Introducing
HCR – 188C
A Climate-Friendly Hydrocarbon Refrigerant For Safer, More Efficient Cooling

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A technological breakthrough in refrigeration, "HCR-188C" is a highly efficient hydrocarbon refrigerant with astonishing characteristics

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*** HCR-188C is the most "environmentally friendly" commercial refrigerant ever developed.**

*** HCR-188C is extremely energy efficient and will significantly reduce electrical power consumption in refrigerators, air conditioners, and other appliances.**

*** HCR-188C is the first hydrocarbon refrigerant to be approved for sale in the United States by the U.S. Environmental Protection Agency.**

*** HCR-188C can be retrofitted for use in most, if not all, existing refrigeration systems; including Air Conditioners, Refrigerators, Chillers, etc.**

*** HCR-188C can help slow global warming as it has a very low Global Warming Potential (GWP) of <5 over 100 years.**

*** HCR-188C can help reverse ozone depletion since it has a zero ozone depletion factor.**

*** HCR-188C was developed entirely in the USA using USA research, production, and testing companies.**

*** HCR-188C is currently undergoing EPA approval for use in automotive air conditioning systems, and once approved for use in new cars and as a drop in replacement retrofit for existing auto air conditioners, HCR-188C will improve gas mileage, lower the cost to recharge auto air conditioners, and result in a longer average life span for the engine.**

The current generation of energy consuming, inefficient, and environmentally damaging refrigerants has become obsolete with the advent of HCR-188C technology

Recent Milestones:

December 15, 2008 – Final EPA Completeness Determination was issued. EPA review was conducted under the Significant New Alternatives Policy (SNAP) program. HCR-188C is now approved for sale in the United States as a replacement for CFC-12 (R-12) coolant fluid in household refrigeration and air conditioning units.

April 14, 2008 – The inventor of HCR-188C, Richard Maruya, was honored with the 2008 Environmental Achievement Award from EPA's Region IX office.

June 7, 2005 – U.S. Patent 6,902,686 was awarded for HCR-188C, which is also patented in Japan, Korea, China, UK, France, and Germany, with other patents pending.

Favorable Characteristics of HCR-188C:

* Safer for the atmosphere: zero ozone depletion and < 5 global warming potential (GWP).
* Inherently safer in use: it lowers the flammability risk due to the smaller quantities needed.
* Uses one-quarter the mass of current compositions for same purpose.
* Resistant to leakage due to high molecular weight.
* Good solubility with refrigerant oils and lubricating oils, ensuring efficient circulation and therefore cooling.
* All research, development and testing, by the inventor and by independent companies under contract, has been performed within the United States.

An Introduction to HCR-188C:

Historically, chlorofluorocarbons (CFCs) have been used as refrigerants in air conditioners and refrigerators. CFCs have the advantages of safe incombustibility, high stability and low toxicity, but unfortunately destroy the ozone layer. In the past decade, the production and use of CFCs has been virtually abolished, replaced by various hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs). The latter compositions indeed present less degradation of the ozone layer, but have been shown to be strong greenhouse gases.

A. S. Trust & Holdings has developed a substitute hydrocarbon (HC) formulation, HCR-188C, that has been independently evaluated to have a zero ozone depletion potential (ODP) and a

GWP of less than 5 over the standard 100 year time horizon. HCR-188C is made from all naturally occurring substances approved for common use, including ethane, propane, isobutene, normal butane, isopentane, and normal pentane, adding hexane and heptane for specific applications. The key element to the performance is the exact proportions of these components. This substance can be used independently of CFCs and HFCs/HCFCs, and its cooling efficiency is such that compared to a full charge of the CFC R-12, just one-quarter the mass of HCR-188C is needed in a refrigerator or automotive air-conditioning system; similar results hold compared to the high-GWP formula HFC R-134a. A major safety improvement of HCR-188C over current HCs lies in its reduced charge rate compared to common propane/butane combinations. Another problem with current HFCs is decomposition upon leakage, which causes the HFC to become less efficient and require more frequent replacement. HCR-188C's higher molecular weight makes it less apt to leak through joints or o-rings; it also retains its cooling properties, extending the lifetime of the unit. A.S. Trust has been using HCR-188C for automotive and refrigerator cooling for over ten years.

Historical Perspective:

For decades, chlorofluorocarbons (CFCs) such as dichlorodifluoromethane and monochlorodifluoromethane were used as refrigerants in air conditioners, refrigerators, and freezers for consumer, industry and automotive use. The CFCs were effective in their function and displayed the advantages of safe incombustibility, high stability and low toxicity. Unfortunately, they were ultimately shown to have been rapidly contributing to the destruction of the ozone layer.

Restrictions on CFCs were enacted and their use was greatly reduced. Various alternatives with similar functionalities were developed in the form of hydrofluorocarbons (HFCs) such as 1,1,1,2-tetrafluoroethane and 1,1,1-trifluoroethane. These HFCs did not degrade the ozone layer to the same extent, but were still found to have an adverse effect on global warming. Thus, more recently there has been interest in developing hydrocarbon (HC) compositions that display similar properties but be non-fluoro- and non-chloro-based. Such compositions would not contribute significantly to destroying the ozone and/or causing global warming.

A.S. Trust & Holdings set out to develop one or more HC combinations for new coolant fluids that would be based on purely green chemistry, friendly to the climate and also energy efficient. Target applications included **cooling systems** such as those found in consumer (home) air-conditioning systems, commercial/industrial air-conditioning systems, and air conditioners for use in automobiles and other vehicles, refrigerators, freezers and beverage vending machines.

Previous Efforts:

Work has been done elsewhere in combining current HCs with small amounts of CFCs and HFCs/HCFCs for cooling applications. For example, Japanese Patent Application Public Disclosure No. HEI 01-139676(A) discloses working composites containing, as essential components, at least one selected from the group of HCs having a carbon number of 4-5, plus the

HCFC monochlorodifluoromethane and CFC monochloropentafluoroethane. The hydrocarbons having a carbon number of 4-5 are listed as n-butane, isobutene, cyclobutane, n-pentane, isopentane, and cyclopentane. Other hydrocarbon compositions are disclosed in Japanese Patent Application Public Disclosures Nos. SHO 54-6882(A), HEI 01-139677(A), and HEI 08-176536(A). Also, U.S. Pat. No. 6,336,333 describes a refrigerant mixture of propane and butane.

However, since these HCs have required operation in combination with some amount of CFCs and HFCs/HCFCs, they are still not very green and are undesirable from the standpoint of the environment. A.S. Trust & Holdings has therefore worked to develop a purely hydrocarbon blend based on naturally occurring substances that would be non-toxic and non-ozone-depleting. The result is HCR-188C, patented in the U.S. on June 7, 2005 and approved as of December 15, 2008 (per the EPA's Significant New Alternatives Policy (SNAP) program) for sale in the United States as a replacement for CFC-12 (R-12) coolant fluid in household refrigeration and air conditioning units.

HCR-188C has also been patented in Japan (July 2002), UK/France/ Germany (September 2003), Korea (August 2006), and China (June 2007). The goal is to also have HCR-188C approved for all the various applications described above, replacing not only R-12 but also R22 (due to the ozone depletion problems presented by both of those compositions), and R-134a (due to its global warming problems).

Significance for Green Chemistry:

HRC-188C improves on current refrigerant offerings as follows:

1) **It eliminates the pollutant impact** on the environment of previously employed CFC, HCFC and HFC chemicals, or of HCs combined with CFC and HFC/HCFC chemicals, particularly serving as a direct replacement for the coolant R-12, which has been mandated to be phased out of use by 2010, as well as for the most common refrigerants used today, HCFC R-22 and HFC R-134a.. As evaluated by Intertek ETL-SEMKO Division, an independent testing laboratory in Columbus, OH, the ozone depletion potential (ODP) of the HCR-188C blend has been calculated to be zero, due to the absence of any halogenated compounds, and its GWP has been calculated to be less than 5 over the standard span of 100 years.

2) **A.S. Trust & Holdings can readily transfer the technology** from its approved use in household refrigerators and freezers and residential and light commercial air-conditioning systems (window units only) to other cooling systems, including but not limited to usage in beverage-vending machines and air-conditioning systems for autos, trucks, railroad vehicles and civil aircraft.

3) **HCR-188C offers a cost-effective approach to (1) and (2)** compared to current CFC and HFC/HCFC use due to the combination of standard, naturally occurring, price-competitive chemicals including some or all of ethane, propane, isobutane, normal butane, isopentane, normal pentane, methane, hexane and heptane. Pound per pound, one-quarter the amount of HCR-188C can replace a full charge of currently used R-12. Operational testing has also demonstrated that systems running on HCR-188C use less energy while at the same time offering a greater degree of cooling than that of the traditional refrigerants.

Benefits to human health and the environment are evident during all aspects of HCR-188C's lifecycle. Synthesis of the formulation is a simple physical combination of these naturally occurring substances. As stated above, use of the coolant has zero impact on the ozone layer and an extremely small impact on global warming. End-of-life disposal of any unused or spent HCR-188C is simple: if the HCR-188C had been mixed with a small amount of oil or lubricant for its usage, disposal would simply involve mechanically filtering out any residual oil or lubricant and using the remaining mixture as a fuel on a par with propane (e.g., loaded into a small tank and used for an outdoor grill).

Per the Toxic Substance Control Act (TSCA), this is a non-toxic substance because it is a combination of previously approved naturally occurring substances.

Description of the HCR-188C Formulation and Properties:

The innovation of this chemical formulation lies in the exact proportions of the separate components, which comprise (at a minimum) propane, isobutane, normal butane, ethane, isopentane and normal pentane, with variations also containing hexane, methane and heptane. The hexane and heptane in the composition may include various types of isomers, such as n-hexane, 2-methylpetane, 3-methylpetane, 2,2-dimethyle butane, and 2,3-dimethyle butane and/or n-heptane, 2-methylhexane, 3-methylhexane, 2,3-dimethylpentane, 2,4-dimethylpentane and ethylpentane. Propane, isobutene and normal butane comprise 75% or more by volume of all the constituent components of the HC composition.

Experimentation and testing by the independent testing laboratories Intertek and Chemir Analytical Services (Maryland Heights, MO) have shown that the mutual interaction of the respective components, particularly with the addition of hexane, is such that the composition behaves like a single constituent and is highly resistant to decomposition. As such, the ignition temperature of the composition is at least equal to or greater than that of the individual components. Moreover, since its use for cooling is effective in quantities on the order of just two ounces in a household refrigerator, the resulting fire safety is therefore comparable to that of having two butane cigarette lighters in the kitchen.

Furthermore, this stability of the composition ensures that even if some HCR-188C were to leak outside of a cooling system, the respective proportions of the essential components would be maintained, and the operating efficiency would not deteriorate. This would offer another improvement over such current formulations as R-12, since less recharging of the system would be required.

Refrigerant and air-conditioning fluids are typically mixed with lubricating oils to minimize corrosion and wear on materials with which they come in operational contact. R-12 and R-134a are highly acidic and corrosive to aluminum; however, as a petroleum-based product, HCR-188C has no such corrosion issues, and requires very small amounts of oil for operation. It can also be used as a refrigerant without requiring mixing with any conventional refrigerants such chlorofluorocarbons, and runs with a near-zero wear-factor, as evidenced by visual inspection of systems that have used HCR-188C for more than ten years during its development and testing phases. In fact, the solubility properties of HCR-188C with both refrigerant and lubricating oils

keeps the internal structure of the cooling system exceptionally clean as it does not allow any oil to stay in a single location.

Test Results/Cost Comparisons with Existing Formulations

Since it is highly desirable to create environmental improvements at low costs, the primary goal of developing HCR-188C has been to develop a non-toxic formulation that can replace such CFCs, HCFCs, and HFCs as R-12, R22 and R-134a. To demonstrate success toward this goal, A.S. Trust contracted with the testing laboratory Intertek ETL SEMKO (Cortland, NY), Haier America (New York City, NY), a manufacturer of such home appliances as refrigerators and air-conditioners, and Valeo Engine Cooling's Vehicle Wind Tunnel facility (Jamestown, NY) to conduct a series of tests on HCR-188C and compare the results to those of a relevant HFC. The investigations looked at both material properties and efficiency performance, evaluating the formulation as a refrigerant in a household refrigerator-freezer and as a coolant in a vehicle air-conditioning system.

Using approved Department of Energy (DOE) standards as guidelines (DOE 10CFR PT 430-B-A1*AEI), Intertek tested both R-134a and HCR-188C to compare the energy consumption of the two formulations when used in electric refrigerators and electric refrigerator-freezers. The initial name-plate charge was 113 grams, so the tests were first conducted with 113 grams of R-134a. The appliance was then evacuated and charged with a direction replacement of HCR-188C of just 28.3 grams (25% by weight of the original formulation, less than 2 Tablespoons by volume). The results were as shown in Table 1:

Table 1: Results of Comparison Tests of Energy Consumption of R-134a and HCR-188C in a Refrigerator

Test Run	Test with R-134a	Test with 25% of rating plate charge of HCR-188C
Average Ambient deg F	89.5	89.3
Average Freezer deg F	4.0	-1.4
Average Refrigerator deg F	30.1	30.5
Average Voltage, volts	119.7	120.6
Average Current, amps	1.1	0.8
Total Power Input, watts	134.6	90.9
Compressor Discharge, deg F	131	136
Compressor Suction, deg F	5	55
Compressor Discharge, psig	-	135
Compressor Suction, psig	-	10

The results show that the refrigerator/freezer, when running with HCR-188C, draws only 68% of the total power required when running with the original R-134a. Moreover, not only is the average refrigerator temperature maintained within less than 1% difference, the average freezer temperature is improved (lowered) by more than 5 degrees F, all based on using one-quarter the original amount of refrigerant.

It is appropriate at this point to state that the results with HCR-188C show that using this material, ***employing only 25% of the original material by weight***, still required ***only 68% of the original power*** to function as well or better in thermal performance. Furthermore, comparing prices, a typical 2-ounce charge of R-134a costs $0.62, while the corresponding 0.5-ounce charge of HCR-188C (all that is needed) costs $0.20, i.e., ***at less than 1/3 the cost***. HCR-188C therefore costs less for manufacturers and saves energy for consumers.

Haier America confirmed this type of test result by pulling two refrigerators at random from their warehouse: a small cube-type (college dorm) model that includes a tiny freezer section and a large household refrigerator with a well-insulated, separate freezer. For both units, Haier used thermocouples to measure ambient temperature and temperature in the freezer and various locations in the refrigerator, first with the original R-134a refrigerant and then with that refrigerant drained, flushed and replaced with 25% by weight of HCR-188C. The results are shown in Tables 2 and 3.

Table 2: Cooling Performance of Small Cube Refrigerator Comparing Two Coolants

R-134a	**HCR-188C**
Ambient Temp 81.4 deg F	Ambient Temp 84.2 deg F
Freezer 27.1 deg F	Freezer 26.3 deg F
Top Shelf 31.5 deg F	Top Shelf 30.6 deg F
Mid Shelf 30.8 deg F	Mid Shelf 29.8 deg F
Bottom Shelf 34.5 deg F	Bottom Shelf 33.4 deg F

In the above test, all values for HCR-188C performance are better than those for R-134a.

Table 3: Cooling Performance of Large Refrigerator/Freezer Comparing Two Coolants

R-134a	**HCR-188C**
Ambient Temp 84.1 deg F	Ambient Temp 82.9 deg F
Freezer Top -1.7 deg F	Freezer Top -0.7 deg F
Freezer Bottom -2.7	Freezer Bottom -1.6
Top Shelf 36.4	Top Shelf 34.8
Mid Shelf Center 36.5	Mid Shelf Center 34.8
Mid Shelf Side 37.8	Mid Shelf Side 36.1
Bottom Shelf 37.8	Bottom Shelf 36.2

In the above test, all values for HCR-188C performance are within 2 degrees of the results with R-134a, yet the cost of materials would again be one-third, there would be no corrosion problems, and the global warming potential is extremely small.

Intertek also performed material-property testing on samples of R-12, R-134a (mixed with 1% R-12 as is common practice), and HCR-188C, with each formula combined with mineral oil and/or polyalkylene glycol as a lubricant. Testing was done according to Society of Automotive

Engineers (SAE) standard practices as found in SAE J1662, Compatibility of Retrofit Refrigerants with Air-Conditioning System Materials, and SAE J2670, Stability and Compatibility Criteria for Additives and Flushing Materials Intended for Use in Vehicle Air-Conditioning Systems Using R-134a (Proposed Draft). The results for the HCR-188C tests versus R-12 (per SAE J1662) complied with the standards for miscibility, wear-testing, and stability in the presence of copper, aluminum, nylon 66, PTFE in skived (thin) sheets, polymide and PBT. Linear swelling values of various o-rings were higher than that for the criteria, but A.S. Trust believes this property would actually create a softer, thicker form of the o-rings that would result in a tighter fit.

Material property results compared to those for a 99% R-134a/1% R-12 mixture (per SAE J2670) complied with the standards for viscosity, wear, and stability in the presence of copper, aluminum, iron, PTFE skived (thin) sheet, nylon 66, and various o-ring materials.

Actual vehicle cooling tests were performed by Valeo Engine Cooling at its Vehicle Wind Tunnel facility in Jamestown, NY. Here, a 2007 Toyota Camry air-conditioning system was tested using both the baseline R-134a coolant charge and HCR-188C. Prior to taking thermocouple readings at 35 locations in the vehicle, the Valeo technicians tested various charge values of HCR-188C; they determined that the discharge temperature stabilized at 60 deg F with values of 4.9 ounces and above, so the comprehensive testing was done with that quantity of refrigerant.

Data was recorded in the wind tunnel with the vehicle operating at 65 mph/running with load, at 25 mph/running with load, and at park/idle, all at an exterior temperature of 109 deg F with 20% humidity. Average temperatures of the interior air at the a/c discharge outlet were 54 deg F at 65 mph and 59.5 deg F at 25 mph; even at park/idle, the a/c temperature still stabilized at 80 deg F, cooling the car by almost 30 deg F. By comparison, the standard system required 18.6 ounces of R-134a to stabilize the a/c discharge temperature to 60 deg F, and at park/idle only maintained the interior temperature to the high 90s deg F.

Current Status:

A.S. Trust & Holdings Inc. holds the following patents for HCR-188C:
U.S. Patent No. 6,902,686, June 7, 2005, Hydrocarbon composition, and refrigerant and detergent consisting thereof; **Japan Patent** No. 3452915; **Korea Patent** No. 10-0619263; **China Patent** No. ZL03158406.3; **UK, France, Germany – EU Patent** No. 15149515; **Hong Kong Patent** No. HK1075911; with other patents pending.

A White Goods Letter of Completeness was issued December 15, 2008 for HCR-188C, making it legal to sell the formulation in the U.S. as follows: the Completeness Determination for SNAP Submission for HCR-188C is as a Refrigerant for Use in White Goods (Household refrigerators and freezers, and residential and light commercial air conditioning (window units only), as a replacement for CFC-12.

On April 14, 2008, Richard Maruya of A.S. Trust received the U.S. EPA Region IX 2008 Environmental Achievement Award for “innovative work developing the Hydro Carbon Refrigerant 188C (as) an environmentally safe and efficient alternative to the traditional hydrocarbon-based products harmful to the ozone layer.”

The Intertek company in Cortland, NY has been using HCR-188C in a plant refrigerator and is very pleased with its operation. In addition, Richard Maruya has been running the formulation in the air-conditioning system of a 1996 Toyota T100 truck for more than five years (60,000 miles) without having to recharge the system. Recently he took the compressor apart and examined the internal components under a magnifying glass; the filter had captured very little residue, the parts were spotless, and the o-rings and hoses were in excellent condition. A.S. Trust believes that a vehicle a/c system operating with HCR-188C would last a minimum of ten years.

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