



Coolant Purification System



**Introduction to the Patented Deionization Process
For Recycling Used Antifreeze**

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Glossary of Abbreviations

ASTM	American Society for Testing and Materials
CPS	Coolant Purification System
CFR	Code of Federal Regulations
EPA	Environmental Protection Agency
GM	General Motors
KFM	KFM, LLC – Manufacturer of the CPS
MSPP	Multi-Stage Purification Process
SARA	Superfund Amendment Reauthorization Act
STG	Service Technology Group of General Motors

EG	Ethylene Glycol
HD	Heavy Duty
RA	Reserve Alkalinity
SCA	Supplement Coolant Additive
TDS	Total Dissolved Solids
TSS	Total Suspended Solids

cm	centimeter
F	Fahrenheit
hr	hour
L	liter
m	meter

mg	milligram
mg/Kg	milligram per kilo gram
mg/L	milligrams per liter
min	minute
ml	milliliter
ppm	parts per million
um	micrometer
μS/cm	microsiemens per centimeter

ND	not detected
NDA	no data available
NR	not required
UC	under consideration

KFM Coolant Purification System * Patented Deionization Process**

Introduction

The subject of recycling used antifreeze/coolant is a popular and very complex issue. One of the greatest challenges facing today's automotive and industrial shops is complying with governmental regulations concerning the proper disposal of hazardous waste. In recent years, world attention has increasingly focused on Earth's delicate ecology and ways to restore and preserve the natural environment. This attention has been aimed at reducing sources of waste, producing more biodegradable materials, and recycling a larger portion of the materials we use. We have seen massive changes in business and industry to adapt and to provide products designed for these new markets. Recycling used antifreeze represents a viable alternative to disposal but poses technical challenges never before attempted.

This report describes a unique, multi-stage purification process for used engine coolant based on dual-bed deionization. The process can be effectively utilized in automotive or heavy-duty applications to remove inhibitors and contaminants in both ionic and particulate form.

Background

The deionization process and patents as applied to automotive coolants were developed by BG Products of Wichita, KS in the early 1990's. They initially marketed the product as the "Cool'r Clean'r" through their automotive fluids distribution network. That product eventually became the "CPS" or Coolant Purification System that, combined with its accompanying patents, evolved into the "stand-alone" company today known as:

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In 1991, through a series of tests, General Motors approved the BG Cool'r Clean'r for all of its vehicles. Under the American Society of Testing Materials Standards, the deionization process passed all testing. The report ended with this statement: "One point of interest is that BG/KFM's recycled coolant performed better in this test than GM's virgin antifreeze." The BG/KFM system was the only antifreeze recycling system approved by General Motors.

In 1993, the Mobility Technology Center-Belvoir (MTCB) approved the BG/KFM system and the Finish Thompson BE Coolant Recycling Systems Vacuum Distillation Process for the Department of Defense (DoD). These were the only systems that passed their very rigorous testing procedures. We have the supporting DoD documents that confirm these results.

During this period, former President Clinton issued Executive Order #12856. This order calls for the head of each Federal agency to develop voluntary goals to reduce the "total releases of toxic chemicals to the environment and off-site transfers of such toxic chemicals for treatment and disposal from facilities covered by this order by 50% by December 31, 1999." The Army has established a goal of 100% reduction for ethylene glycol waste. The most effective way to achieve this goal is by the onsite recycling of antifreeze.

In 1998, KFM was honored with GSA contract #7F-0075J extending through October 2003. Government agencies have the flexibility of ordering all equipment, chemicals, filters and supplies directly from KFM at (800) 736-1404.

In 1999, KFM renewed its contract with the Defense Supply Center Richmond, code SG9, to supply all requirements including complete machines, chemical additives, filters, parts, and accessories.

The remainder of this report provides specific information to support our belief that the KFM Coolant Purification System is the premier recycler on the market.

Why Recycle Used Antifreeze/Coolant?

ETHYLENE GLYCOL

- Ethylene glycol is the major constituent in antifreeze/coolant.
- Legislation has designated ethylene glycol a toxic chemical (SARA Title III Sec. 313).
- The Environmental Protection Agency defines used ethylene glycol as a hazardous waste (40 CFR 414.60).
- Former President Clinton's Executive Order #12856 calls for improved recycling and waste reduction, including reducing offsite transfers.
- The United States Army has established a reduction goal for ethylene glycol disposal of 100%.
- One way to achieve the goal is by the onsite recycling of antifreeze.

LEAD

- Lead is usually present in significant concentration (4 to 10 ppm) as a corrosion by-product from soldered joints.
- More than 5 ppm of lead makes antifreeze a hazardous waste (40 CFR 261.24).

ENVIRONMENTAL PROTECTION

- Finally, recycling can be done properly, thoroughly, and cost effectively to protect our environment from hazardous pollutants!

Approved Systems

As of March of 1998, these were the only two DoD approved systems.

Basic Comparison of the two DoD Approved Systems:

KFM	BE
Portable - No installation required	Must be hard wired – fixed location
150-180 gallons per hour	1 to 3.2 gallons per hour
Reduces hazardous waste by over 95%, Hazardous waste produced: spent filters	Hazardous waste produced: liquid distillation bottoms

Field Testing:

Both the BE and KFM units were field tested during FY97. Two installations received the KFM unit, two the BE unit. Each facility was trained on how to operate these systems. Thorough testing was done and records kept regarding suggestions and improvements. **The KFM unit was found to be “simple to use and the manual was easy to follow and understand”**. There were no negative comments.

Summary: The KFM unit is versatile, quicker, easier to operate, and generates less hazardous waste than the competition.

Non-DoD Approved Systems

Additional products for onsite recycling are currently available. Most of these consist of filtration systems that only remove particulate contamination in excess of the filter pore sizes. None of these filtration systems are approved by DoD. This includes filtration systems using chemical pretreatment.

In fact, a serious concern has been raised as to the effectiveness of filtration recycling. While particulates are adequately removed, corrosivity of the regenerated antifreeze is an issue. The remaining dissolved solids (iron, phosphates, sulfates, chlorides, and salts) may contribute to a continued corrosive environment that may not be relieved by adding new corrosion inhibitors. Since corrosion inhibitors are available in many formulations, there is a concern that when different formulas are mixed, the desired anti-corrosion chemistry may not be achieved.

KFM's Innovative Use of Specific Ion-Exchange Resin

The use of ion-exchange resins for the purification of water for everyday applications has a long history. Common uses include household areas with extremely hard (mineral laden) water, purification for production of semi-conductor chips, and modern kidney dialysis machines. However, the use of specific ion-exchange resins for the purification of used engine antifreeze represents a novel approach, which is complicated and technically challenging.

Used engine coolant from internal combustion engines contains a myriad of contaminants and components that render it a hazardous material and pose a problem of disposal. These include various glycols (i.e. ethylene, diethylene) which are poisonous to humans, corrosion inhibitor additives (many of which pose health and environmental hazards), as well as heavy metals such as lead, which are picked up mainly from soldered joints in the cooling system while the antifreeze is in service.

Shop owners and fleet managers are currently faced with increased pressure from the EPA, as well as state and local agencies, to properly dispose of spent antifreeze. This has created a need to recycle used antifreeze, but also created a dilemma for the people faced with making a decision about whether or not to recycle. Their concerns are: Does recycled antifreeze have the same quality as new antifreeze, and will it protect the cooling system? The answers to these questions are fully dependent on how the spent coolant is recycled.

Many “black box” units currently on the market simply filter the coolant through a conventional filter(s), add a concentrated inhibitor package, and return the coolant to service or for resale. This method does not address the vitally important technical concerns.

The KFM Coolant Purification System utilizes a combination of filtration and ion-exchange in a portable unit. Used antifreeze can be thought of as a cup of over-sweetened and stale coffee. Filtering the coffee cannot remove the extra sugar because it is soluble in its solvent or carrier (water). Other means of separation must be employed due to the solubility limits of the common additives used in antifreeze. Over concentrated, these additives can come out of solution to cause a variety of problems within the cooling system. **This is why the use of ion-exchange resins or other means of chemical separation is imperative in recycling used antifreeze.**

These resins are tiny beads consisting of an organic polymeric backbone with a charged terminal functional group attached. Usually these functional groups are specifically attracted to either positively charged ions (cations) or negatively charged ions (anions). When placed in a bed or column through which a solution of ions, in this case antifreeze, is passed through, the resins attract and then exchange ions with those in the solution.

Effectively, this solves the earlier stated problem in our example using the over-sweetened coffee. More realistically, it **solves the problem of purifying used antifreeze.**

The end product, ethylene glycol and deionized water, is then blended and brought to the desired freeze point. We then introduce a virgin corrosion inhibitor package which brings the product back to a “like new quality”. The system processes bulk used antifreeze efficiently: a 55 gallon drum in less than 20 minutes.



Dual resin bed deionization tanks

What Are Total Dissolved Solids?

Total Dissolved Solids (TDS) is a term of major importance concerning the issue of recycling antifreeze. Following is a definition of TDS and some significant facts you should know:

- TDS is a measure (usually in parts per million, or ppm) of the amount of dissolved or ionic species in coolants.
- The greatest contributor to TDS is the inhibitors dissolved in the coolant to protect against corrosion.
- Normal levels of TDS in new coolants range from 5,000 to 10,000 ppm.
- Normal levels of TDS in used coolants range from 10,000 to 30,000 ppm.
- TDS levels above 30,000 ppm have been known to aggravate water pump failure through face seal leaks. Additives can also come out of solution to clog cooling systems and plate-out on internal components, thus reducing heat transfer.
- The KFM Coolant Purification System reduces TDS levels below 150 ppm when the coolant is processed. Filtering systems actually increase TDS with the addition of concentrated inhibitor packages after recycling and may reach the TDS limit after only one or two services.

Examples of Dissolved Solids:

	SOURCE	PROBLEMS ASSOCIATED
ADDITIVES		
Borates, nitrates, nitrites, phosphates, silicates, azoles	antifreeze/SCA*/water (minor)	gel/deposits
CONTAMINANTS		
Calcium, magnesium	water	scale
Chloride, sulfate	water	corrosion
Formate, glycolate, acetate	glycol oxidation	corrosion

*Supplemental Coolant Additive

Patented Deionization Process

Removes Total Dissolved Solids, Including:

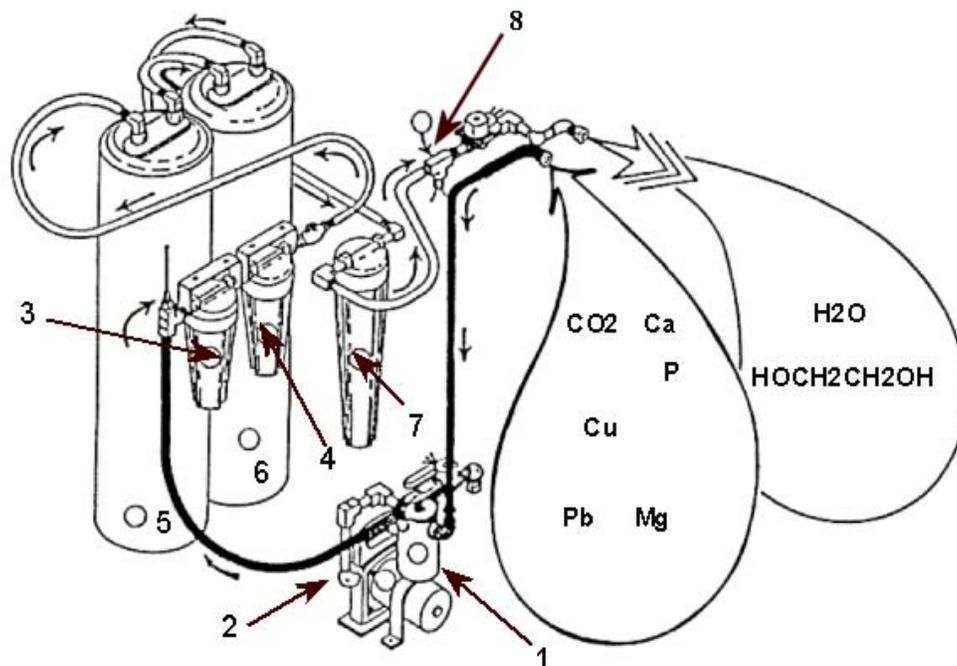
CATIONS POSITIVE IONS (+)	ANIONS NEGATIVE IONS (-)
Calcium	Chlorides
Magnesium	Sulfates
Sodium	Nitrates
Potassium	Carbonates
Iron	Bicarbonates
Manganese	Silica
Copper	Fluoride
Aluminum	Nitrate NO ₂
Ammonium	Nitrogen
Barium	Oxygen
Arsenic	Carbon Dioxide
Lead	Phosphorus
Cadmium	Sulfite
Mercury	Sulfur
Silver	Selenium
Chromium	Hydroxide
Zinc	
Hydrogen (Acid)	

CATION EXCHANGER	ANION EXCHANGER
H ⁺ ion	OH ⁻ ion
MINERAL FREE WATER HOH=H ₂ O=WATER	

Description of the KFM Multi-Stage Purification Process

The KFM Coolant Purification System was designed to purify used antifreeze/coolant through a multi-stage purification process (MSPP), combining successive stages of suspended solids and dissolved solids removal. Below is a simplified flow diagram of the MSPP where the graduated shading depicts the successive stages of purification.

MSPP Flow Diagram



Filtration begins with the intake and “Y” strainers (1) removing large particulates such as stop leak materials that are greater than 115 μm in size. The strainer’s main purpose is to protect the system pump (2) and to extend cartridge filter (3, 4) life. Cartridge filter (3) removes suspended solids greater than 20 μm is followed by a 1 μm cartridge filter (4). This protects the ion-exchange resins from organic fouling which renders the resins ineffective. Since oil can be a common engine contaminant, this is an important design concept.

After the filtration stages, the coolant, now free of particulates and heavy organics, flows into the cation exchange tank (5) where it flows evenly contacting the ion-exchange resin. All positively charged ions (cations) are replaced by hydrogen (H^+) ions during this stage. In stage 6, all negatively charged ions (anions) are exchanged for hydroxide ions (OH^-). The H^+ and OH^- ions exchanged in stages 5 and 6 combine to form water (H_2O) in an amount depending on the number of equivalents (moles of charge) of ions removed from the used engine coolant. The resulting purified fluid flows into a final activated carbon filter to absorb organics (7) and remove any entrained gases from the liquid stream.

Finally, the completely purified EG/H₂O mixture passes through an in-line conductivity probe (8) which measures the conductivity of the solution as an indication of the degree of purification by the ion-exchange system in stages 5 and 6. The probe is designed to show a green light when the conductivity is below 50 microsiemens per centimeter (µS/cm). This ensures high-quality effluent and also gives the operator a visible indication that the process is under control and that the ion-exchange beds have not exceeded their capacity. When the ion-exchange resins are exhausted, dissolved solids remain in solution and the conductivity of the effluent rises and quickly exceeds the set point of the probe assembly at 50 µS/cm. This trips the green light off and lights a red light, indicating to the operator that the ion-exchange tanks must be removed for regeneration and replaced with a fresh set of tanks. The µS/cm set point is normally reached within a few seconds after the beds have been exhausted, and maximum Total Dissolved Solids (TDS) at the 50 µS/cm point is 53 mg/L (as NaCl). Since glycol suppresses the conductivity of ions in solution, this suppression must be taken into consideration in all calculations of Total Dissolved Solids.

What is pH?

The pH of a solution is equal to the negative logarithm of its hydrogen-ion concentration in moles/liter. The pH scale runs from 0 to 14 where 0 indicates extreme acidity and 14 indicates extreme basicity.

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
(very acidic)							(neutral)			(very basic)				
			(vinegar)				(pure water)				(Ideal coolant)			
			(oranges)								(finished CPS AF*)			

*Finished Antifreeze (AF)/coolant produced with the KFM Coolant Purification System (CPS) and Treatment Kit.

What is Reserve Alkalinity?

Reserve Alkalinity is defined as the number of milliliters of 0.1N hydrochloric acid needed to titrate a 10.0 milliliter sample of antifreeze to a pH of 5.5.

Examples	Reserve Alkalinity
Depleted Antifreeze/Coolant	0 to 4
Typical Used Antifreeze/Coolant	4 to 6
New Automotive Antifreeze/Coolant	5 to 10
New Heavy-Duty Antifreeze/Coolant	6 to 20

Developments in Acceptable pH and RA Limits

TARDEC

July 1995- January 1998: According to TARDEC, the TACOM Research, Development, and Engineering Center in a report prepared for the U.S. Environmental Center, Aberdeen Proving Ground, a one year field test of the Cool'r Clean'r (now the KFM CPS) to determine performance revealed "no problems found at any participating installation". An earlier study had shown that the Cool'r Clean'r (CPS) "produces a product chemically compatible with and equal in performance to virgin military coolant" (MIL-A-46153). At the time, the accepted range for pH level was 9-12.

Manufacturer's Recommendation

According to the manufacturer of KFM's new one part corrosion inhibitor, the "1980's vintage coolant specifications, including the GM[®] 1825-M and 1899-M specifications, called for a minimum RA of 10. It is necessary to note that these specifications are no longer active specifications; GM has now moved to advanced coolant technologies that no longer follow these performance specifications."

June 1997 - "TMC RP-329, 330" (Technology and Maintenance Council of the ATA – American Trucking Association) "and ASTM specifications D-3306 and 4985 remain current. Unlike the above-mentioned GM specifications, the ASTM specifications are periodically updated and revised to reflect the state-of-the-art in coolant technology. In the past two years, coolant technology has been developed that provides superior corrosion and other cooling system protection at pH and RA values dramatically different from those that the industry was accustomed to. Acknowledging the capabilities of the new technology, ASTM removed the specific RA requirement from both the automotive (D-3306) and the Heavy-duty (D-4985) specifications. Some of the advanced technologies in the marketplace today exhibit low pH and/or RA values. These values should not be interpreted as weaknesses or as a suggestion of compromised quality. The reverse is true; the best and newest technologies are the lower pH and lower RA chemistries."

"Customers are strongly cautioned not to rely on antiquated, obsolete concepts and specifications when purchasing coolant inhibitors. The vast majority of coolants used or scheduled to be used in America's car, truck and bus factories are from the new family of products. Coolant users who continue to specify RA of 10 and high pH coolant will find themselves" trailing current technological advancements, denying themselves of the vastly improved benefits, reduced cost, and positive environmental impact that they offer.

TACOM

February 1997 and September 2001: According to TACOM, the U.S. Army Tank and Automotive Command, the military specification MIL-A-46153 has been cancelled, superseded by (commercial item description) CID-A-A-52624 and CID A-A-52624A. The new KFM one-part additive, P/N 570P meets the specifications of each.

TACOM now cites ASTM D-6210 as superseding ASTM D-3306 and D-4985 as the specification to which all ethylene glycol based automotive engine antifreeze, virgin or recycled, is required to comply. “This antifreeze is to be suitable for use in all administrative vehicles, construction and material handling vehicles and equipment, and military ground combat and tactical vehicles and equipment.”

Sources available upon request

Hazardous Waste and the KFM Coolant Purification System

ASTM (American Society for Testing and Materials) Rating - Meets or exceeds the requirements for **ASTM D-3306**, and more recently, **ASTM D-6210**

The filtration process consist of a filter screen, a prepump screen, two yarn filters (1 micron and 20 micron), two activated carbon filters, and two deionization tanks.

- **ACTIVATED CARBON FILTER:** Inert. No hazardous waste material produced.
- **PREPUMP SCREEN:** Inert. No hazardous waste material produced.
- **DEIONIZATION TANKS:** Inert. No hazardous waste produced if tanks are recharged and reused. Tanks can be recharged through KFM and transportation of the resin tanks by a DOT approved carrier is an acceptable procedure.
- **1 MICRON YARN FILTER,** less than one pound each: Possible lead contamination. Should be properly disposed of in the same manner that used oil filters are disposed.
- **20 MICRON YARN FILTER,** less than one pound each: Possible lead contamination. Should be properly disposed of in the same manner that used oil filters are disposed.



Coolant Purification Treatment Kit

Recycling Used Antifreeze/Coolant Conclusions

- Data presented in this brochure shows that the use of ion-exchange resins or other means of chemical separation is imperative in recycling used antifreeze/coolant.
- Even average levels of ethylene glycol oxidation products can be corrosive, especially to aluminum and these species must be removed in a viable recycling process.
- The removal of a large portion of Total Dissolves Solids (TDS) in a recycling process is key, both to minimize potential water pump failures and to ensure proper additive compatibility and shelf life.
- Efficient removal of TDS in engine coolant must also be accomplished by a recycling process in order to provide a consistent finished product.
- The combination of mechanical filtration and dual-bed deionization, such as that employed by the KFM Coolant Purification System, represents a sound technical process to purify used antifreeze/coolant.
- The patented KFM Coolant Purification System strips 95% of the used coolant back to essentially ethylene glycol and deionized water and re-inhibits to provide total cooling system maintenance.
- Recycled antifreeze/coolant produced by the KFM Coolant Purification System and Treatment Kit meets the general/performance requirements of American Society for testing and Materials (“ASTM”) D-3306 and all requirements of ASTM D-4656 for automotive antifreeze/coolant, and the general/performance requirements of ASTM D-4985 for heavy-duty antifreeze/coolant. The CPS meets the specifications in the newest accepted standard D-6210.
- **Recycled antifreeze produced by the KFM CPS complies with all requirements of the now outdated MIL-A-46153 and the new MIL-A-52624, which deemphasizes pH because of the advancements made in corrosion inhibitor technology.**

Contaminated * Purified *** Restored**

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