Controls	Melinex	215.47	21814.7	15.34
	Mylar	175.95	23507.8	16.53
	Dacron/Mylar/Dacron	209.53	13255.9	9.32

Aged Film/Phase Insulation	Refrigerant	Lubricant	Elongation %	Tensile lb/in^2	Tensile kg/mm^2	Tensile % (Loss)/Gain	Samples Lost
Melinex	R-22	32 ISO 3GS					5 of 5
		BWMO 2% BTPP	1.58	1332.3	0.94	-93.89	3 of 5
	R-417A	32 ISO 3GS					5 of 5
		BWMO 2% BTPP					5 of 5
	R-422D	32 ISO 3GS					5 of 5
		BWMO 2% BTPP	22.25	5374.6	3.78	-75.36	4 of 5
	R-424A	32 ISO 3GS					5 of 5
		BWMO 2% BTPP					5 of 5
	R-434A	32 ISO 3GS	2.75	7610.5	5.35	-65.11	3 of 5
		BWMO 2% BTPP					5 of 5
	R-438A	32 ISO 3GS					5 of 5
		BWMO 2% BTPP					5 of 5
Mylar	R-22	32 ISO 3GS					5 of 5
		BWMO 2% BTPP	2.85	998.4	0.70	-95.75	3 of 5
	R-417A	32 ISO 3GS					5 of 5
		BWMO 2% BTPP					5 of 5
	R-422D	32 ISO 3GS					5 of 5
		BWMO 2% BTPP					5 of 5
	R-424A	32 ISO 3GS					5 of 5
		BWMO 2% BTPP					5 of 5
	R-434A	32 ISO 3GS	2.35	96.0	0.34	-99.59	4 of 5
		BWMO 2% BTPP					5 of 5
	R-438A	32 ISO 3GS					5 of 5
		BWMO 2% BTPP					5 of 5
Dacron/Mylar/Dacron	R-22	32 ISO 3GS	2.68	3364.5	2.37	-74.62	
		BWMO 2% BTPP	3.03	4890.9	3.44	-63.10	
	R-417A	32 ISO 3GS	3.03	2842.4	2.00	-78.56	
		BWMO 2% BTPP	2.67	3592.7	2.53	-72.90	
	R-422D	32 ISO 3GS	2.52	2746.8	1.93	-79.28	
		BWMO 2% BTPP	3.39	5246.5	3.69	-60.42	
	R-424A	32 ISO 3GS	2.87	3387.8	2.38	-74.44	
		BWMO 2% BTPP	2.55	3838.3	2.70	-71.04	2 of 5
	R-434A	32 ISO 3GS	3.19	5312.4	3.73	-59.92	
		BWMO 2% BTPP	2.59	2366.9	1.66	-82.14	
	R-438A	32 ISO 3GS	2.75	4097.1	2.88	-69.09	
		BWMO 2% BTPP	2.51	3273.3	2.30	-75.31	

Data shown is the average of 5 samples of each film tested in each refrigerant/lubricant mixture, except where otherwise noted

APPENDIX F

Like New (LN) 30 Day Aged Elastomer Seal Materials

Seal Materials	Refrigerant / Lube	Batch #	Elongation[1]		Tensile Strength[1]
			Distance at Break (in)	% Elongation	(psi)
C0873-70	Control Unaged	840995	4.26	870	2441
V0747		80111829	3.28	674	2337
PTFE			3.59	735	4162

[1]Average of 5 Samples

Seal Materials	Refrigerant / Lube	Batch #	After Aging (Loss)/Gain						Elongation			Tensile Strength	
			Weight		Cross Section		Dx[1]		Distance at Break	% Elongation	Mean	(psi)	Mean
			± g	%	± in	%	±	%					
C0873-70 1	R-22 / 32 ISO 3GS	840995	0.34	24.7	0.02	8.3	-8	-11	4.43	904	841	1558	1433
			0.33	23.3	0.02	6.6	-9	-13	4.37	892		1585	
			0.32	22.2	0.02	4.2	-11	-15	4.56	930		1687	
			0.33	20.8	0.02	11.3	-11	-15	3.63	744		1182	
			0.38	23.3	0.02	11.0	-5	-7	3.58	734		1153	
C0873-70 2	R-22 / BWMO 2% BTPP	840995	0.20	14.1	0.02	3.8	-7	-10	3.69	756	718	1489	1570
			0.21	14.6	0.01	4.8	-2	-3	3.24	666		1469	
			0.21	14.0	0.02	4.0	-5	-7	3.29	676		1678	
			0.21	14.1	0.01	2.9	-4	-6	3.87	792		1692	
			0.21	13.2	0.02	2.2	-5	-7	3.41	700		1521	
C0873-70 3	R-417A / 32 ISO 3GS	840995	0.35	24.6	0.02	11.7	-12	-17	4.42	902	957	1347	1479
			0.34	24.2	0.02	3.3	-14	-19	4.62	942		1519	
			0.34	22.6	0.02	-0.1	-12	-17	5.03	1024		1575	
			0.34	22.2	0.02	4.1	-11	-16	4.86	990		1472	
			0.34	21.5	0.02	5.1	-12	-17	4.54	926		1483	
C0873-70 4	R-417A / BWMO 2% BTPP	840995	0.20	14.5	0.01	-0.5	-6	-8	4.53	924	905	1927	1906
			0.20	13.9	0.01	-0.1	-6	-8	4.38	894		1891	
			0.20	13.5	0.01	5.6	-8	-11	4.46	910		1992	
			0.21	14.3	0.02	3.9	-6	-8	4.37	892		1817	
			0.21	12.9	0.02	4.9	-8	-11	4.43	904		1902	
C0873-70 5	R-422D / 32 ISO 3GS	840995	0.36	25.7	0.02	6.2	-6	-8	4.90	998	981	1635	1702
			0.34	23.1	0.02	11.8	-10	-14	5.09	1036		1783	
			0.30	20.2	0.02	13.0	-10	-14	4.65	948		1735	
			0.33	20.9	0.02	10.7	-10	-14	4.83	984		1727	
			0.32	20.2	0.02	12.0	-9	-13	4.60	938		1628	

APPENDIX F

Like New (LN) 30 Day Aged Elastomer Seal Materials

Seal Materials	Refrigerant / Lube	Batch #	Elongation[1]		Tensile Strength[1]
			Distance at Break (in)	% Elongation	(psi)
C0873-70	Control Unaged	840995	4.26	870	2441
V0747		80111829	3.28	674	2337
PTFE			3.59	735	4162

[1]Average of 5 Samples

Seal Materials	Refrigerant / Lube	Batch #	After Aging (Loss)/Gain						Elongation			Tensile Strength	
			Weight		Cross Section		Dx[1]		Distance at Break	% Elongation	Mean	(psi)	Mean
			± g	%	± in	%	±	%					
C0873-70 6	R-422D / BWMO 2% BTPP	840995	0.21	14.6	0.01	4.2	-5	-7	4.43	904	855	2032	1974
			0.19	13.0	0.01	5.6	-6	-8	4.42	902		2106	
			0.22	14.9	0.02	6.2	-7	-10	3.78	774		1798	
			0.22	14.2	0.01	8.1	-8	-11	4.28	874		2105	
			0.22	13.5	0.01	5.6	-8	-11	4.02	822		1829	
C0873-70 7	R-424A / 32 ISO 3GS	840995	0.36	25.2	0.02	11.6	-9	-13	5.07	1032	968	1688	1579
			0.34	24.2	0.02	10.3	-9	-13	4.43	904		1599	
			0.35	23.1	0.02	11.9	-7	-10	4.14	846		1310	
			0.35	22.6	0.02	11.5	-9	-13	5.13	1044		1642	
			0.35	23.2	0.02	11.4	-7	-10	4.99	1016		1655	
C0873-70 8	R-424A / BWMO 2% BTPP	840995	0.22	15.6	0.01	2.7	-5	-7	4.20	858	855	1791	1781
			0.23	15.5	0.01	6.0	-5	-7	4.34	886		1866	
			0.27	17.8	0.01	2.3	-6	-8	4.26	870		1763	
			0.18	11.6	0.01	8.3	-4	-6	3.94	806		1696	
			0.22	13.9	0.01	5.9	-7	-10	4.20	858		1791	
C0873-70 9	R-434A / 32 ISO 3GS	840995	0.31	22.6	0.02	10.7	-4	-6	4.60	938	931	1619	1604
			0.30	21.4	0.01	9.8	-6	-8	4.54	926		1656	
			0.30	20.9	0.02	8.9	-6	-8	4.50	918		1605	
			0.33	21.7	0.02	10.1	-7	-10	4.47	912		1571	
			0.35	22.2	0.02	10.3	-6	-8	4.71	960		1567	
C0873-70 10	R-434A / BWMO 2% BTPP	840995	0.24	17.2	0.01	7.5	-3	-4	4.64	946	846	2036	1828
			0.23	15.7	0.02	10.1	-5	-7	4.32	882		1806	
			0.23	15.7	0.01	9.6	-6	-8	4.39	896		1902	
			0.25	16.2	0.01	2.5	-4	-6	3.47	712		1638	
			0.23	14.4	0.01	0.4	-7	-10	3.89	796		1758	

APPENDIX F

Like New (LN) 30 Day Aged Elastomer Seal Materials

Seal Materials	Refrigerant / Lube	Batch #	Elongation[1]		Tensile Strength[1]
			Distance at Break (in)	% Elongation	(psi)
C0873-70	Control Unaged	840995	4.26	870	2441
V0747		80111829	3.28	674	2337
PTFE			3.59	735	4162

[1]Average of 5 Samples

Seal Materials	Refrigerant / Lube	Batch #	After Aging (Loss)/Gain						Elongation			Tensile Strength	
			Weight		Cross Section		Dx[1]		Distance at Break	% Elongation	Mean	(psi)	Mean
			± g	%	± in	%	±	%					
C0873-70 11	R-438A / 32 ISO 3GS	840995	0.36	26.2	0.02	13.6	-3	-4	3.67	751	788	1132	1283
			0.36	25.1	0.02	10.0	-2	-3	4.01	820		1277	
			0.36	24.6	0.02	14.1	-3	-4	3.94	805		1330	
			0.36	23.5	0.02	11.6	-3	-4	3.72	761		1285	
			0.36	23.2	0.02	7.6	-5	-7	3.94	805		1393	
C0873-70 12	R-438A / BWMO 2% BTPP	840995	0.22	15.9	0.01	7.3	-2	-3	4.41	900	797	1953	1715
			0.23	15.7	0.01	7.4	-5	-7	3.86	790		1570	
			0.22	14.5	0.01	5.3	-2	-3	3.80	777		1634	
			0.23	14.5	0.01	5.8	0	0	3.81	781		1713	
			0.22	13.9	0.01	5.9	-2	-3	3.60	737		1705	
V0747 1	R-22 / 32 ISO 3GS	80113612	0.01	0.8	0.00	0.9	-2	-3	3.34	686	649	2386	2133
			0.01	0.8	0.00	1.1	-2	-3	3.04	626		2078	
			0.02	1.3	0.02	2.0	-2	-3	3.22	662		1940	
			0.01	0.4	0.01	0.0	0	0	3.11	640		2149	
			0.02	0.9	0.01	1.2	-1	-1	3.08	634		2113	
V0747 2	R-22 / BWMO 2% BTPP	80113612	0.06	3.4	0.01	-1.2	-6	-8	3.58	734	756	1798	1876
			0.05	3.1	0.01	-0.3	-4	-5	3.79	776		1950	
			0.06	3.2	0.01	1.6	-5	-7	3.89	796		1964	
			0.06	3.1	0.01	1.6	-4	-5	3.35	688		1683	
			0.06	3.0	0.01	2.4	-5	-7	3.84	786		1985	
V0747 3	R-417A / 32 ISO 3GS	80113612	0.08	4.9	0.01	0.8	-6	-8	3.60	738	717	1833	1785
			0.08	4.8	0.01	4.1	-6	-8	3.58	734		1859	
			0.08	4.4	0.01	3.5	-4	-5	3.56	730		1798	
			0.08	4.3	0.01	1.6	-4	-5	3.63	744		1902	
			0.08	4.2	0.01	1.2	-7	-9	3.10	638		1532	

APPENDIX F

Like New (LN) 30 Day Aged Elastomer Seal Materials

Seal Materials	Refrigerant / Lube	Batch #	Elongation[1]		Tensile Strength[1]
			Distance at Break (in)	% Elongation	(psi)
C0873-70	Control Unaged	840995	4.26	870	2441
V0747		80111829	3.28	674	2337
PTFE			3.59	735	4162

[1]Average of 5 Samples

Seal Materials	Refrigerant / Lube	Batch #	After Aging (Loss)/Gain						Elongation			Tensile Strength	
			Weight		Cross Section		Dx[1]		Distance at Break	% Elongation	Mean	(psi)	Mean
			± g	%	± in	%	±	%					
V0747 4	R-417A / BWMO 2% BTPP	80113612	0.09	5.3	0.01	1.4	-6	-8	3.41	700	657	1715	1636
			0.09	5.3	0.01	0.9	-7	-9	2.82	582		1408	
			0.09	5.0	0.01	2.9	-7	-9	3.32	682		1694	
			0.09	4.7	0.01	3.0	-5	-7	3.22	662		1680	
			0.10	5.1	0.01	2.2	-6	-8	3.21	660		1680	
V0747 5	R-422D / 32 ISO 3GS	80113612	0.01	0.6	0.01	-0.7	-3	-4	3.46	710	655	2260	2064
			0.01	0.6	0.00	2.1	-1	-1	3.11	640		1999	
			0.01	0.7	0.01	1.1	0	0	3.28	674		2149	
			0.00	0.2	0.01	1.3	1	1	2.90	598		1828	
			0.01	0.5	0.01	-0.3	0	0	3.17	652		2084	
V0747 6	R-422D / BWMO 2% BTPP	80113612	0.02	1.1	0.01	0.2	-4	-5	2.12	442	538	1075	1481
			0.02	1.4	0.00	1.9	-2	-3	2.54	526		1443	
			0.02	1.2	0.00	-1.3	-1	-1	2.81	580		1648	
			0.02	1.0	0.00	-1.2	-3	-4	2.94	606		1757	
V0747 7	R-424A / 32 ISO 3GS	80113612	0.08	4.5	0.01	1.5	-6	-8	3.02	622	681	1522	1720
			0.08	4.3	0.00	0.9	-6	-8	3.33	684		1766	
			0.07	4.1	0.01	-0.7	-3	-4	3.53	724		1854	
			0.08	4.0	0.01	-1.5	-5	-7	3.50	718		1833	
			0.07	3.9	0.01	0.8	-5	-7	3.19	656		1625	
V0747 8	R-424A / BWMO 2% BTPP	80113612	0.08	4.5	0.00	1.7	-7	-9	3.51	720	694	1819	1757
			0.07	4.2	0.01	1.0	-4	-5	3.54	726		1823	
			0.08	4.3	0.00	2.5	-5	-7	3.40	698		1732	
			0.08	4.3	0.00	0.2	-4	-5	3.17	652		1662	
			0.08	4.4	0.01	2.9	-4	-5	3.28	674		1750	

APPENDIX F

Like New (LN) 30 Day Aged Elastomer Seal Materials

Seal Materials	Refrigerant / Lube	Batch #	Elongation[1]		Tensile Strength[1]
			Distance at Break (in)	% Elongation	(psi)
C0873-70	Control Unaged	840995	4.26	870	2441
V0747		80111829	3.28	674	2337
PTFE			3.59	735	4162

[1]Average of 5 Samples

Seal Materials	Refrigerant / Lube	Batch #	After Aging (Loss)/Gain						Elongation			Tensile Strength	
			Weight		Cross Section		Dx[1]		Distance at Break	% Elongation	Mean	(psi)	Mean
			± g	%	± in	%	±	%					
V0747 9	R-434A / 32 ISO 3GS	80113612	0.01	0.7	0.00	0.1	-2	-3	3.34	686	695	2205	2237
			0.01	0.8	0.00	0.2	-3	-4	3.62	742		2436	
			0.01	0.8	0.00	1.0	0	0	3.33	684		2215	
			-0.11	-5.6	0.01	-1.4	0	0	3.21	660		2098	
			0.14	7.5	0.00	0.8	-1	-1	3.43	704		2228	
V0747 10	R-434A / BWMO 2% BTPP	80113612	0.06	3.6	0.01	2.5	-5	-7	3.59	736	685	1872	1723
			0.06	3.3	0.01	2.0	-5	-7	3.59	736		1888	
			0.06	3.5	0.01	2.5	-3	-4	2.64	546		1257	
			0.05	2.9	0.00	0.9	-6	-8	3.52	722		1823	
			0.06	3.0	0.01	1.5	-3	-4	3.35	688		1776	
V0747 11	R-438A / 32 ISO 3GS	80113612	0.01	0.8	0.00	1.2	-1	-1	3.12	641	690	2013	2195
			0.01	0.7	0.00	-0.7	-1	-1	3.59	735		2383	
			0.01	0.6	0.00	1.7	-1	-1	3.68	753		2440	
			0.01	0.7	0.00	0.6	-3	-4	3.40	698		2241	
			0.01	0.6	0.00	0.4	0	0	3.02	621		1898	
V0747 12	R-438A / BWMO 2% BTPP	80113612	0.06	3.6	0.01	2.0	-5	-7	3.34	686	735	1777	1949
			0.06	3.5	0.00	0.5	-5	-7	3.68	753		1991	
			0.06	3.4	0.00	0.9	-4	-5	3.63	743		2013	
			0.06	3.3	0.01	2.3	-3	-4	3.70	758		1985	
			0.06	3.2	0.01	0.2	-3	-4	3.58	733		1978	
PTFE 1	R-22 / 32 ISO 3GS		0.01	0.5	0.00	-0.7	-1	-1	3.80	778	810	4506	4593
			0.00	0.1	0.00	-0.5	0	0	4.27	872		4942	
			0.01	0.4	0.00	-1.1	0	0	3.77	772		4361	
			0.01	0.4	0.00	-0.2	0	0	3.97	812		4546	
			0.01	0.3	0.00	-0.5	1	1	3.99	816		4612	

APPENDIX F

Like New (LN) 30 Day Aged Elastomer Seal Materials

Seal Materials	Refrigerant / Lube	Batch #	Elongation[1] Distance at Break (in)	Elongation[1] % Elongation	Tensile Strength[1] (psi)
C0873-70	Control Unaged	840995	4.26	870	2441
V0747		80111829	3.28	674	2337
PTFE			3.59	735	4162

[1]Average of 5 Samples

Seal Materials	Refrigerant / Lube	Batch #	After Aging (Loss)/Gain						Elongation			Tensile Strength	
			Weight		Cross Section		Dx[1]		Distance at Break	% Elongation	Mean	(psi)	Mean
			± g	%	± in	%	±	%					
PTFE 2	R-22 / BWMO 2% BTPP		0.02	0.9	0.00	-0.3	-1	-1	4.16	850	751	4278	4097
			0.02	0.9	0.00	0.8	-1	-1	3.96	811		4080	
			0.02	0.8	0.00	-0.2	1	1	4.16	850		4138	
			0.02	0.7	0.00	-0.2	1	1	4.49	916		4387	
			0.02	0.7	0.00	0.3	1	1	1.56	330		3602	
PTFE 3	R-417A / 32 ISO 3GS		0.04	1.9	0.01	1.3	-2	-2	4.05	828	832	4402	4385
			0.03	1.6	0.00	-0.7	-3	-3	3.76	770		4077	
			0.03	1.5	0.00	0.5	1	1	4.13	844		4433	
			0.03	1.5	0.00	-1.0	0	0	4.04	826		4392	
			0.03	1.4	0.00	-0.3	-1	-1	4.37	892		4621	
PTFE 4	R-417A / BWMO 2% BTPP		0.03	1.7	0.00	1.1	0	0	4.54	926	845	4391	4127
			0.04	1.7	0.00	0.7	-2	-2	4.34	886		4243	
			0.04	1.9	0.00	0.5	1	1	3.89	796		3998	
			0.04	1.7	0.00	1.0	0	0	3.81	780		3948	
			0.04	1.8	0.00	0.8	1	1	4.11	840		4055	
PTFE 5	R-422D / 32 ISO 3GS		0.00	0.2	0.00	0.4	-1	-1	4.11	840	793	5084	4368
			0.00	0.1	0.00	-1.3	-1	-1	3.85	788		4026	
			0.00	0.2	0.00	-0.8	0	0	4.04	826		4375	
			0.00	0.2	0.00	-0.2	1	1	3.74	766		4524	
			0.00	0.2	0.00	-1.8	1	1	3.63	744		3830	
PTFE 6	R-422D / BWMO 2% BTPP		0.00	0.1	0.00	0.4	-2	-2	2.48	514	665	3942	4054
			0.00	0.2	0.00	-0.3	-3	-3	2.47	512		4097	
			0.00	0.2	0.00	-0.9	-3	-3	3.58	734		3976	
			0.01	0.3	0.00	-1.7	0	0	4.22	862		4084	
			0.00	0.1	0.00	-1.3	-3	-3	3.42	702		4173	

APPENDIX F

Like New (LN) 30 Day Aged Elastomer Seal Materials

Seal Materials	Refrigerant / Lube	Batch #	Elongation[1]		Tensile Strength[1]
			Distance at Break (in)	% Elongation	(psi)
C0873-70	Control Unaged	840995	4.26	870	2441
V0747		80111829	3.28	674	2337
PTFE			3.59	735	4162

[1]Average of 5 Samples

Seal Materials	Refrigerant / Lube	Batch #	After Aging (Loss)/Gain						Elongation			Tensile Strength	
			Weight		Cross Section		Dx[1]		Distance at Break	% Elongation	Mean	(psi)	Mean
			± g	%	± in	%	±	%					
PTFE 7	R-424A / 32 ISO 3GS		0.03	1.6	0.00	-0.2	-3	-3	2.24	466	705	3814	3953
			0.03	1.4	0.00	-0.2	0	0	3.39	696		3849	
			0.03	1.3	0.00	-0.4	2	2	3.38	694		3795	
			0.03	1.6	0.00	-0.3	2	2	4.03	824		4173	
			0.03	1.3	0.00	-0.8	1	1	4.14	846		4132	
PTFE 8	R-424A / BWMO 2% BTPP		0.03	1.6	0.00	0.1	0	0	2.57	532	552	3865	3754
			0.03	1.6	0.00	-0.6	-1	-1	2.96	610		3726	
			0.03	1.6	0.00	0.1	0	0	2.63	544		3822	
			0.03	1.6	0.00	-0.4	1	1	2.75	568		3761	
			0.03	1.5	0.00	0.4	2	2	2.44	506		3596	
PTFE 9	R-434A / 32 ISO 3GS		0.00	0.1	0.00	-0.1	0	0	4.37	892	761	4422	3983
			0.00	0.1	0.00	-0.5	2	2	3.55	728		3738	
			0.00	0.1	0.00	-0.5	-1	-1	3.89	796		3927	
			0.00	0.2	0.00	-1.0	1	1	4.10	838		4068	
			0.00	0.1	0.00	-0.5	2	2	2.67	552		3761	
PTFE 10	R-434A / BWMO 2% BTPP		0.07	3.3	0.00	-0.7	2	2	4.04	826	792	4004	3955
			0.02	0.9	0.01	0.2	1	1	4.00	818		3735	
			0.01	0.6	0.00	-1.3	1	1	4.15	848		3984	
			0.02	0.8	0.01	-0.7	3	3	3.13	644		3907	
			0.02	0.8	0.00	-0.2	-3	-3	4.04	826		4144	
PTFE 11	R-438A / 32 ISO 3GS		0.00	0.2	0.00	-0.6	-1	-1	2.57	533	661	3822	3991
			0.00	0.1	0.00	-1.0	2	2	3.26	669		3885	
			0.00	0.2	0.00	-0.7	-1	-1	3.94	807		4144	
			0.00	0.2	0.00	-1.0	3	3	3.82	782		4074	
			0.01	0.3	0.00	-1.1	3	3	2.48	515		4033	

APPENDIX F

Like New (LN) 30 Day Aged Elastomer Seal Materials

Seal Materials	Refrigerant / Lube	Batch #	Elongation[1]		Tensile Strength[1]
			Distance at Break (in)	% Elongation	(psi)
C0873-70	Control Unaged	840995	4.26	870	2441
V0747		80111829	3.28	674	2337
PTFE			3.59	735	4162

[1]Average of 5 Samples

Seal Materials	Refrigerant / Lube	Batch #	After Aging (Loss)/Gain						Elongation			Tensile Strength	
			Weight		Cross Section		Dx[1]		Distance at Break	% Elongation	Mean	(psi)	Mean
			± g	%	± in	%	±	%					
PTFE 12	R-438A / BWMO 2% BTPP		0.02	1.2	0.01	0.1	1	1	4.26	871	834	4154	4102
			0.03	1.3	0.00	-0.5	0	0	4.48	914		4379	
			0.03	1.3	0.00	-0.4	1	1	3.30	678		3621	
			0.03	1.3	0.00	-0.2	1	1	3.80	777		3830	
			0.03	1.2	0.00	-0.2	1	1	4.56	930		4524	

APPENDIX G

Parallel (PT) R-22/Alternative Refrigerant 60 Day Aged Elastomer Seal Materials

Seal Materials	Refrigerant / Lube	Batch #	Elongation[1]		Tensile Strength[1]
			Distance at Break (in)	% Elongation	(psi)
C0873-70	Control Unaged	840995	4.26	870	2441
V0747		80111829	3.28	674	2337
PTFE			3.59	735	4162

[1]Average of 5 Samples

Seal Materials	Refrigerant / Lube	Batch #	After Aging (Loss)/Gain						Elongation			Tensile Strength	
			Weight		Cross Section		Dx[1]		Distance at Break	% Elongation	Mean	(psi)	Mean
			± g	%	± in	%	±	%					
C0873-70 1	R-22 / BWMO 2% BTPP	840995	0.22	15.8	0.01	9.4	5	7	3.76	770	775	1140	1166
			0.23	15.4	0.01	5.3	5	8	3.89	796		1252	
			0.23	14.7	0.01	8.0	5	8	3.78	774		1124	
			0.23	13.7	0.01	-1.7	3	4	3.70	758		1162	
			0.23	13.0	0.01	0.3	4	6	3.79	776		1154	
C0873-70 2	R-22 / 32 ISO 3GS	840995	0.32	22.8	0.02	17.5	1	1	4.03	824	794	787	753
			0.26	17.7	0.02	12.7	0	0	4.21	860		889	
			0.30	18.5	0.02	13.5	-1	-1	3.93	804		787	
			0.24	14.0	0.02	13.7	2	3	3.36	690		549	
C0873-70 3	R-417A / BWMO 2% BTPP	840995	0.23	16.0	0.03	-1.3	3	4	3.81	779	774	1132	1137
			0.23	15.1	0.02	7.3	3	4	3.60	738		1000	
			0.23	14.3	0.02	0.5	2	3	3.75	768		1177	
			0.23	14.4	0.01	-0.6	3	4	3.85	788		1193	
			0.24	13.8	0.02	2.1	3	4	3.89	796		1184	
C0873-70 4	R-417A / 32 ISO 3GS	840995	0.38	25.7	0.02	16.7	1	1	4.06	830	844	828	820
			0.39	25.7	0.02	9.5	4	6	4.31	880		889	
			0.37	23.9	0.03	14.4	3	4	4.05	828		793	
			0.48	30.0	0.03	-2.8	2	3	4.25	868		825	
			0.28	16.5	0.03	9.7	1	2	3.98	814		766	
C0873-70 5	R-422D / BWMO 2% BTPP	840995	0.23	15.6	0.02	7.1	4	6	3.48	714	697	987	889
			0.23	15.4	0.02	16.4	2	3	3.41	700		960	
			0.24	15.1	0.02	8.1	2	3	3.64	746		780	
			0.24	14.6	0.02	6.4	5	8	3.29	676		918	
			0.24	14.0	0.02	-1.1	3	4	3.15	648		803	

APPENDIX G

Parallel (PT) R-22/Alternative Refrigerant 60 Day Aged Elastomer Seal Materials

Seal Materials	Refrigerant / Lube	Batch #	Elongation[1]		Tensile Strength[1]
			Distance at Break (in)	% Elongation	(psi)
C0873-70	Control Unaged	840995	4.26	870	2441
V0747		80111829	3.28	674	2337
PTFE			3.59	735	4162

[1]Average of 5 Samples

Seal Materials	Refrigerant / Lube	Batch #	After Aging (Loss)/Gain						Elongation			Tensile Strength	
			Weight		Cross Section		Dx[1]		Distance at Break	% Elongation	Mean	(psi)	Mean
			± g	%	± in	%	±	%					
C0873-70 6	R-422D / 32 ISO 3GS	840995	0.37	25.2	0.02	14.9	-1	-1	4.14	846	889	883	942
			0.38	24.6	0.02	8.1	-2	-3	4.29	876		889	
			0.36	23.2	0.02	5.0	-2	-3	4.52	922		1006	
			0.38	22.6	0.02	9.9	-3	-4	4.56	930		1000	
			0.38	21.6	0.03	13.4	0	0	4.27	872		932	
C0873-70 7	R-424A / BWMO 2% BTPP	840995	0.23	16.2	0.01	9.6	1	2	3.83	784	749	1200	1090
			0.23	15.2	0.01	3.1	3	5	3.63	744		1094	
			0.24	15.3	0.01	11.9	0	0	3.92	802		1192	
			0.24	14.6	0.02	7.7	2	3	3.55	728		1080	
			0.23	13.9	0.02	10.4	2	3	3.36	690		882	
C0873-70 8	R-424A / 32 ISO 3GS	840995	0.36	25.1	0.02	8.9	-2	-3	4.35	888	826	923	832
			0.37	24.0	0.02	13.6	-3	-4	3.62	742		679	
			0.37	23.9	0.02	8.0	-2	-3	4.25	868		911	
			0.37	21.4	0.02	9.3	-1	-1	3.94	806		803	
			0.37	20.9	0.02	9.8	-5	-7	4.05	828		844	
C0873-70 9	R-434A / BWMO 2% BTPP	840995	0.23	15.4	0.01	4.9	0	0	3.95	808	769	1293	1212
			0.23	15.0	0.01	-4.1	-3	-4	3.58	734		1155	
			0.23	14.8	0.01	3.5	-1	-1	3.97	812		1392	
			0.24	14.7	0.01	-0.4	-3	-4	3.68	754		1132	
			0.23	13.2	0.01	8.1	0	0	3.61	740		1087	
C0873-70 10	R-434A / 32 ISO 3GS	840995	0.35	24.3	0.02	9.7	-1	-2	4.09	836	817	1025	860
			0.36	23.3	0.02	7.6	0	0	4.29	876		950	
			0.36	22.2	0.02	9.8	-1	-2	4.40	898		1032	
			0.36	21.8	0.02	6.6	0	0	3.52	722		623	
			0.36	21.2	0.02	13.9	-3	-4	3.67	752		671	

APPENDIX G

Parallel (PT) R-22/Alternative Refrigerant 60 Day Aged Elastomer Seal Materials

Seal Materials	Refrigerant / Lube	Batch #	Elongation[1]		Tensile Strength[1]
			Distance at Break (in)	% Elongation	(psi)
C0873-70	Control Unaged	840995	4.26	870	2441
V0747		80111829	3.28	674	2337
PTFE			3.59	735	4162

[1]Average of 5 Samples

Seal Materials	Refrigerant / Lube	Batch #	After Aging (Loss)/Gain						Elongation			Tensile Strength	
			Weight		Cross Section		Dx[1]		Distance at Break	% Elongation	Mean	(psi)	Mean
			± g	%	± in	%	±	%					
C0873-70 11	R-438A / BWMO 2% BTPP	840995	0.18	12.5	0.02	11.0	5	8	3.75	768	778	1170	1153
			0.25	16.6	0.01	8.1	2	3	3.74	766		1162	
			0.24	15.2	0.01	11.4	1	1	3.94	806		1232	
			0.24	14.4	0.02	7.0	0	0	3.89	796		1147	
			0.23	13.3	0.02	-4.9	-1	-1	3.68	754		1054	
C0873-70 12	R-438A / 32 ISO 3GS	840995	0.20	13.8	0.02	11.4	-1	-1	4.41	900	853	984	819
			0.37	24.5	0.03	8.6	0	0	4.08	834		774	
			0.38	24.3	0.03	22.9	1	1	3.95	808		692	
			0.37	23.4	0.02	13.0	1	1	4.26	870		867	
			0.37	22.3	0.03	10.4	2	3	4.17	852		776	
V0747 1	R-22 / BWMO 2% BTPP	80113612	0.06	3.3	0.00	3.9	-6	-8	3.13	644	693	1122	1246
			0.06	3.4	0.00	2.1	-6	-8	3.46	710		1327	
			0.06	3.1	0.00	4.4	-5	-7	3.31	680		1209	
			0.06	3.0	0.00	1.7	-7	-9	3.70	758		1352	
			0.06	3.1	0.00	2.4	-5	-7	3.29	676		1218	
V0747 2	R-22 / 32 ISO 3GS	80113612	0.01	0.8	0.00	-1.3	-4	-5	3.06	630	627	1114	1156
			0.01	0.7	0.00	-0.3	-4	-5	3.11	640		1236	
			0.02	1.2	0.00	6.5	-3	-4	2.89	596		1082	
			0.01	0.6	0.00	8.9	-3	-4	3.06	630		1146	
			0.01	0.7	0.00	1.5	-2	-3	3.12	642		1201	
V0747 3	R-417A / BWMO 2% BTPP	80113612	0.09	5.3	0.01	1.8	-8	-11	2.80	578	655	942	1076
			0.09	5.4	0.01	1.5	-8	-11	3.27	672		1106	
			0.09	5.2	0.01	0.8	-9	-12	3.48	714		1236	
			0.09	4.8	0.01	4.7	-9	-12	3.09	636		975	
			0.09	4.8	0.01	-2.8	-9	-12	3.30	678		1122	

APPENDIX G

Parallel (PT) R-22/Alternative Refrigerant 60 Day Aged Elastomer Seal Materials

Seal Materials	Refrigerant / Lube	Batch #	Elongation[1]		Tensile Strength[1]
			Distance at Break (in)	% Elongation	(psi)
C0873-70	Control Unaged	840995	4.26	870	2441
V0747		80111829	3.28	674	2337
PTFE			3.59	735	4162

[1]Average of 5 Samples

Seal Materials	Refrigerant / Lube	Batch #	After Aging (Loss)/Gain						Elongation			Tensile Strength	
			Weight		Cross Section		Dx[1]		Distance at Break	% Elongation	Mean	(psi)	Mean
			± g	%	± in	%	±	%					
V0747 4	R-417A / 32 ISO 3GS	80113612	0.08	4.9	0.02	3.3	-6	-8	2.64	546	594	840	994
			0.09	4.8	0.01	1.8	-6	-8	2.89	596		955	
			0.08	4.6	0.01	-0.9	-7	-9	2.99	616		1084	
			0.09	4.6	0.02	0.8	-6	-8	2.92	602		1047	
			0.08	4.4	0.02	-3.7	-6	-8	2.97	612		1047	
V0747 5	R-422D / BWMO 2% BTPP	80113612	0.07	4.1	0.01	4.3	-8	-11	3.46	710	705	1159	1215
			0.07	4.1	0.00	0.9	-8	-10	3.51	720		1290	
			0.07	4.1	0.01	1.5	-6	-8	3.43	704		1254	
			0.08	4.3	0.01	-4.5	-7	-9	3.48	714		1209	
			0.08	3.9	0.01	-2.8	-6	-8	3.31	680		1163	
V0747 6	R-422D / 32 ISO 3GS	80113612	0.07	4.2	0.00	2.1	-7	-9	3.08	634	618	1201	1150
			0.07	4.0	0.00	3.6	-5	-7	2.89	596		1075	
			0.07	3.8	0.01	1.0	-4	-5	3.25	668		1262	
			0.07	3.7	0.00	-0.6	-5	-7	2.94	606		1138	
			0.07	3.6	0.00	-2.0	-4	-5	2.85	588		1075	
V0747 7	R-424A / BWMO 2% BTPP	80113612	0.08	4.4	0.01	4.7	-8	-11	2.60	538	668	824	1096
			0.08	4.3	0.01	-3.7	-7	-9	3.67	752		1262	
			0.08	4.3	0.01	-2.5	-7	-9	3.26	670		1114	
			0.08	3.9	0.01	-0.9	-7	-9	3.48	714		1184	
V0747 8	R-424A / 32 ISO 3GS	80113612	0.04	2.4	0.01	-4.4	-4	-5	3.02	622	646	1218	1303
			0.04	2.4	0.01	-2.2	-3	-4	3.23	664		1381	
			0.04	2.5	0.00	-3.1	-4	-5	3.17	652		1308	
			0.04	2.2	0.01	0.2	-3	-4	3.20	658		1299	
			0.04	2.1	0.00	-3.0	-3	-4	3.09	636		1308	

APPENDIX G

Parallel (PT) R-22/Alternative Refrigerant 60 Day Aged Elastomer Seal Materials

Seal Materials	Refrigerant / Lube	Batch #	Elongation[1]		Tensile Strength[1]
			Distance at Break (in)	% Elongation	(psi)
C0873-70	Control Unaged	840995	4.26	870	2441
V0747		80111829	3.28	674	2337
PTFE			3.59	735	4162

[1]Average of 5 Samples

Seal Materials	Refrigerant / Lube	Batch #	After Aging (Loss)/Gain						Elongation			Tensile Strength	
			Weight		Cross Section		Dx[1]		Distance at Break	% Elongation	Mean	(psi)	Mean
			± g	%	± in	%	±	%					
V0747 9	R-434A / BWMO 2% BTPP	80113612	0.07	4.0	0.00	-2.4	-7	-9	3.50	718	706	1361	1306
			0.07	3.8	0.00	-4.1	-7	-9	3.58	734		1352	
			0.07	3.7	0.00	-0.1	-6	-8	3.50	718		1299	
			0.07	3.8	0.00	1.0	-6	-8	3.22	662		1236	
			0.07	3.6	0.00	2.6	-7	-9	3.41	700		1280	
V0747 10	R-434A / 32 ISO 3GS	80113612	0.07	4.1	0.00	0.9	-6	-8	3.15	648	625	1192	1189
			0.07	4.0	0.00	-1.5	-5	-7	2.86	590		1090	
			-0.03	-1.8	0.00	4.3	-6	-8	3.19	656		1280	
			0.07	3.7	0.00	-5.2	-4	-5	3.07	632		1236	
			0.07	3.6	0.01	6.8	-5	-7	2.91	600		1146	
V0747 11	R-438A / BWMO 2% BTPP	80113612	0.08	4.9	0.01	2.0	-7	-9	3.52	722	708	1227	1229
			0.06	3.6	0.00	1.2	-7	-9	3.41	700		1218	
			0.09	4.7	0.00	-1.9	-7	-9	3.41	700		1209	
			0.09	4.6	0.00	7.1	-8	-11	3.46	710		1218	
			0.09	4.4	0.00	5.2	-6	-8	3.45	708		1271	
V0747 12	R-438A / 32 ISO 3GS	80113612	0.08	4.6	0.00	2.7	-6	-8	3.05	628	632	1138	1152
			0.08	4.5	0.00	0.6	-6	-8	2.83	584		1052	
			0.13	7.4	0.00	6.0	-5	-7	3.17	652		1209	
			0.08	4.3	0.00	1.4	-6	-8	3.20	658		1218	
			0.08	4.2	0.01	-3.4	-6	-8	3.11	640		1143	
PTFE 1	R-22 / BWMO 2% BTPP		0.01	0.6	0.00	-0.2	-2	-2	3.92	802	821	2845	2689
			0.01	0.5	0.00	0.1	-2	-2	4.33	884		2579	
			0.01	0.5	0.00	0.0	-3	-3	3.63	744		2508	
			0.01	0.6	0.00	1.2	0	0	4.04	826		2689	
			0.01	0.4	0.00	0.3	-1	-1	4.17	852		2825	

APPENDIX G

Parallel (PT) R-22/Alternative Refrigerant 60 Day Aged Elastomer Seal Materials

Seal Materials	Refrigerant / Lube	Batch #	Elongation[1]		Tensile Strength[1]
			Distance at Break (in)	% Elongation	(psi)
C0873-70	Control Unaged	840995	4.26	870	2441
V0747		80111829	3.28	674	2337
PTFE			3.59	735	4162

[1]Average of 5 Samples

Seal Materials	Refrigerant / Lube	Batch #	After Aging (Loss)/Gain						Elongation			Tensile Strength	
			Weight		Cross Section		Dx[1]		Distance at Break	% Elongation	Mean	(psi)	Mean
			± g	%	± in	%	±	%					
PTFE 2	R-22 / 32 ISO 3GS		0.01	0.4	0.00	1.1	-1	-1	4.61	940	937	2802	3041
			0.00	0.1	0.00	-0.4	0	0	4.35	888		3103	
			0.01	0.4	0.00	0.3	-3	-3	4.46	910		2722	
			0.01	0.4	0.00	-0.2	-1	-1	4.44	906		2967	
			0.01	0.3	0.00	-0.5	-1	-1	5.11	1040		3613	
PTFE 3	R-417A / BWMO 2% BTPP		0.02	0.9	0.00	0.8	4	4	4.48	914	893	3201	3028
			0.02	1.1	0.01	2.1	-3	-3	4.49	916		2939	
			0.03	1.2	0.00	1.5	1	1	4.02	822		2716	
			0.02	1.1	0.00	-0.8	-1	-1	4.39	896		3130	
			0.02	1.1	0.00	-0.4	-1	-1	4.49	916		3156	
PTFE 4	R-417A / 32 ISO 3GS		0.02	1.1	0.00	-0.8	-2	-2	4.50	918	728	3043	2633
			0.02	1.0	0.00	-0.5	1	1	3.29	676		2591	
			0.02	1.0	0.00	0.1	-3	-3	3.47	712		2598	
			0.02	0.9	0.01	-1.0	2	2	3.04	626		2271	
			0.02	0.9	0.00	-1.6	-4	-4	3.45	708		2665	
PTFE 5	R-422D / BWMO 2% BTPP		0.02	1.0	0.00	-1.3	-2	-2	3.37	692	660	2613	2522
			0.02	1.1	0.00	0.7	-2	-2	3.28	674		2508	
			0.02	1.0	0.00	-2.8	-1	-1	3.17	652		2490	
			0.02	0.7	0.00	-1.7	0	0	3.27	672		2651	
			0.02	0.8	0.00	0.6	0	0	2.96	610		2347	
PTFE 6	R-422D / 32 ISO 3GS		0.02	1.1	0.00	-1.6	-3	-3	3.39	696	794	2613	2705
			0.02	0.9	0.00	-2.9	-5	-5	3.70	758		2651	
			0.02	1.0	0.00	-1.5	0	0	4.28	874		3009	
			0.02	0.9	0.00	-2.9	0	0	3.26	670		2561	
			0.02	0.9	0.00	-1.6	-1	-1	4.78	974		2689	

APPENDIX G

Parallel (PT) R-22/Alternative Refrigerant 60 Day Aged Elastomer Seal Materials

Seal Materials	Refrigerant / Lube	Batch #	Elongation[1]		Tensile Strength[1]
			Distance at Break (in)	% Elongation	(psi)
C0873-70	Control Unaged	840995	4.26	870	2441
V0747		80111829	3.28	674	2337
PTFE			3.59	735	4162

[1]Average of 5 Samples

Seal Materials	Refrigerant / Lube	Batch #	After Aging (Loss)/Gain						Elongation			Tensile Strength	
			Weight		Cross Section		Dx[1]		Distance at Break	% Elongation	Mean	(psi)	Mean
			± g	%	± in	%	±	%					
PTFE 7	R-424A / BWMO 2% BTPP		0.02	1.0	0.00	-1.9	4	4	4.15	848	893	3201	3221
			0.02	1.0	0.00	-1.5	0	0	4.46	910		3296	
			0.02	0.9	0.00	-6.1	-1	-1	4.50	918		3343	
			0.02	0.8	0.00	-1.5	2	2	4.45	908		3178	
			0.02	0.8	0.00	-3.3	3	3	4.33	884		3086	
PTFE 8	R-424A / 32 ISO 3GS		0.01	0.5	0.00	-1.8	-2	-2	4.43	904	837	2834	2789
			0.01	0.4	0.00	-2.0	-4	-4	4.32	882		3037	
			0.01	0.5	0.00	-5.4	0	0	4.77	972		2802	
			0.01	0.5	0.00	-3.7	0	0	4.06	830		2638	
			0.01	0.5	0.00	-2.5	0	0	2.89	596		2635	
PTFE 9	R-434A / BWMO 2% BTPP		0.02	0.9	0.00	-5.6	0	0	4.55	928	899	2782	2820
			0.02	0.9	0.00	-2.9	-1	-1	4.57	932		2794	
			0.02	0.9	0.00	-5.0	-4	-4	4.70	958		2971	
			0.02	0.9	0.00	-8.8	-1	-1	4.11	840		2918	
			0.02	0.8	0.00	-1.6	-1	-1	4.11	840		2638	
PTFE 10	R-434A / 32 ISO 3GS		0.02	1.0	0.00	-2.6	-3	-3	4.49	916	907	2748	2702
			0.02	1.1	0.00	-0.4	-3	-3	4.76	970		2782	
			0.02	1.0	0.00	0.0	-4	-4	4.34	886		2654	
			0.02	1.0	0.00	-2.4	-1	-1	4.10	838		2635	
			0.02	1.0	0.00	-1.1	-2	-2	4.54	926		2689	
PTFE 11	R-438A / BWMO 2% BTPP		0.02	1.0	0.00	-1.4	-5	-5	4.20	858	799	2907	2739
			0.02	0.9	0.00	-2.0	-5	-5	4.85	988		2866	
			0.02	1.0	0.00	-1.2	-4	-4	4.13	844		2762	
			0.02	1.0	0.00	-0.7	-4	-4	3.03	624		2670	
			0.02	0.9	0.00	-1.3	-2	-2	3.33	684		2488	

APPENDIX G

Parallel (PT) R-22/Alternative Refrigerant 60 Day Aged Elastomer Seal Materials

Seal Materials	Refrigerant / Lube	Batch #	Elongation[1]		Tensile Strength[1]
			Distance at Break (in)	% Elongation	(psi)
C0873-70	Control Unaged	840995	4.26	870	2441
V0747		80111829	3.28	674	2337
PTFE			3.59	735	4162

[1]Average of 5 Samples

Seal Materials	Refrigerant / Lube	Batch #	After Aging (Loss)/Gain						Elongation			Tensile Strength	
			Weight		Cross Section		Dx[1]		Distance at Break	% Elongation	Mean	(psi)	Mean
			± g	%	± in	%	±	%					
PTFE 12	R-438A / 32 ISO 3GS		0.02	0.9	0.00	-0.6	-3	-3	3.41	700	711	2843	2695
			0.02	0.8	0.00	-0.5	-2	-2	3.47	712		2635	
			0.02	0.8	0.00	-3.3	-2	-2	3.98	814		2876	
			0.02	0.8	0.00	-0.2	0	0	3.27	672		2579	
			0.02	0.8	0.00	-1.1	-3	-3	3.19	656		2544	

APPENDIX H

Pyrohydrolytic Testing of 4AXH6 Desiccant Aged 14 Days at 180°F

Desiccant		R-22 Control			R-417A			R-422D		
IRI ID	Description	Sample ID	Fluoride (mg / g)	Chloride (mg / g)	Sample ID	Fluoride (mg / g)	Chloride (mg / g)	Sample ID	Fluoride (mg / g)	Chloride (mg / g)
D	3A 4AXH6 - neat	1	0.039	0.036	4	0.000	0.000	7	0.000	0.000
D 3GS	3A 4AXH6 - 3GS	2	0.035	0.035	5	0.000	0.000	8	0.000	0.000
D-MO	3A 4AXH6 - BWMO 2% BTPP	3	0.032	0.032	6	0.000	0.000	9	0.000	0.000
DA	3A 4AXH6 (75%)/activated alumina (25%) - neat	19	0.039	0.034	22	0.000	0.000	25	0.009	0.000
DA 3GS	3A 4AXH6 (75%)/activated alumina (25%) - 3GS	20	0.039	0.039	23	0.000	0.000	26	0.000	0.000
DA MO	3A 4AXH6 (75%)/activated alumina (25%) - BWMO 2% BTPP	21	0.039	0.037	24	0.000	0.000	27	0.000	0.000

Desiccant		R-424A			R-434A			R-438A		
IRI ID	Description	Sample ID	Fluoride (mg / g)	Chloride (mg / g)	Sample ID	Fluoride (mg / g)	Chloride (mg / g)	Sample ID	Fluoride (mg / g)	Chloride (mg / g)
D	3A 4AXH6 - neat	10	0.000	0.000	13	0.000	0.000	16	0.002	0.000
D 3GS	3A 4AXH6 - 3GS	11	0.000	0.000	14	0.000	0.000	17	0.002	0.000
D-MO	3A 4AXH6 - BWMO 2% BTPP	12	0.000	0.000	15	0.000	0.000	18	0.002	0.000
DA	3A 4AXH6 (75%)/activated alumina (25%) - neat	28	0.012	0.000	31	0.000	0.000	34	0.008	0.000
DA 3GS	3A 4AXH6 (75%)/activated alumina (25%) - 3GS	29	0.000	0.000	32	0.000	0.000	35	0.009	0.000
DA MO	3A 4AXH6 (75%)/activated alumina (25%) - BWMO 2% BTPP	30	0.000	0.000	33	0.000	0.000	36	0.011	0.000

Sample	Fluoride (mg / g)	Chloride (mg / g)
Desiccant, As Received	0.000	0.000
[1]120c Phosphate Rock	0.121	0.000

Oil	[2]TAN (mg KOH / g of sample)
3GS	0.024
200 2% BTPP	0.014

NOTES

[1]F and Cl content were determined by UOP method 3662 with measurements by Dionex ICS 2000. Calibration was performed with NBS Standard Reference Material 120c phosphate rock (Florida).

[2]The TAN values are pre-test results; oil samples were completely absorbed by the desiccant and no samples were available for post test TAN analyses.

Desiccant samples were aged in refrigerant/lubricant mixtures (95%/5% w/w).

Appendix I

Aged Thread Locker and Sealants

Controls - Unaged			
Loctite 620		Loctite 272	
Breakaway in/lb	Prevailing in/lb	Breakaway in/lb	Prevailing in/lb
120.0	57.0	100.0	56.0

Like New (LN) 30 Day Aged Thread Locker Assemblies									
Refrigerant	Lubricant	Loctite 620				Loctite 272			
		Breakaway		Prevailing		Breakaway		Prevailing	
		in/lb	± in/lb	in/lb	± in/lb	in/lb	± in/lb	in/lb	± in/lb
R-22	3GS	81.6	-38.4	25.0	-32.0	100.4	0.4	36.0	-20.0
	BWMO 2%BTPP	98.0	-22.0	45.0	-12.0	136.0	36.0	41.0	-15.0
R-417A	3GS	91.4	-28.6	40.0	-17.0	104.0	4.0	39.0	-17.0
	BWMO 2%BTPP	101.4	-18.6	54.0	-3.0	131.0	31.0	29.0	-27.0
R-422D	3GS	81.6	-38.4	24.4	-32.6	96.0	-4.0	46.0	-10.0
	BWMO 2%BTPP	92.8	-27.2	39.6	-17.4	82.4	-17.6	37.2	-18.8
R-424A	3GS	103.6	-16.4	32.0	-25.0	118.4	18.4	47.2	-8.8
	BWMO 2%BTPP	104.0	-16.0	42.0	-15.0	108.4	8.4	56.8	0.8
R-434A	3GS	85.4	-34.6	26.2	-30.8	110.0	10.0	43.0	-13.0
	BWMO 2%BTPP	78.0	-42.0	27.2	-29.8	96.8	-3.2	38.4	-17.6
R-438A	3GS	108.0	-12.0	52.0	-5.0	121.0	21.0	58.0	2.0
	BWMO 2%BTPP	89.6	-30.4	30.4	-26.6	96.8	-3.2	37.2	-18.8

Data shown is the average of 5 samples of each sealant in each refrigerant/lubricant mixture

Parallel (PT) R-22/Alternative Refrigerant 60 Day Aged Thread Locker Assemblies									
Refrigerant	Lubricant	Loctite 620				Loctite 272			
		Breakaway		Prevailing		Breakaway		Prevailing	
		in/lb	± in/lb	in/lb	± in/lb	in/lb	± in/lb	in/lb	± in/lb
R-22	3GS	84.2	-35.8	48.0	-9.0	125.4	25.4	74.4	18.4
	BWMO 2%BTPP	86.0	-34.0	39.6	-17.4	102.4	2.4	54.6	-1.4
R-417A	3GS	91.2	-28.8	35.0	-22.0	131.2	31.2	63.0	7.0
	BWMO 2%BTPP	97.6	-22.4	35.2	-21.8	136.8	36.8	61.0	5.0
R-422D	3GS	84.6	-35.4	48.4	-8.6	100.4	0.4	48.4	-7.6
	BWMO 2%BTPP	83.4	-36.6	44.6	-12.4	99.0	-1.0	42.4	-13.6
R-424A	3GS	89.0	-31.0	38.0	-19.0	93.6	-6.4	35.6	-20.4
	BWMO 2%BTPP	75.6	-44.4	31.2	-25.8	87.6	-12.4	41.2	-14.8
R-434A	3GS	90.4	-29.6	44.4	-12.6	106.6	6.6	43.8	-12.2
	BWMO 2%BTPP	74.2	-45.8	38.4	-18.6	104.6	4.6	42.6	-13.4
R-438A	3GS	87.6	-32.4	47.2	-9.8	122.2	22.2	71.0	15.0
	BWMO 2%BTPP	74.0	-46.0	32.6	-24.4	121.4	21.4	39.8	-16.2

Data shown is the average of 5 samples of each sealant in each refrigerant/lubricant mixture

Appendix J
Like New (LN) Tensile Properties 30 Day Aged Engineering Plastics

Polymer Controls	Cross Sectional (in^2)	Cross Sectional (mm^2)	Tensile lbs/in^2	Tensile kg/mm^2	Elongation %
PEEK	0.017	10.72	12741	8.96	125.4
Nylon 6,6	0.017	10.67	4957	3.48	342.5
Valox (PBT)	0.016	10.57	9743	6.85	404.2

Polymer	Refrigerant	Lubricant	After Aging Measurements: Tensile lbs/in^2	After Aging Measurements: Tensile kg/mm^2	After Aging Measurements: Elongation %	After Aging % Change: Tensile	After Aging % Change: Elongation %	# Samples Lost
PEEK	R-22	32 ISO 3GS	5728.7	11.13	119.7	-55.04	-4.52	
		BWMO 2% BTPP	5735.5	11.02	120.3	-54.98	-4.05	
	R-417A	32 ISO 3GS	5768.6	11.36	123.2	-54.72	-1.69	
		BWMO 2% BTPP	5762.9	10.89	118.3	-54.77	-5.64	
	R-422D	32 ISO 3GS	5838.7	11.30	120.7	-54.17	-3.68	
		BWMO 2% BTPP	5865.0	12.11	131.9	-53.97	5.22	
	R-424A	32 ISO 3GS	5894.5	11.25	120.1	-53.74	-4.21	
		BWMO 2% BTPP	5831.7	11.53	124.4	-54.23	-0.75	
	R-434A	32 ISO 3GS	5896.0	12.08	128.6	-53.72	2.60	
		BWMO 2% BTPP	5822.8	11.65	124.6	-54.30	-0.59	
	R-438A	32 ISO 3GS	6021.6	10.60	113.0	-52.74	-9.86	
		BWMO 2% BTPP	5868.3	12.01	127.4	-53.94	1.61	
Nylon 6,6	R-22	32 ISO 3GS	4713.8	7.46	80.1	-4.90	-76.61	
		BWMO 2% BTPP	585.0	0.46	5.1	-88.20	-98.51	2 of 4
	R-417A	32 ISO 3GS	3501.4	2.98	32.7	-29.36	-90.46	
		BWMO 2% BTPP	1550.6	0.79	8.7	-68.72	-97.47	
	R-422D	32 ISO 3GS	3503.3	20.17	217.3	-29.32	-36.55	
		BWMO 2% BTPP	3163.7	1.26	13.8	-36.17	-95.98	
	R-424A	32 ISO 3GS	3813.5	3.20	34.6	-23.06	-89.88	
		BWMO 2% BTPP	1366.6	0.71	7.7	-72.43	-97.76	
	R-434A	32 ISO 3GS	3940.9	11.29	121.1	-20.49	-64.65	
		BWMO 2% BTPP	1668.4	0.80	8.7	-66.34	-97.47	
	R-438A	32 ISO 3GS	3991.2	17.57	187.4	-19.48	-45.28	
		BWMO 2% BTPP	4076.0	11.16	120.1	-17.77	-64.94	
Valox (PBT)	R-22	32 ISO 3GS	754.2	0.43	4.6	-92.26	-98.86	
		BWMO 2% BTPP						4 of 4
	R-417A	32 ISO 3GS						4 of 4
		BWMO 2% BTPP	199.4	0.91	3.2	-97.95	-99.21	1 of 4
	R-422D	32 ISO 3GS	533.7	0.37	4.0	-94.52	-99.01	
		BWMO 2% BTPP	269.8	0.22	3.2	-97.23	-99.21	1 of 4
	R-424A	32 ISO 3GS						4 of 4
		BWMO 2% BTPP						4 of 4
	R-434A	32 ISO 3GS	414.0	0.29	3.0	-95.75	-99.26	
		BWMO 2% BTPP						4 of 4
	R-438A	32 ISO 3GS	364.9	0.30	3.2	-96.26	-99.21	
		BWMO 2% BTPP	484.6	0.63	6.7	-95.03	-98.34	2 of 4

Notes:

Controls were heat-aged in nitrogen

Unless otherwise noted, data shown is the average of 4 samples of each plastic after testing in each refrigerant/lubricant mixture.

Appendix K

Parallel (PT) R-22/Alternative Refrigerant Tensile Properties of 60 Day Aged Engineering Plastics

Polymer Controls	Cross Sectional (in^2)	Cross Sectional (mm^2)	Tensile lbs/in^2	Tensile kg/mm^2	Elongation %
PEEK	0.017	10.72	12741	8.96	125.4
Nylon 6,6	0.017	10.67	4957	3.48	342.5
Valox (PBT)	0.016	10.57	9743	6.85	404.2

Polymer	Refrigerant	Lubricant	After Aging Measurements			After Aging % Change		# Samples Lost
			Tensile lbs/in^2	Tensile kg/mm^2	Elongation %	Tensile	Elongation %	
PEEK	R-22	32 ISO 3GS	12914.4	9.08	123.2	1.36	-1.69	
		BWMO 2% BTPP	13306.7	9.36	89.6	4.44	-28.55	
	R-417A	32 ISO 3GS	12686.0	8.92	103.7	-0.43	-17.24	
		BWMO 2% BTPP	12799.8	9.00	120.5	0.46	-3.89	
	R-422D	32 ISO 3GS	12944.8	9.10	119.3	1.60	-4.83	
		BWMO 2% BTPP	12726.5	8.95	100.4	-0.11	-19.91	
	R-424A	32 ISO 3GS	12841.7	9.03	89.0	0.79	-29.02	
		BWMO 2% BTPP	13213.9	9.29	77.4	3.71	-38.28	
	R-434A	32 ISO 3GS	12812.7	9.01	127.2	0.57	1.45	
		BWMO 2% BTPP	12317.1	8.66	86.8	-3.32	-30.75	
	R-438A	32 ISO 3GS	13495.9	9.49	98.8	5.93	-21.17	
		BWMO 2% BTPP	12830.1	9.02	105.5	0.70	-15.87	
Nylon 6,6	R-22	32 ISO 3GS	5615.5	3.95	11.0	13.29	-96.78	
		BWMO 2% BTPP	2274.3	1.60	7.9	-54.12	-97.70	1 of 4
	R-417A	32 ISO 3GS	4676.8	3.29	9.4	-5.65	-97.24	
		BWMO 2% BTPP	1045.2	0.73	4.7	-78.91	-98.62	2 of 4
	R-422D	32 ISO 3GS	4298.3	3.02	8.7	-13.28	-97.47	
		BWMO 2% BTPP	2864.8	2.01	6.3	-42.20	-98.16	
	R-424A	32 ISO 3GS	3605.7	2.54	8.7	-27.26	-97.47	
		BWMO 2% BTPP	1309.6	0.92	5.5	-73.58	-98.39	3 of 4
	R-434A	32 ISO 3GS	3941.2	2.77	8.5	-20.49	-97.53	
		BWMO 2% BTPP	1926.7	1.35	5.9	-61.13	-98.28	
	R-438A	32 ISO 3GS	3259.1	2.29	7.7	-34.25	-97.76	
		BWMO 2% BTPP	2151.3	1.51	5.5	-56.60	-98.39	
Valox (PBT)	R-22	32 ISO 3GS						4 of 4
		BWMO 2% BTPP						4 of 4
	R-417A	32 ISO 3GS						4 of 4
		BWMO 2% BTPP						4 of 4
	R-422D	32 ISO 3GS	1075.2	0.76	2.4	-88.97	-99.42	2 of 4
		BWMO 2% BTPP						4 of 4
	R-424A	32 ISO 3GS	1134.0	0.80	2.9	-88.36	-99.29	1 of 4
		BWMO 2% BTPP						4 of 4
	R-434A	32 ISO 3GS	789.8	0.74	1.6	-91.89	-99.61	3 of 4
		BWMO 2% BTPP						4 of 4
	R-438A	32 ISO 3GS	813.7	0.57	5.5	-91.65	-98.64	3 of 4
		BWMO 2% BTPP						4 of 4

Notes:

Controls were heat-aged in nitrogen

Unless otherwise noted, data shown is the average of 4 samples of each plastic after testing in each refrigerant/lubricant mixture.

Appendix L
Valox 7, 15 and 30 Day Aging With R-22

Valox Tensile Test												
Oil	7-Days				15-Days				30-Days			
	ID#	Extension (in)	Breaking Point kg	Breaking Point lbs	ID#	Extension (in)	Breaking Point kg	Breaking Point lbs	ID#	Extension (in)	Breaking Point kg	Breaking Point lbs
3GS[1]	1	1.988	40	88.185	1	0.047	28	61.729	1	0.035	22	48.502
	2	2.193	44	97.003	2	0.063	32	70.548	2	0.032	18	39.683
	3	2.882	50	110.231	3	0.051	30	66.139	3	0.043	24	52.911
	4	1.551	32	70.548	4	0.051	30	66.139	4	0.039	22	48.502
BW[1]	1	0.252	48	105.822	1	0.047	32	70.548	1	0.035	22	48.502
	2	0.339	46	101.413	2	0.039	26	57.320	2	0.028	16	35.274
	3	0.28	50	110.231	3	0.035	26	57.320	3	0.032	22	48.502
	4	0.193	32	70.548	4	0.047	30	66.139	4	0.032	22	48.502
V-3GS[2]	1	0.504	48	105.822	1	0.079	40	88.185	1	0.028	14	30.865
	2	0.406	50	110.231	2	0.063	34	74.957	2	0.028	18	39.683
	3	0.201	48	105.822	3	0.059	30	66.139	3	0.016	8	17.637
	4	0.311	46	101.413	4	0.055	32	70.548	4	0.024	14	30.865
V-BW[2]	1	0.417	48	105.822	1	0.043	26	57.320	1	Insufficient Data - Test cylinder developed pressure leak.		
	2	0.299	46	101.413	2	0.043	26	57.320	2			
	3	1.327	34	74.957	3	0.039	24	52.911	3			
	4	1.102	34	74.957	4	0.043	28	61.729	4			

All samples aged with R-22 at 127°C under 275-300psig.

[1]As received samples

[2]Vacuum-dried samples

APPENDIX M

R-22 Thermal Stability Tube Observations

UNC26000 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-22	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							
	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	slight tarnish	yellow with particulates
		14	tarnish	dulled	tarnish	very tarnished	yellow with black particulates
						Before Aging	
							
		After Aging				After Aging	
							

APPENDIX M

R-22 Thermal Stability Tube Observations

C37700 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

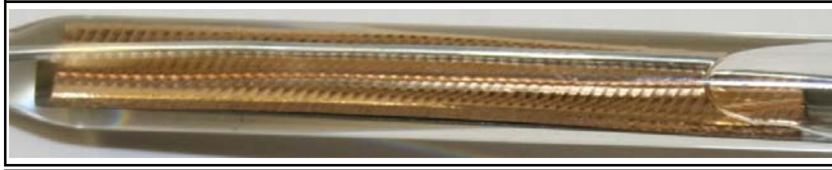
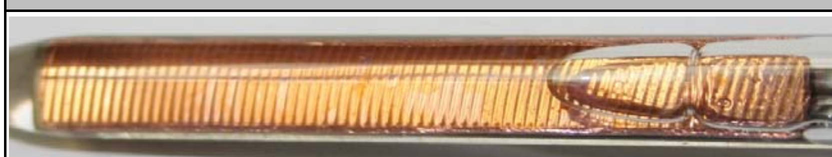
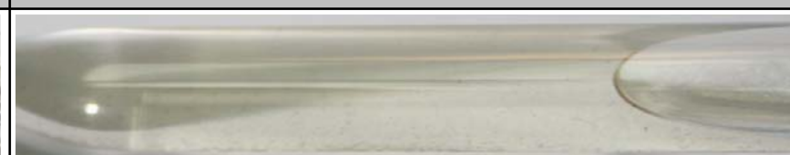
Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-22	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							
	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	tarnish	N/R	tarnish	N/R	particulates
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							

APPENDIX M

R-22 Thermal Stability Tube Observations

CDA C5400 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

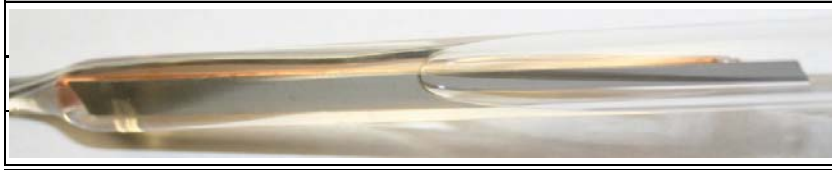
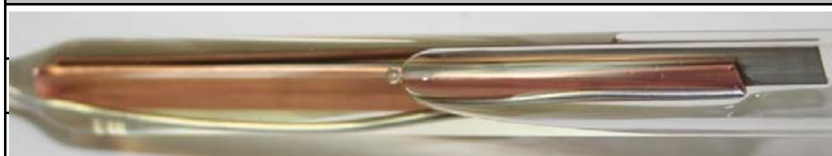
Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-22	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							
	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							

APPENDIX M

R-22 Thermal Stability Tube Observations

CDA120/AA1100/Sandvick 100 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-22	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				**Before Aging**	
							
		After Aging				**After Aging**	
							
	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				**Before Aging**	
							
		After Aging				**After Aging**	
							

APPENDIX M

R-22 Thermal Stability Tube Observations

PTFE DU Bearing Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

R-22

3GS

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-22	3GS	3	N/R	N/R	N/R	N/R	clear
		7	N/R	N/R	N/R	N/R	clear
		14	N/R	N/R	N/R	N/R	clear

Before Aging	Before Aging
	

After Aging	After Aging
	

BWMO 2% BTPP

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-22	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	clear
		7	N/R	N/R	N/R	N/R	clear
		14	N/R	slight tarnish	slight tarnish	N/R	clear

Before Aging	Before Aging
	

After Aging	After Aging
	

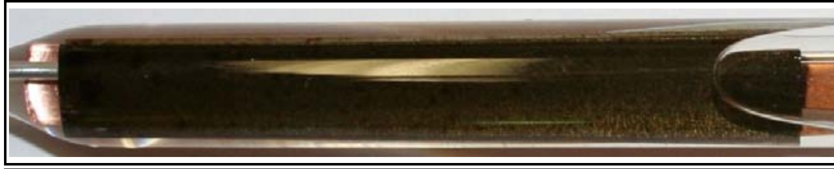
APPENDIX M

R-22 Thermal Stability Tube Observations

Lubrite Treated 20 Gauge Steel Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-22	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

Before Aging	Before Aging
	
After Aging	**After Aging**
	

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-22	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

Before Aging	Before Aging
	
After Aging	**After Aging**
	

APPENDIX M

R-22 Thermal Stability Tube Observations

SAE 794 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-22	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

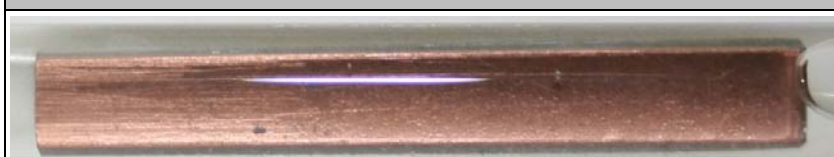
R-22 / 3GS

Before Aging	Before Aging
	

After Aging	After Aging
	

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-22	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

R-22 / BWMO 2% BTPP

Before Aging	Before Aging
	

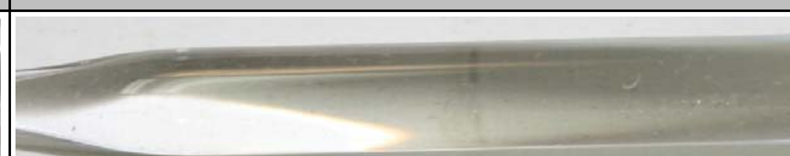
After Aging	After Aging
	

APPENDIX M

R-22 Thermal Stability Tube Observations

ZA-8 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

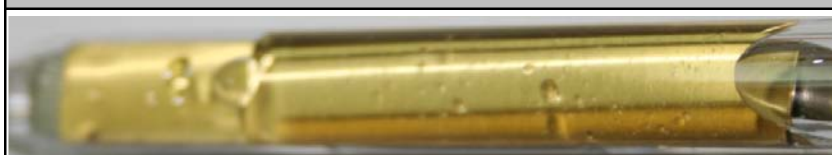
Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-22	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
			Before Aging			Before Aging	
							
			After Aging			After Aging	
							
	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
			Before Aging			Before Aging	
							
			After Aging			After Aging	
							

APPENDIX N

R-417A Thermal Stability Tube Observations

UNC26000 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

<table>
<tr><th>Refrigerant</th><th>Lubricant</th><th>Obs. Day</th><th>Test Coupon</th><th>Aluminum</th><th>Copper</th><th>Iron</th><th>Liquid</th></tr>
<tr><td rowspan="14">R-417A</td><td rowspan="7">3GS</td><td>3</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td></tr>
<tr><td>7</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td></tr>
<tr><td>14</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td></tr>
<tr><td colspan="4">Before Aging</td><td colspan="2">Before Aging</td></tr>
<tr><td colspan="4"></td><td colspan="2"></td></tr>
<tr><td colspan="4">After Aging</td><td colspan="2">After Aging</td></tr>
<tr><td colspan="4"></td><td colspan="2"></td></tr>
<tr><td rowspan="7">BWMO 2% BTPP</td><td>3</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td></tr>
<tr><td>7</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td></tr>
<tr><td>14</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td></tr>
<tr><td colspan="4">Before Aging</td><td colspan="2">Before Aging</td></tr>
<tr><td colspan="4"></td><td colspan="2"></td></tr>
<tr><td colspan="4">After Aging</td><td colspan="2">After Aging</td></tr>
<tr><td colspan="4"></td><td colspan="2"></td></tr>
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APPENDIX N

R-417A Thermal Stability Tube Observations

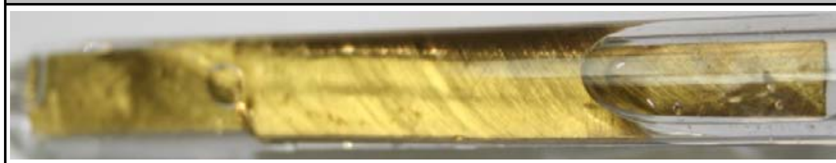
C37700 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-417A	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

R-417A, 3GS

Before Aging	Before Aging
	

After Aging	After Aging
	

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-417A	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

R-417A, BWMO 2% BTPP

Before Aging	Before Aging
	

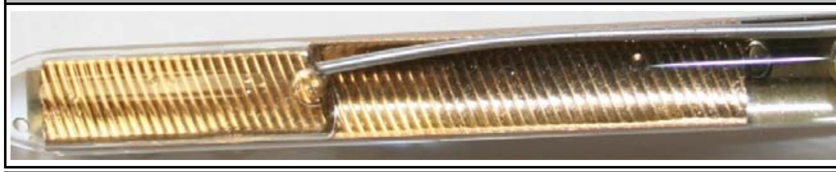
After Aging	After Aging
	

APPENDIX N

R-417A Thermal Stability Tube Observations

CDA C5400 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

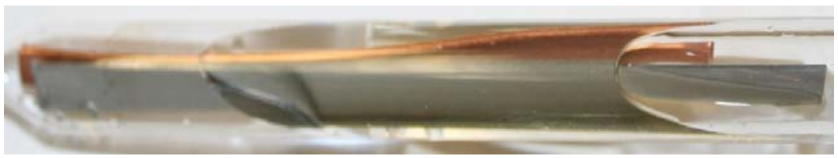
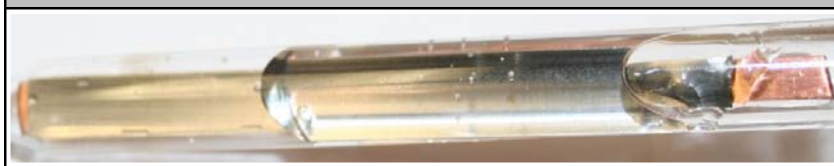
Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-417A	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							
	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							

APPENDIX N

R-417A Thermal Stability Tube Observations

CDA120/AA1100/Sandvick 100 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

<table>
<tr><th>Refrigerant</th><th>Lubricant</th><th>Obs. Day</th><th>Test Coupon</th><th>Aluminum</th><th>Copper</th><th>Iron</th><th>Liquid</th></tr>
<tr><td rowspan="14">R-417A</td><td rowspan="7">3GS</td><td>3</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td></tr>
<tr><td>7</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td></tr>
<tr><td>14</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td></tr>
<tr><td colspan="4">Before Aging</td><td colspan="2">Before Aging</td></tr>
<tr><td colspan="4"></td><td colspan="2"></td></tr>
<tr><td colspan="4">After Aging</td><td colspan="2">After Aging</td></tr>
<tr><td colspan="4"></td><td colspan="2"></td></tr>
<tr><td rowspan="7">BWMO 2% BTPP</td><td>3</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td></tr>
<tr><td>7</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td></tr>
<tr><td>14</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td></tr>
<tr><td colspan="4">Before Aging</td><td colspan="2">Before Aging</td></tr>
<tr><td colspan="4"></td><td colspan="2"></td></tr>
<tr><td colspan="4">After Aging</td><td colspan="2">After Aging</td></tr>
<tr><td colspan="4"></td><td colspan="2"></td></tr>
</table>

APPENDIX N

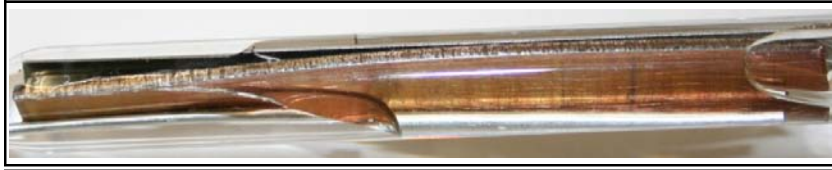
R-417A Thermal Stability Tube Observations

PTFE DU Bearing Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-417A	3GS	3	N/R	N/R	N/R	N/R	white/gray gel
		7	trace corrosion	trace corrosion	N/R	N/R	heavy gray gel
		14	slight corrosion	slight corrosion	See Appendix S Analysis		hazy
	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	clear
		7	trace corrosion	trace corrosion	Black spots	N/R	light yellow
		14	significant pit corrosion	significant pit corrosion	See Appendix S Analysis		light yellow with black particulates

3GS

Before Aging	Before Aging
	
After Aging	**After Aging**
	

BWMO 2% BTPP

Before Aging	Before Aging
	
After Aging	**After Aging**
	

APPENDIX N

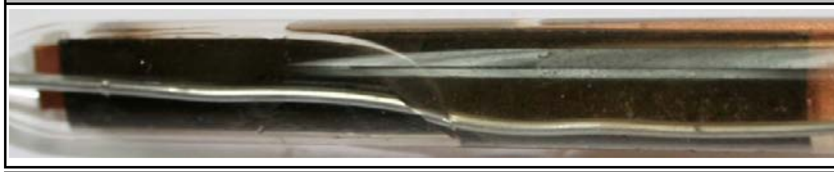
R-417A Thermal Stability Tube Observations

Lubrite Treated 20 Gauge Steel Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-417A	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

Before Aging | **Before Aging**



After Aging | **After Aging**

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-417A	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

Before Aging | **Before Aging**

After Aging | **After Aging**

APPENDIX N

R-417A Thermal Stability Tube Observations

SAE 794 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-417A	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

Before Aging / **Before Aging**

After Aging / **After Aging**

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-417A	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

Before Aging / **Before Aging**

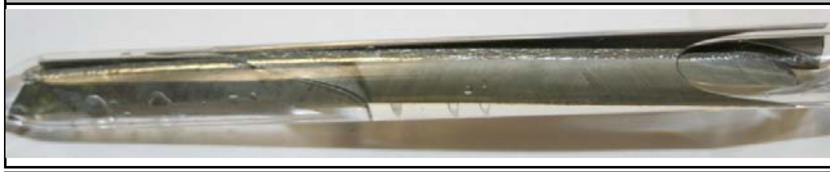
After Aging / **After Aging**

APPENDIX N

R-417A Thermal Stability Tube Observations

ZA-8 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-417A	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							
	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							

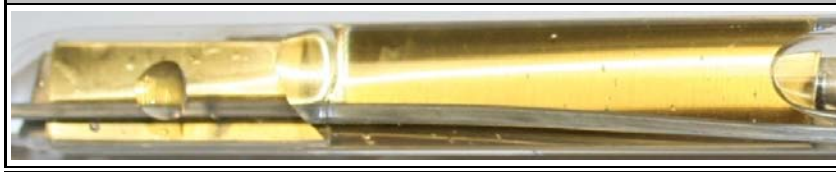
APPENDIX O

R-422D Thermal Stability Tube Observations

UNC26000 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-422D	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

Before Aging	Before Aging
	
After Aging	**After Aging**
	

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-422D	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

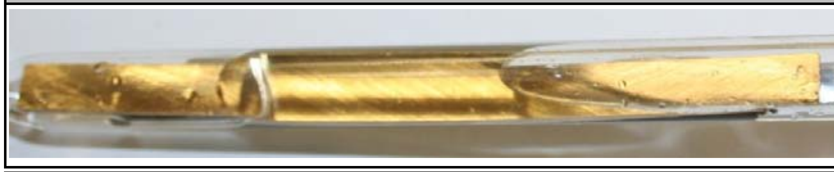
Before Aging	Before Aging
	
After Aging	**After Aging**
	

APPENDIX O

R-422D Thermal Stability Tube Observations

C37700 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-422D	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							
	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							

APPENDIX O

R-422D Thermal Stability Tube Observations

CDA C5400 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

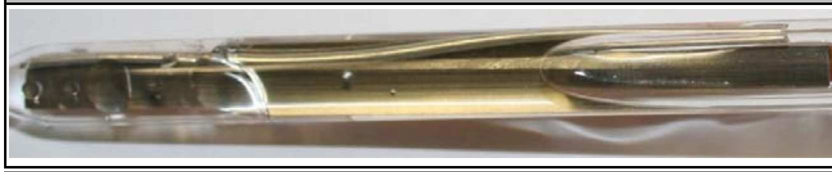
Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-422D	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							
	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							

APPENDIX O

R-422D Thermal Stability Tube Observations

CDA120/AA1100/Sandvick 100 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-422D	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							
	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							

APPENDIX O

R-422D Thermal Stability Tube Observations

PTFE DU Bearing Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-422D	3GS	3	N	N/R	N/R	N/R	clear
		7	N	N/R	N/R	N/R	grey gel
		14	light corrosion	light corrosion	liquid phase tarnish	N/R	dark gray gel
	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	clear
		7	N/R	N/R	N/R	tarnish	gray gel
		14	corrosion/tarnish	corrosion/tarnish	See Appendix S analysis		gray/white gel

3GS

Before Aging	Before Aging
	

After Aging	After Aging
	

BWMO 2% BTPP

Before Aging	Before Aging
	

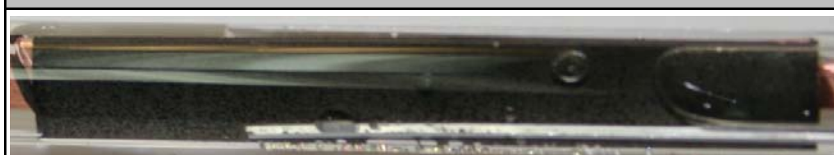
After Aging	After Aging
	

APPENDIX O

R-422D Thermal Stability Tube Observations

Lubrite Treated 20 Gauge Steel Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-422D	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							
	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							

APPENDIX O

R-422D Thermal Stability Tube Observations

SAE 794 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-422D	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							
	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							

APPENDIX O

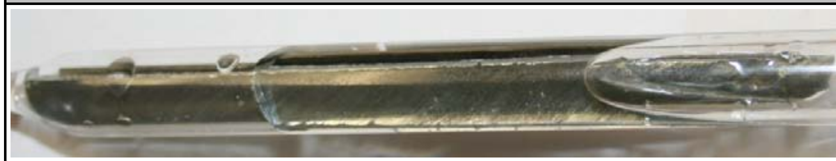
R-422D Thermal Stability Tube Observations

ZA-8 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-422D	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

Before Aging



Before Aging

After Aging

After Aging

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-422D	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

Before Aging

Before Aging

After Aging

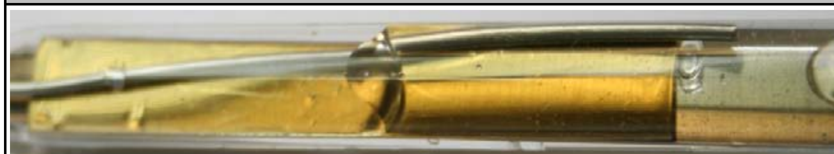
After Aging

APPENDIX P

R-424A Thermal Stability Tube Observations

UNC26000 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

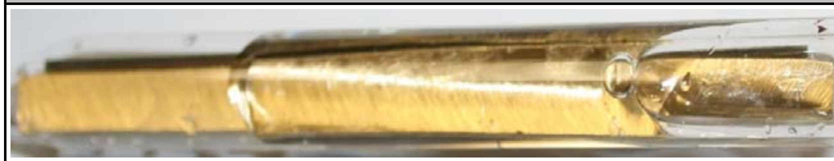
<table>
<tr><th>Refrigerant</th><th>Lubricant</th><th>Obs. Day</th><th>Test Coupon</th><th>Aluminum</th><th>Copper</th><th>Iron</th><th>Liquid</th></tr>
<tr><td rowspan="14">R-424A</td><td rowspan="7">3GS</td><td>3</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td></tr>
<tr><td>7</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td></tr>
<tr><td>14</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td></tr>
<tr><td colspan="4">Before Aging</td><td colspan="2">Before Aging</td></tr>
<tr><td colspan="4"></td><td colspan="2"></td></tr>
<tr><td colspan="4">After Aging</td><td colspan="2">After Aging</td></tr>
<tr><td colspan="4"></td><td colspan="2"></td></tr>
<tr><td rowspan="7">BWMO 2% BTPP</td><td>3</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td></tr>
<tr><td>7</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td></tr>
<tr><td>14</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td><td>N/R</td></tr>
<tr><td colspan="4">Before Aging</td><td colspan="2">Before Aging</td></tr>
<tr><td colspan="4"></td><td colspan="2"></td></tr>
<tr><td colspan="4">After Aging</td><td colspan="2">After Aging</td></tr>
<tr><td colspan="4"></td><td colspan="2"></td></tr>
</table>

APPENDIX P

R-424A Thermal Stability Tube Observations

C37700 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-424A	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							
	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							

APPENDIX P

R-424A Thermal Stability Tube Observations

CDA C5400 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-424A	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

R-424A – 3GS

Before Aging	Before Aging
	
After Aging	**After Aging**
	

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-424A	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

R-424A – BWMO 2% BTPP

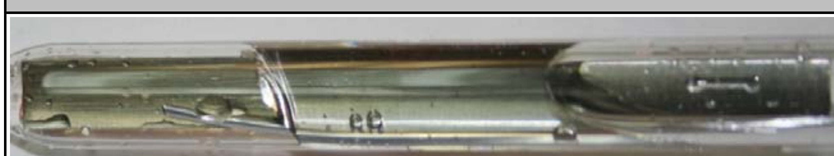
Before Aging	Before Aging
	
After Aging	**After Aging**
	

APPENDIX P

R-424A Thermal Stability Tube Observations

CDA120/AA1100/Sandvick 100 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-424A	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							
	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							

APPENDIX P

R-424A Thermal Stability Tube Observations

PTFE DU Bearing Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-424A	3GS	3	N/R	N/R	N/R	N/R	light gray gel
		7	N/R	N/R	N/R	N/R	light gray gel
		14	corrosion and pitting	corrosion and pitting	See Appendix S analysis		gray gel
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							
	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	light gray gel
		7	N/R	N/R	N/R	N/R	gray gel
		14	significant pitting/ major corrosion	corrosion	See Appendix S analysis		dark gray gel with black particulates
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							

APPENDIX P

R-424A Thermal Stability Tube Observations

Lubrite Treated 20 Gauge Steel Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

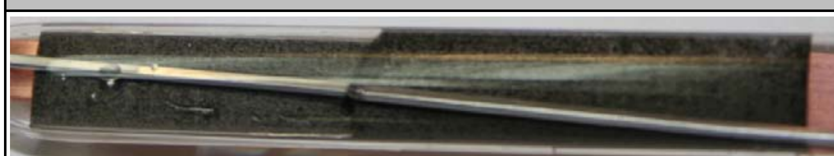
Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-424A	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

Before Aging	Before Aging
	

After Aging	After Aging
	

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-424A	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

Before Aging	Before Aging
	

After Aging	After Aging
	

APPENDIX P

R-424A Thermal Stability Tube Observations

SAE 794 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-424A	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

Before Aging	Before Aging
	

After Aging	After Aging
	

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-424A	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

Before Aging	Before Aging
	

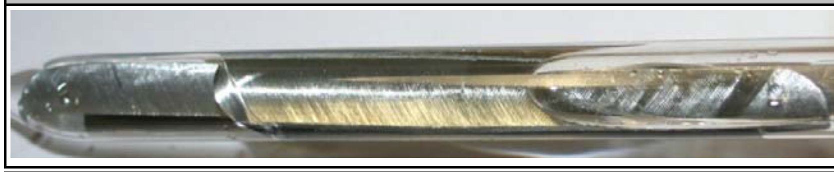
After Aging	After Aging
	

APPENDIX P

R-424A Thermal Stability Tube Observations

ZA-8 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-424A	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							
	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							

APPENDIX Q

R-434A Thermal Stability Tube Observations

UNC26000 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

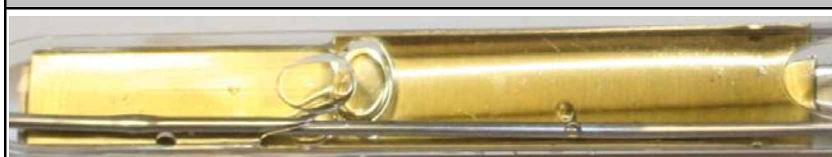
Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-434A	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

R-434A / 3GS

Before Aging	Before Aging
	

After Aging	After Aging
	

R-434A / BWMO 2% BTPP

Before Aging	Before Aging
	

After Aging	After Aging
	

APPENDIX Q

R-434A Thermal Stability Tube Observations

C37700 Test Coupon

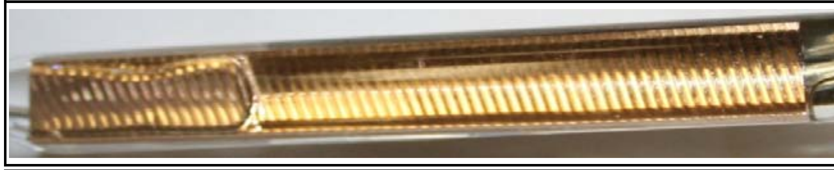
Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-434A	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							
	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							

APPENDIX Q

R-434A Thermal Stability Tube Observations
CDA C5400 Test Coupon
Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-434A	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

Before Aging	Before Aging
	

After Aging	After Aging
	

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-434A	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

Before Aging	Before Aging
	

After Aging	After Aging
	

APPENDIX Q

R-434A Thermal Stability Tube Observations

CDA120/AA1100/Sandvick 100 Test Coupon

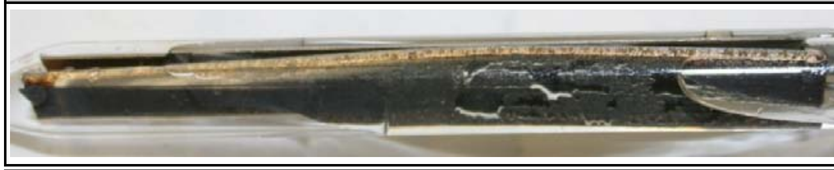
Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-434A	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							
	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							

APPENDIX Q
R-434A Thermal Stability Tube Observations
PTFE DU Bearing Test Coupon
Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-434A	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	tarnish and pitting	tarnish and pitting	N/R	N/R	N/R
		14	corrosion and pitting	corrosion and pitting	See Appendix S Analysis		N/R

Before Aging | **Before Aging**

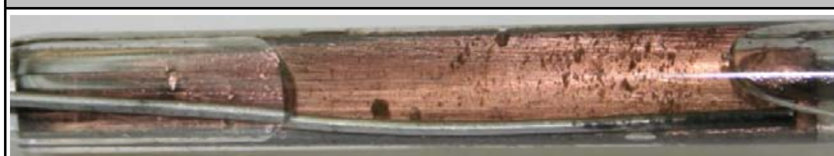


After Aging | **After Aging**

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-434A	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	gray powder-like
		7	tarnish and pitting	N/R	N/R	N/R	cloudy
		14	major corrosion	major corrosion	See Appendix S Analysis		cloudy gray gel

Before Aging | **Before Aging**

After Aging | **After Aging**



APPENDIX Q

R-434A Thermal Stability Tube Observations

Lubrite Treated 20 Gauge Steel Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-434A	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

Before Aging	Before Aging
	
After Aging	**After Aging**
	

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-434A	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

Before Aging	Before Aging
	
After Aging	**After Aging**
	

APPENDIX Q
R-434A Thermal Stability Tube Observations
SAE 794 Test Coupon
Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-434A	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							
	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							

APPENDIX Q

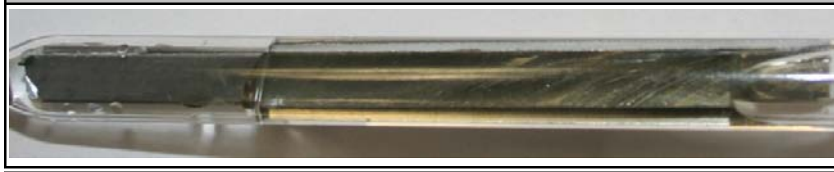
R-434A Thermal Stability Tube Observations

ZA-8 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-434A	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

Before Aging



Before Aging

After Aging

After Aging

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-434A	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

Before Aging

Before Aging

After Aging

After Aging

APPENDIX R

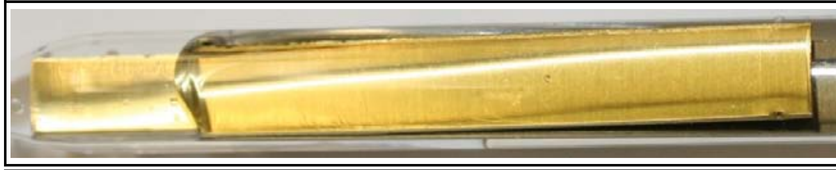
R-438A Thermal Stability Tube Observations

UNC26000 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-438A	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

3GS

Before Aging	Before Aging
	

After Aging	After Aging
	

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-438A	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

BWMO 2% BTPP

Before Aging	Before Aging
	

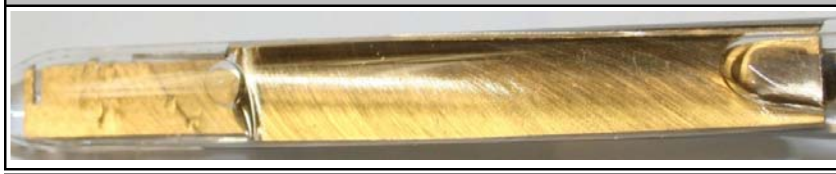
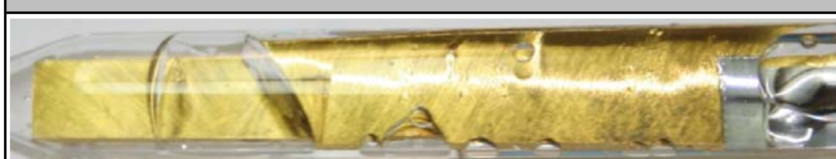
After Aging	After Aging
	

APPENDIX R

R-438A Thermal Stability Tube Observations

C37700 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

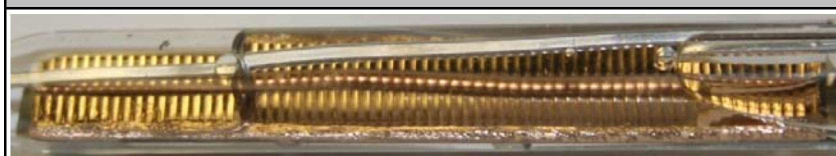
Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-438A	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							
	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							

APPENDIX R

R-438A Thermal Stability Tube Observations

CDA C5400 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-438A	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							
	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				Before Aging	
							
		After Aging				After Aging	
							

APPENDIX R

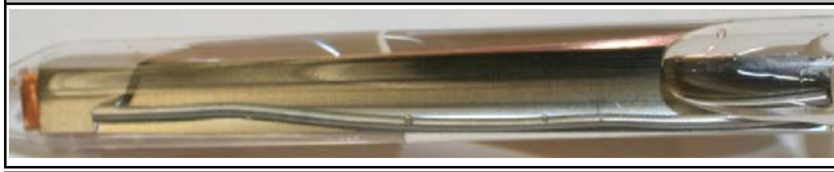
R-438A Thermal Stability Tube Observations

CDA120/AA1100/Sandvick 100 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-438A	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

3GS

Before Aging	Before Aging
	

After Aging	After Aging
	

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-438A	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

BWMO 2% BTPP

Before Aging	Before Aging
	

After Aging	After Aging
	

APPENDIX R

R-438A Thermal Stability Tube Observations

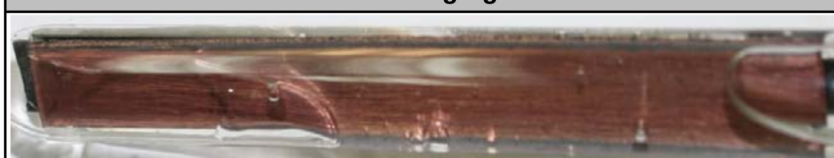
PTFE DU Bearing Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-438A	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	slight tarnish	slight tarnish	N/R	N/R	slightly cloudy
		14	slight pitting	slight pitting	See Appendix S Analysis		clear with some haze

Before Aging	Before Aging
	
After Aging	**After Aging**
	

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-438A	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	some corrosion	some corrosion	slight tarnish	N/R	clear and hazy
		14	corrosion and slight pitting	corrosion and slight pitting	See Appendix S Analysis		particulates and haze

Before Aging	Before Aging
	
After Aging	**After Aging**
	

APPENDIX R

R-438A Thermal Stability Tube Observations

Lubrite Treated 20 Gauge Steel Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-438A	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				**Before Aging**	
							
		After Aging				**After Aging**	
							
	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R
		Before Aging				**Before Aging**	
							
		After Aging				**After Aging**	
							

APPENDIX R

R-438A Thermal Stability Tube Observations

SAE 794 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-438A	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

Before Aging

Before Aging

After Aging

After Aging

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-438A	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

Before Aging

Before Aging

After Aging

After Aging

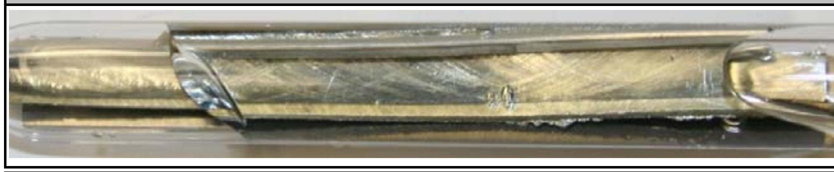
APPENDIX R

R-438A Thermal Stability Tube Observations

ZA-8 Test Coupon

Refrigerant/Lubricant Sample 50/50 (w/w) after Reaction at 175°C for 14 Days

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-438A	3GS	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

Before Aging	Before Aging
	

After Aging	After Aging
	

Refrigerant	Lubricant	Obs. Day	Test Coupon	Aluminum	Copper	Iron	Liquid
R-438A	BWMO 2% BTPP	3	N/R	N/R	N/R	N/R	N/R
		7	N/R	N/R	N/R	N/R	N/R
		14	N/R	N/R	N/R	N/R	N/R

Before Aging	Before Aging
	

After Aging	After Aging
	

APPENDIX S

Atomic Absorption Spectroscopy and TAN Results of Glass Sealed Tubes Displaying Corrosion

	Lubricant	TAN (mg KOH / g of sample)
As Received	3GS	0.024
	BWMO	0.014

Sample	Refrigerant	Lubricant	Copper	Iron	Lead	Aluminum	TAN (mg KOH / g of sample)
UNC26000	R-22	BWMO	0.607	5.020	0.740	2.520	1.155
C37700	R-22	BWMO	0.582	6.500	0.820	6.830	0.530
DU Bearing	R-22	3GS	0.084	0.011	0.400	1.470	0.144
		BWMO	0.043	0.010	0.170	1.550	0.149
	R-417A	3GS	0.020	0.007	0.320	1.230	0.143
		BWMO	0.042	0.896	2.090	9.700	0.206
	R-422D	3GS	0.043	0.003	1.180	1.620	0.158
		BWMO	0.054	0.001	1.400	3.500	0.600
	R-424A	3GS	0.032	0.026	0.410	3.070	0.162
		BWMO	0.121	0.078	3.550	5.310	0.175
	R-434A	3GS	0.024	0.000	0.000	2.020	0.166
		BWMO	0.054	0.001	1.400	5.480	0.153
	R-438A	3GS	0.030	0.000	0.530	2.600	0.135
		BWMO	0.043	0.150	0.800	2.400	0.145

Appendix T

Gas Chromatographic Area Counts of Refrigerants After Glass Sealed Tube Aging of DU Bearing Material at 175°C for 14 Days

Refrigerant	As Received		After exposure with DU material and 3GS		After exposure with DU material and BWMO	
	Area Count	%	Area Count	%	Area Count	%
R-417A	421394	99.5	1400606	99.5	23571	98.1
R-422D	303714	100.0	455171	98.6	69202	86.3
R-424A	345648	98.8	203406	99.8	300092	95.8
R-434A	4022289	99.4	420157	95.8	848332	99.6
R-438A	368585	100.0	307647	93.0	85838	100.0

APPENDIX U - Literature Survey

Date	Title	Author(s)
9/30/2009	Substitute Refrigerants Under SNAP	EPA Air and Radiation Stratospheric Protection Division
2009	Mobil-branded Refrigeration Lubricant Selection Guide	Exxon Mobil Corporation
1/10/2008	R-22 Phaseout: Timing, Alternatives and Implications for System Performance and Cost	Jim Lavelle, NRI
8/1/2009	R-22 Alternatives: Choices for 2010	Jim Lavelle, NRI
Oct-06	DuPont Refrigerants U.S. Refrigerants Cross Reference Guide	DuPont
9/6/2009	Vapour condensation of R22 retrofit substitutes R417A, R422A and R422D on CuNi turbo C tubes	José Fernández-Seara, Francisco J. Uhía, Rubén Diz and J. Alberto Dopazo
10/1/2003	Experimental comparison of R22 with R417A performance in a vapour compression refrigeration plant subjected to a cold store	C. Aprea and C. Renno
Apr-09	Thermodynamic Properties of DuPont ISCEON MO99	DuPont
6/8/2006	An Investigation of R417a as a Drop-in Alternative for R22 in a Residential Heat Pump	Zhiming Gao, Viun C. Mei, Fang C. Chen, John Tomlinson
2005	Energy Saving Refrigerant Blends Comprising R125, R134a, R600 or R600a	Neil A. Roberts, Rhodia UK Ltd. Development Laboratory
	MSDS - R-417A	National Refrigerants
7/3/2008	Environment Friendly alternatives to halogen refrigerants - A review	M. Mohanraj, S. Jayaraj, C. Muraleedharan
Aug-09	Service Guidelines HCFC R22 to HFC Refrigerant Blends	Tecumseh Products Company
2/21/2003	Replacement of R22 in Existing Installations: Experiences from the Swedish Phase Out	Anders Johansson, Per Lundqvist, Royal Institute of Technology
Feb-06	Retrofit Guidelines for DuPont ISCEON 9 Series Refrigerants (R-417A, R-422A)	DuPont
2008	R422D HEAT TRANSFER SYSTEMS AND R22 SYSTEMS RETROFITTED WITH R422D (WO/2008/079235)	E. I. DU PONT DE NEMOURS AND COMPANY [US/US]; 1007 Market Street, Wilmington, Delaware 19898 (US) *(All Except US)* . STRICKLAND, Roger Nicholas
1/29/2009	Thermodynamic analysis of R422 series refrigerants as alternative refrigerants to HCFC22 in vapour compression	Akhilesh Arora and H.L. Sachdev
10/17/2006	MSDS - R-422D	BOC Gases
Jan-06	Thermodynamic Properties of DuPont ISCEON MO29 (R422D)	DuPont
	MSDS - R-424A	Refrigerant Services, Inc.
3/7/2009	RS-44 (R-424A) General Information	Refrigerant Services, Inc.
	RS-45 (R-434A) General Information	Refrigerant Services, Inc.
	MSDS - R-438A	DuPont
Sep-09	Retrofit Guidelines for of DuPont ISCEON	DuPont
11/2/2009	The Professor: Retrofit R-438A	John Tomczyk Professor of HVACR at Ferris State University, Big Rapids MI
1/11/2005	Fluorocarbon, oxygenated and non-oxygenated lubricant, and compatibilizer composition, and method for replacing refrigeration composition in a refrigeration system	Barbara Minor, DuPont
8/21/2007	Refrigerant Composition	Neil Roberts, Owen Chambers, DuPont
8/12/2008	Refrigerant Composition	Neil Roberts, Owen Chambers, DuPont
8/4/2009	Compositions Comprising a Fluoroolefin	Barbara Minor, DuPont
1/5/2010	Refrigerant Compositions	Neil Roberts, Owen Chambers
4/1/2004	Refrigerant Blend	James Tieken
4/21/2005	Refrigerant with lubricating oil for replacement of R22 refrigerant	Kenneth Punder, Steffan Thomas JR
2/9/2006	Fine Particle Dispersion Composition and uses thereof	Thomas Leck, Douglas Spahr, Walter Mahler, DuPont
12/13/2007	Refrigerant Composition Containing Perfluoropolyethers	Thomas Leck, Thomas Saturno, Gregory Bell, DuPont
12/4/2008	Method of Determining the Components of a Fluoroolefin composition, method of recharging a fluid system in response thereto, and sensors used therefor	Barbara Minor, DuPont
11/26/2009	Phenol Stabilizers for Fluoroolefins	Velliyur Rao, Mario Nappa, Barbara Minor, Thomas Leck, Nandini Mouli, DuPont

APPENDIX U - Literature Survey

Date	Title	Author(s)
10/22/2009	PENTAFLUOROETHANE, TETRAFLUOROETHANE AND N-BUTANE COMPOSITIONS	Donald Bivens, Deepak Perti, DuPont
8/31/2004	Compositions of difluoromethane, pentafluoroethan, 1,1,1,2-tetrafluoroethane and hydrocarbons	Donald Bivens, Barbara Minor, Akimichi Yokozoki, DuPont
Sep-00	Refrigerant Use in Europe	Horst Kruse, Fellow ASHRAE
2007	Replacement Refrigerant for R22-Based Refrigeration Systems	Stefko Properties, LLC., Kenneth Ponder, Steffen Thomas
1/11/1994	Near-Azeotropic Blends for Use as Refrigerants	Donld Bivens, Mark Shiflett, Akimichi Yokozeki, DuPont
Aug-04	R-22 Replacement Status	J. Calm, P. Domanski
2008	ANALYSIS OF R434A (RS-45) APPLYING IN R22 AIR CONDIIONER SYSTEM[A]	Zhang Lei (Shanghai Hitachi Electrical Appliances Co.,Ltd.,201206)