

# Examinations of Extended Life Heavy Duty Engine Coolant Filters

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## ABSTRACT

Since 1996 engine coolants and/or coolant management programs that offer extended service have been heavily promoted. Coolant chemistry is often affected by both depletion and dilution of important protective additives. Two different strategies are prevalent in the marketplace. The first utilizes advanced fully formulated conventionally inhibited ethylene glycol coolants with a controlled-delivery coolant filter that both filters the fluid and provides replenishment of corrosion inhibition chemistry as the coolant ages to greatly extend the life of the coolant compared to earlier practices. The second alternative employs the use of ethylene glycol inhibited with fully formulated chemistry dependant on aliphatic or cyclic carboxylic acids that are sometimes combined with inorganic inhibitors (sometimes called organic acid or hybrid organic acid technologies). The success of this approach is dependant on these inhibitors depleting at such a slower rate, so that they need less maintenance, and in the coolant being maintained to prevent dilution of the coolant with water or alternatively inhibited coolants.

Because engine coolant filters are not necessary as additive delivery devices in coolants inhibited with carboxylates, some users have omitted (new production) or removed (existing units) coolant filters from vehicles operating on carboxylate coolants. This was done to reduce cost. However, earlier studies<sup>1</sup> found that the value of coolant filtration extends beyond their convenience as additive delivery devices. The authors pondered the potential negative effects on system reliability when the filters from heavy-duty diesel engines are removed. To date, it has not been suggested that removing diesel fuel, transmission fluid, or engine lubricant filters would be cost-effective. The authors question if coolant systems are fundamentally different?

This paper reports the findings of over seventy heavy-duty coolant filters that were gathered at random from the diesel engine community. Each filter was opened,

carefully examined and the condition of the media and additive (if it contained additive) documented to develop data leading to the determination of the value of coolant filtration to heavy-duty engine coolant systems using any modern engine coolant. It was important to understand if the overall systems has changed since the last such investigation was published in 1988, or if the findings of that paper continue to be valid in today's modern cooling systems.

## INTRODUCTION

Beginning about 1990, heavy-duty diesel engine fleets began practicing various strategies that reduced coolant change intervals and maintenance costs. By 2001 many fleets had achieved the elimination of coolant change intervals before engine overhaul (up to 1 million miles or 25,000 hours) through the adoption of engine coolant compliant with ASTM D 6210 'Standard Specification for Fully-Formulated Glycol-Base Engine Coolant for Heavy-Duty Engines'.<sup>i</sup> Several diesel engine OEMs have openly accepted this practice when properly executed.

Previous to the introduction of extended service (ES) practices, filters were replaced about six times a year. Modern ES filters are remaining in service at least a year, and one in this review had been in service over three years! Clearly, the construction of the ES filters had to change to provide the dramatically longer service life. These changes include more robust cans, innovative polymer filtration media, and wire mesh reinforcements.

Beginning in 1996 General Motors and Caterpillar began to adopt and market engine coolants that offer extended service. These two programs employ ethylene glycol inhibited with organic acids, specifically formulations based on such carboxylates as 2-ethylhexanoic acid and/or sebacic acid with tolyltriazole. The promotion of these new products focused attention on existing

competitive maintenance practices and products. One existing approach, offered by multiple manufacturers, utilizes advanced fully formulated conventionally inhibited ethylene glycol coolants with a controlled-delivery coolant filter that both filters the fluid and provides replenishment of corrosion inhibition chemistry as the coolant ages to greatly extend the life of the coolant. Earlier practices involved routine addition of supplemental coolant additive (SCA) on a time & mileage basis. Those practices, properly executed, were very effective in protecting engines, but the concentration of inorganic inhibitors increased quickly and the coolant had to be changed about every two years.

Most fluids in the cooling system are filtered to remove particulates that negatively impact the reliability and longevity of the system. The fuel, crankcase, and transmission fluids are always full-flow filtered. Diesel engines have traditionally been fitted with bypass coolant filters. Some filters are engineered to be attached to the engine itself, others are added as remote devices in the system. The filters usually contain coolant additives, although some fleets found the use of "blank" coolant filters and liquid SCAs to be more cost-effective. Because engine coolant filters are not necessary as additive delivery devices in various new coolants, some users have omitted (new production) or removed (existing units) coolant filters from vehicles operating on ES coolants. This was done to reduce cost. However, earlier studies found that the value of coolant filtration extends beyond their convenience as additive delivery devices. The authors pondered the potential negative effects on system reliability if the filters from heavy-duty diesel engines are removed.

This paper reports the findings of over seventy heavy-duty coolant filters that were gathered at random from the diesel engine community. Each filter was opened, carefully examined and the condition of the media and additive (if it contained additive) documented to develop data leading to the determination of the value of coolant filtration to heavy-duty engine coolant systems using any modern engine coolant. It was important to understand if the overall systems has changed since the last such investigation was published in 1988, or if the findings of that paper continue to be valid in today's modern cooling systems.

## MAIN SECTION

### BACKGROUND:

Light duty cooling systems (i.e. passenger cars and light trucks) are generally serviced at intervals of 2 years (24,000 miles w.c.f.) to 5 years (100,000 to 150,000 miles w.c.f.) by simple draining and replacing of the coolant with fresh coolant most commonly 50% antifreeze and 50% water. This maintenance interval would be inadequate for

heavy-duty diesel vehicles because conventional coolant additives critical to satisfactory protection of engine components deplete. Heavy-duty engine coolants have traditionally contained inorganic corrosion inhibitors, some of which deplete as the coolant ages and wears in use. Nevertheless, the coolants have always been left in service longer than light duty coolants, a practice made possible by coolant system maintenance practices employing supplemental coolant additives (SCAs) at OEM-specified time & mileage intervals. These additives are commercially available as liquids, or in filters. Filters with additives may be available with quick dissolving or in various controlled delivery technologies that provide protection for a year or more between filter changes.

The industry has expressed a desire to further extend coolant service life. In response to user demand, suppliers have responded with optimized extended life filter technologies and/or new coolant chemistries that use somewhat more expensive, but longer lasting, inhibition chemistries. Some users have, in light of claims made by extended service coolant manufacturers, elected to omit coolant filters from their diesel engines entirely. It is true that coolant filters are usually bypass (as opposed to full flow) filters and as such not all of the coolant in the stream is filtered with each pass. It is also true that many users consider coolant filters as nothing more than a convenient delivery device for SCAs. In spite of these facts, experience and earlier publications<sup>ii</sup> beg investigation of the benefits that the filters may provide cooling systems that are unrelated to coolant chemistry. What is happening in newer, extended service coolants and extended service filters? The authors ponder the question, "Is the filtration role, in and of itself, a necessary and beneficial function?"

It is appropriate, and perhaps helpful, to review some of the major coolant technologies that have been selected by OEMs for factory-fill or branded aftermarket supply. Most OEM companies invest impressive amounts of time and money to develop, test and purchase engine coolants. Therefore, when a coolant is selected it is accorded a certain prestige and importance in the marketplace. It will be upon these coolant families that the authors will base the discussion in this paper.

### DISCUSSION:

The authors will introduce the discussion by offering a self-developed terminology to assist in grouping somewhat similar ES technologies together. These groups are justified in that coolants within the families perform as well together in ASTM standard performance test protocols (i.e. ASTM D3306, "Standard Specification for Glycol Base Engine Coolant for Automobile and Light-Duty Service") and additional OEM standard test protocols (i.e. Ford Galvanostatic Pitting, Cummins Hard Water Scale) testing as each of the coolants alone. Note that these inhibition technologies, and the terminology apply equally

to inhibited ethylene glycol, propylene glycol, or 1,3 Propanediol (PDO).<sup>iii</sup> For example, if one were to purchase and test two coolants per ASTM D4340 “Standard Test Method for Corrosion of Cast Aluminum Alloys in Engine Coolants Under Heat-Rejecting Conditions” and if various mixtures of the two coolants each preformed as well as either coolant independently, then the authors argue that they are so compatible as to be members of the same family. If, on the other hand, performance of any mixture is observed to be poorer than either technology alone, the authors argue to classify them as somewhat different, although not necessarily “compatible” or “incompatible” (terms yet to be defined by ASTM or any other standards-setting organization). The authors propose three nomenclature classifications:

1. **Conventional** coolants; those commonly formulated with a combination of inorganic inhibitors, most commonly including nitrite, nitrate, phosphate and silicate.
  
2. **Hybrid** and **Carboxylate** coolants; those commonly using a cyclic or aliphatic carboxylic acid as a primary corrosion inhibitor. Industry experts differ on the where a ‘carboxylate’ becomes a ‘hybrid’.

There are also different types of coolant filters in the marketplace. Most contain coolant additive (SCA) or extender in a dry form that, once properly installed, delivers a measured weight of replenishing additive to the coolant within a few hours of normal operation. A properly formulated SCA will quickly dissolve in the coolant and provides a significant benefit to the cooling system, thereby extending the life of the coolant and reducing the overall cost of cooling system maintenance. Another type of coolant filter contains no additives. In this case the user, in compliance with the recommendations of the coolant and/or engine manufacturer, must maintain the coolant chemistry manually. These filters would be the most appropriate types for some “extended service” coolant technologies. Finally, there exist sophisticated extended service filters. These filters deliver replenishing additives to conventionally and some hybrid coolants either through time-release or delayed release technology. In this way a robustly constructed filter may stay in service a year or more, providing extended coolant life benefits, protection in the event of minor coolant dilution or contamination, and waste reduction all while being very cost-effective.

Filters removed from service were solicited from various users. In addition to filters, the type of vehicle, mileage and coolant brand information were requested. Over a period of a year the filters trickled in. As they were received each filter was photographed, catalogued, and then carefully opened and inspected. The filters were

photographed as they were dissected to record the condition of the various components. The media was removed as completely as possible from the filter and washed in deionized water. The wash typically contained insoluble particles, but it was heated and stirred to minimize undissolved matter, permitting the best possible analysis of entrapped matter. The wash water was then analyzed for anions by ion chromatography (IC) per ASTM D5827 modified to include additional anions) then by ion coupled plasma chromatography (ICP) per ASTM D6130. Finally, many current coolants use carboxylic acids and azoles in their inhibitor packages. Amalgatech have developed a method to analyze for these inhibitors employing high performance liquid chromatography (HPLC) in a dual gradient-pump equipped Dionex HPLC instrument. The data were recorded in a standard format and then later assembled into a spreadsheet for convenience in discovering trends and for statistical determinations.

The pictures in Figure 1 through Figure 4 reflect the stages of dissection of two types of coolant filters. Any remaining SCA is collected as carefully as possible to estimate the remaining undelivered SCA (if any) by weight. The filtration media is evaluated for oil and deposits (Figure 4) and when insolubles were found they were examined microscopically and photographed (Figure 5).

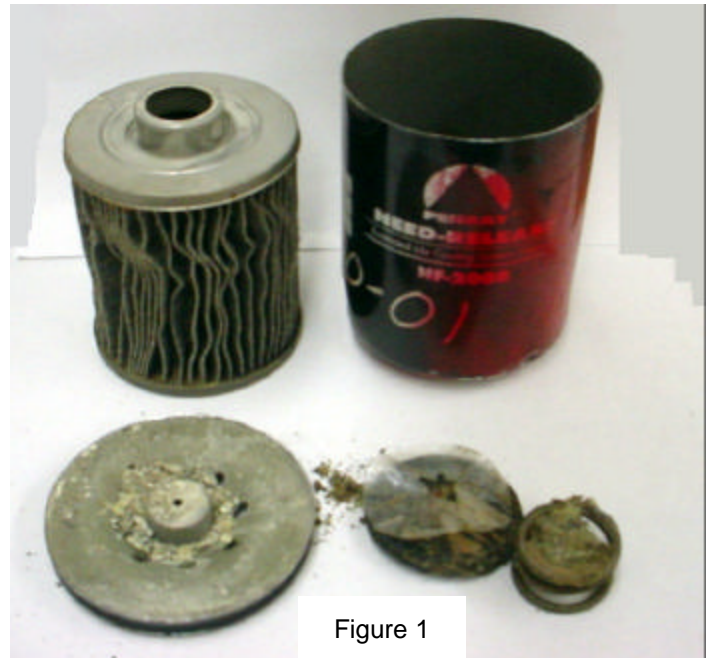


Figure 1

The first two photos were taken of a Penray Need-Release<sup>®</sup> coolant filter. This is a product first introduced about 1988 and has evolved since then with the changing coolant technologies. Since then, other approaches have been introduced. Another technology that was frequently sent from the field was Fleetguard’s ES filter (Figure 4). This filter was different from the Need-Release in that it had a different media support system and employed

Figure 2

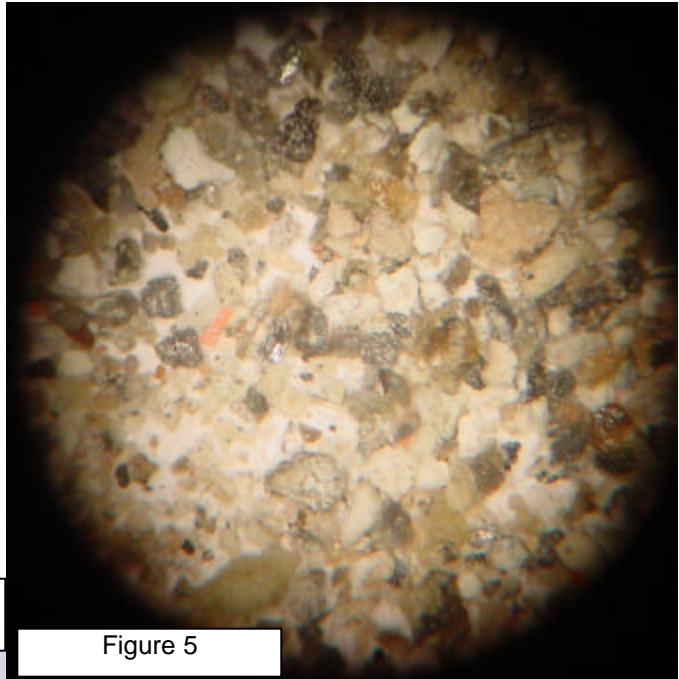


Figure 3

Figure 5

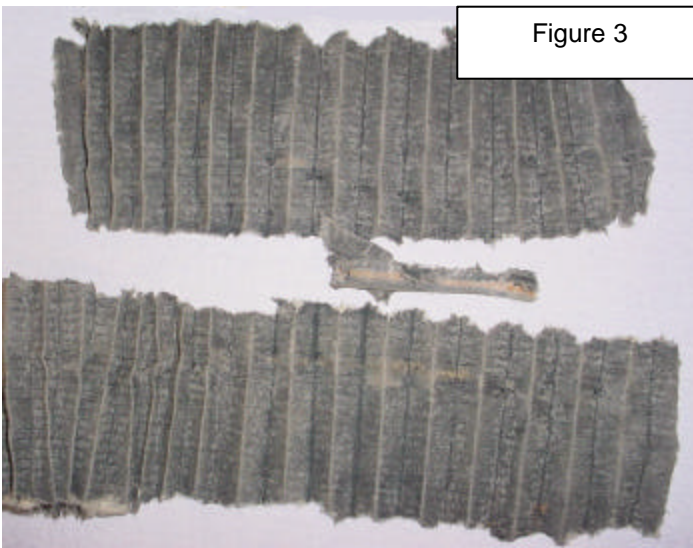


Figure 4

Figure 6



pellets of SCA covered in a semi-permeable polymer coating that results in a slow release of SCA to the coolant over a period of about a year. The media is contained in a wire reinforced polymer cylinder the polymer coated SCA pellets are entrapped in the middle of the cylinder. As the SCA in the pellets is slowly dissolved into the coolant the pellets collapse and form the residual mass of polymer visible at the top right. This

mass is functional, in that it retards the release of chemicals to the system over a very long period of time. Figure 6 is a better picture of the reinforced media cylinder.

In another case illustrated in case a heavy coating of green, oily deposit is clearly visible on the dirty side of the filter (Figure 7). These heavy deposits are common enough that coolant filters are always plumbed in a bypass line to prevent these problems from restricting



Figure 7

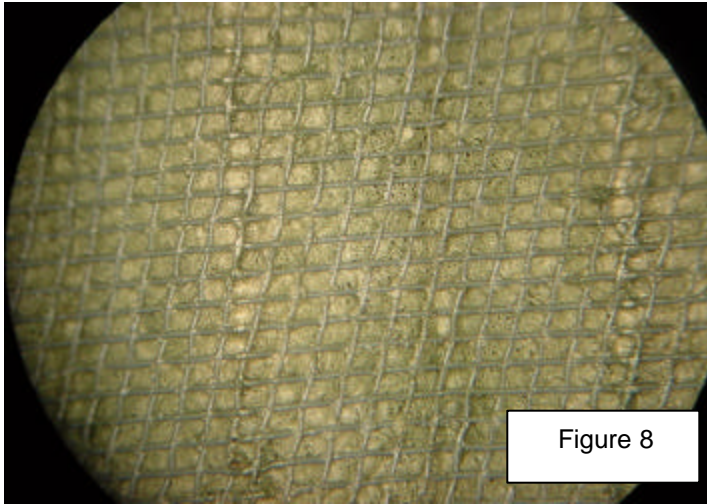


Figure 8

the flow of coolant in the system. Figure 8 shows the wire mesh reinforcement that supports the media in this product.

Figure 9 is an example of a standard coolant filter (unused). It is constructed similar to an oil filter, with less robust features and materials compared to the extended life coolant filters, because it has an intended service life of about 2 months or 20,000 miles. The media is cellulose based but chosen to be used in water/glycol coolant as opposed to oil, and the SCA charge is contained in pressed pellets that are contained on the clean side of the filter. These pellets dissolve quickly when the filter is installed on the vehicle and coolant flows through the filter. Various sizes of filters are produced to address the needs of different size cooling systems.

**FINDINGS:**

In this group of 71 filters 5 were conventional coolant filters and 66 were extended service products designed for a year or more of service. Penray or Fleetguard manufactured these extended service filters.



Figure 9

Table 1: Vehicle Information

Age (months)	Miles in Service	Engine Makes	Service
Shortest 3	Shortest 16,500	Cat 21%	Freight 93%
Average: 11	Average: 127,555	Cummins 25%	Fire 7%
Longest: 20	Longest: 390,011*	DDC 54%	

\*The authors did confirm the record with this supplier.

Figures 10 and 11 are photographs of the filter recorded to have served 390,011 miles. The claim is supported by the advanced aging and the very complete saturation of the media with debris and instability products from coolant inhibitors. This filter was part of an extended product evaluation conducted by the manufacturer, so the authors suppose that it was intentionally abused to test its limits. The filter did not fail, but did manifest far greater fatigue in the media than other filters inspected in this investigation.



Figure 10

Table 2: Media Condition (71 Examinations)				
Sand	Rust	Scale	Sludge (drop-out, mud)	Oil
32%	1%	0%	99%	13%

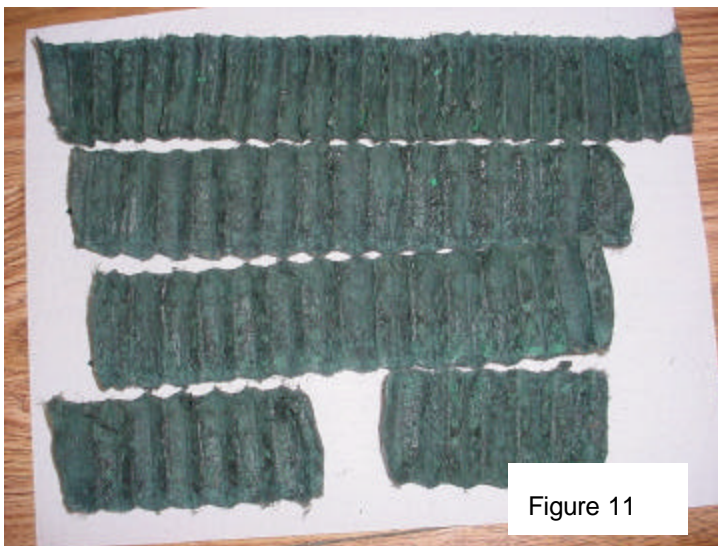
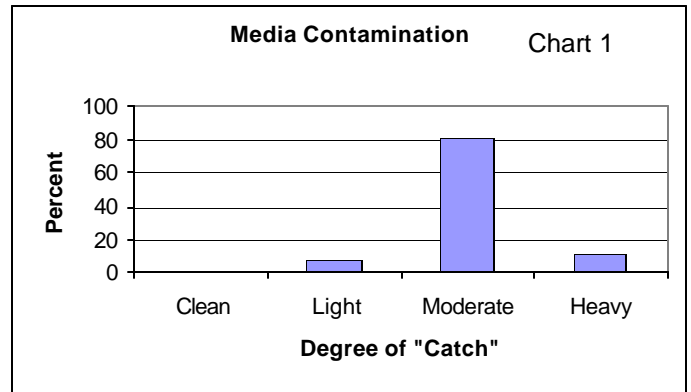


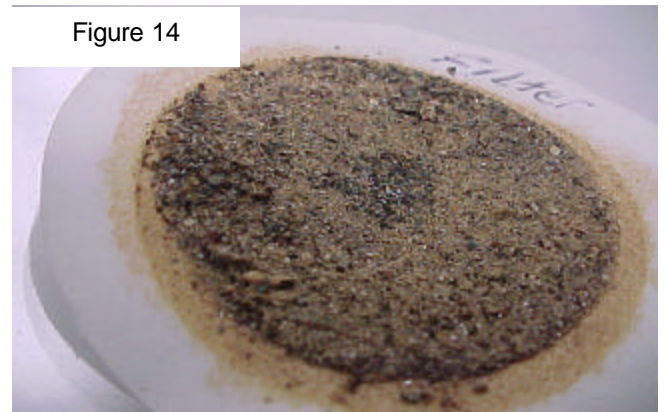
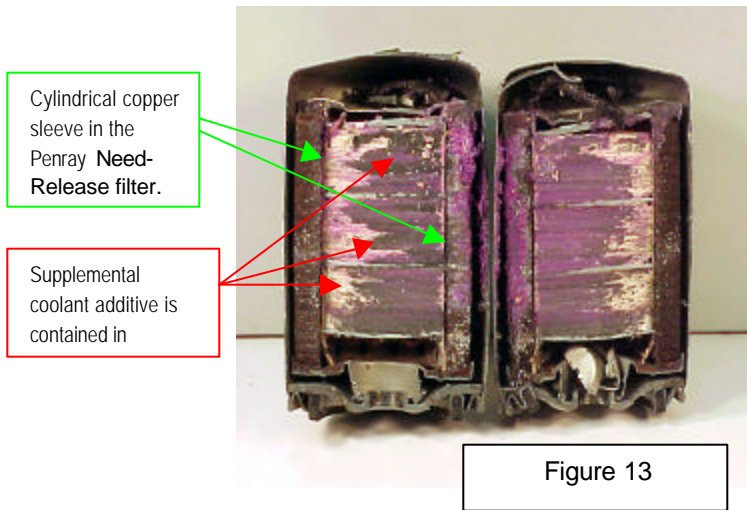
Figure 11



Figure 12

The filters are very clearly entrapping a great deal of debris from the coolant system. (Chart 1) (Figure 12) Every coolant filter that the authors received exhibited significant accumulation of coolant contaminants. The authors found sand (probably from casting) and an assortment of debris including some metal shavings. It is very interesting to note that in these systems that were reviewed, there was rust found in only one of the filters providing evidence that the filters' chemical systems, in combination with the coolants being used, was providing good protection for the system. Almost all of the filters manifested darkening of the media due to finite non-ionic contaminants. These could include common dirt, oils, greases or other inert matter. The data in Table 3 were determined by analyzing

the solution resulting from washing the filtration media from each filter in 250 ml of deionized water. The media, removed from the filter, were immersed in 250 ml of deionized water @ 160 degrees F overnight. Each fluid was allowed to cool to about 100 degrees F and was then removed and wrung to recover as much of the water as possible. The solution was made up to 250 ml to replace evaporated water, covered and then reheated and stirred for about 30 minutes with a magnetic stirring rod to dissolve as much chemistry as possible. The solution was then sampled and analyzed.



Data Analyzed	Method	High	Low	Average
Glycolate, mg/l	Ion chromatography	490	110	301
Formate, mg/l	Ion chromatography	242	6	69
Chloride, mg/l	Ion chromatography	171	5	18
Sulfate, mg/l	Ion chromatography	619	2	57
Nitrite, mg/l	Ion chromatography	839	64	288
Nitrate, mg/l	Ion chromatography	576	15	228
Phosphate, mg/l	Ion chromatography	1827	<1	735
Mercaptobenzothiazole, ppm	HPLC*	62	<1	1
Tolyltriazole, ppm	HPLC	161	6	65
Benzyltriazole, ppm	HPLC	<1	<1	<1
Benzoate, ppm	HPLC	22	<1	<1
Sebacic Acid, ppm	HPLC	<1	<1	<1
2-Ethylhexanoic acid, ppm	HPLC	<1	<1	<1
Pimelic Acid	HPLC	<1	<1	<1
Suberic Acid	HPLC	<1	<1	<1
Azelaic Acid	HPLC	<1	<1	<1
Undecanoic Acid	HPLC	<1	<1	<1
Dodecanoic Acid	HPLC	<1	<1	<1
Dodecanedioic Acid	HPLC	<1	<1	<1
Boron, ppm	ICP-IES**	86	17	44
Calcium, ppm	ICP-IES	>375	3	16
Copper, ppm	ICP-IES	>125***	1	44
Iron, ppm	ICP-IES	202	<1	26
Lead, ppm	ICP-IES	165	<1	32
Magnesium, ppm	ICP-IES	256	<1	42
Molybdenum, ppm	ICP-IES	131	<1	76
Silicon, ppm	ICP-IES	>565	8	111

\*HPLC High pressure liquid chromatography AKA High precision liquid chromatography  
 \*\* ICP-IES Inductively coupled plasma optical emission spectroscopy  
 \*\*\* About half of the filters examined are constructed with a copper sleeve in the center of the filter that holds the SCA. (Figure 13) High measurements of copper do not necessarily suggest corrosion of the cooling system because these filters are designed to deliver inhibitors by employing corrodible membranes. This technology could certainly explain copper found in the filtration media.

EXAMPLES OF FILTER MEDIA CONDITIONS:

Example 1: (Figures 15 & 16) Lighter than average contamination. The media is darkened, and has entrapped a significant amount of matter but fluid flow would not be significantly restricted.

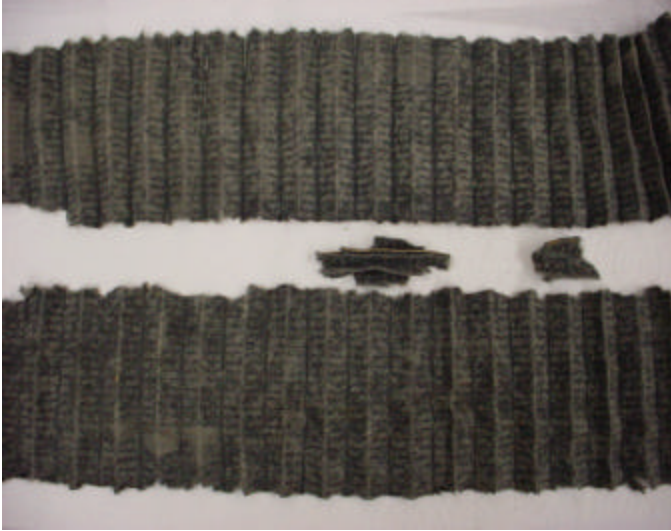


Figure 15

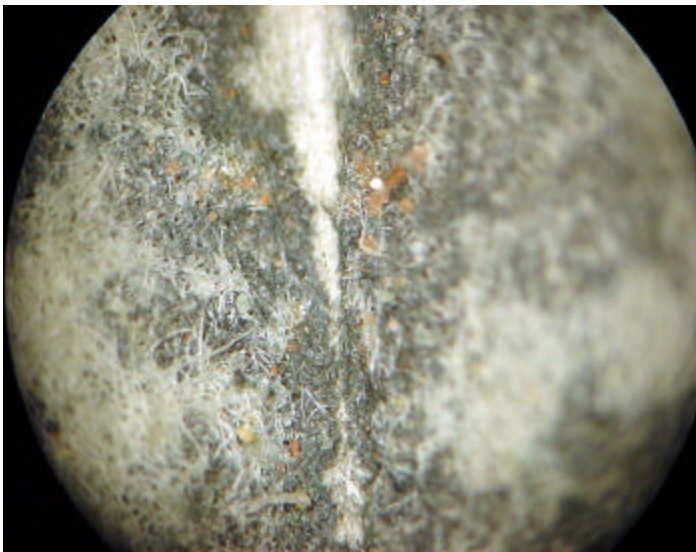


Figure 16

(Figures 17 - 19) Average contamination. The media is covered evenly with a thin accumulation of contaminants, and has entrapped a significant amount of matter. Fluid flow would be somewhat restricted.

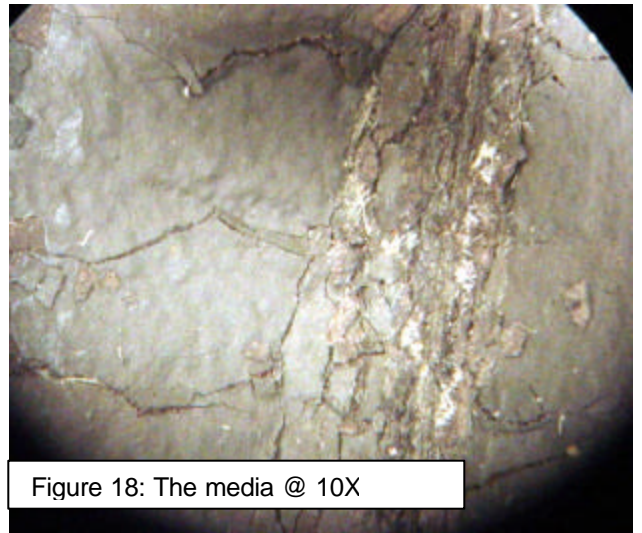
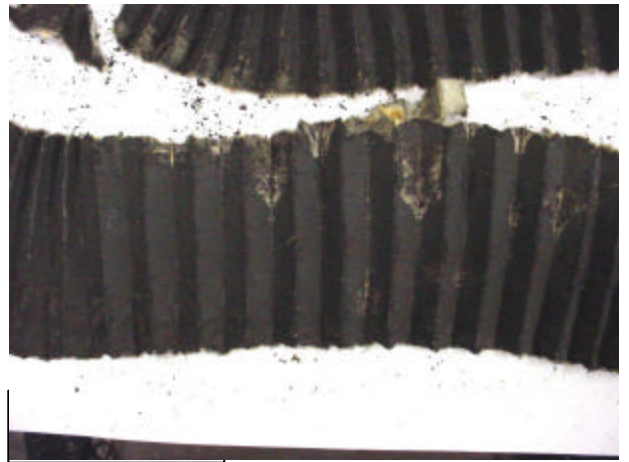


Figure 18: The media @ 10X

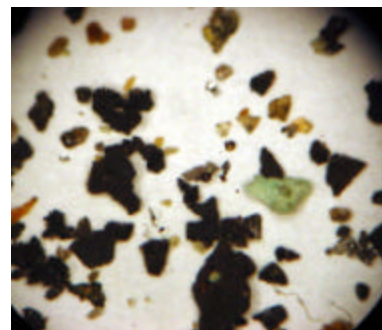


Figure 19: Undissolved granules @ 10X

Example 3: (Figure 20) Above average contamination. The media is blocked by the accumulation of contaminants, and has little or no fluid flow. Granular particles remain undissolved in the beaker after washing the media. It is remarkable that the filter in figure 16, in spite of being plugged with soft deposits, managed to deliver the SCA package to the coolant.



Figure 20: Three images



### SUMMARY:

A review of over seventy coolant filters to learn if they are needed in modern diesel cooling systems has been completed. The information gathered in the investigation supports the conclusions published in 1988<sup>i</sup> by Hudgens and Hercamp that filtration of engine coolant is highly desirable. The filters examined were very dirty, having sifted a number of different contaminants from the coolant.

This project identified abrasives, oily contaminants, corrosion products and additive by-products in the filters. The effects of these contaminants were reported by Hudgens and Hercamp to be very problematic. In particular the contaminants were shown to:

- Initiate and accelerate cavitation corrosion. (Figure 21)
- Dramatically increase erosion corrosion. (Figure 23)
- Cause wear at load-bearing surfaces
- Form problematic deposits on cooling system surfaces<sup>iv</sup>

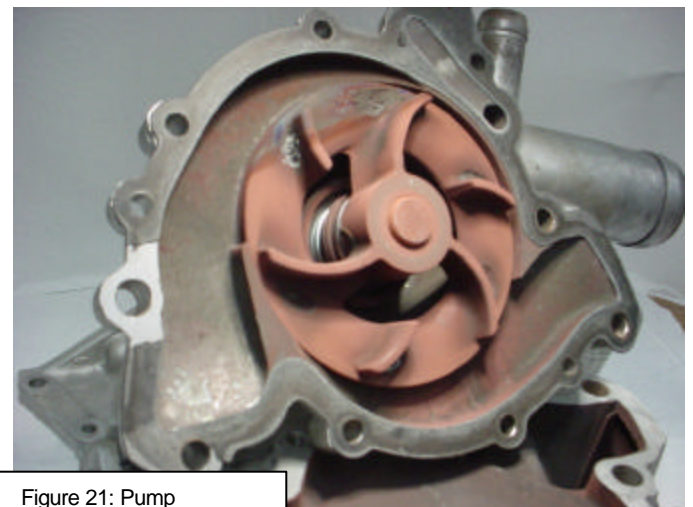


Figure 21: Pump



Figure 22: Deposits stuck in a failed radiator pressure cap.

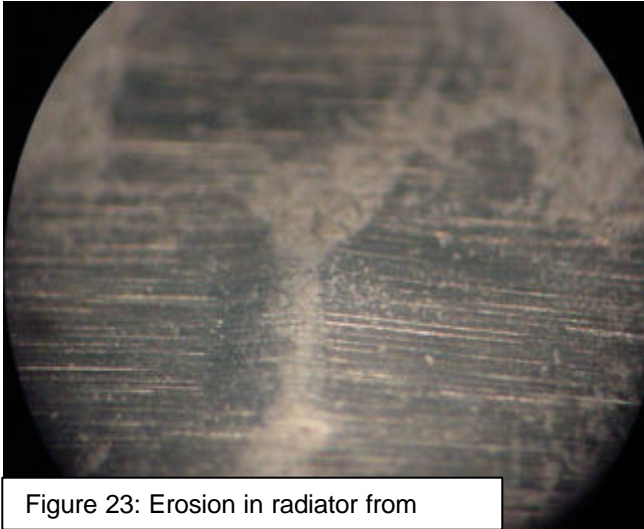


Figure 23: Erosion in radiator from

The findings strongly suggest that regardless of the coolant used in a system, there are significant contaminants that can be removed from the system. Failing to provide the cooling system with filtration could lead to a compromise in cooling system durability and reliability, resulting in increased inconvenience, maintenance and repair costs and for the vehicle owner and operator.

## CONTACT

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<sup>i</sup> 2003 Annual Book of ASTM Standards, Volume 15.05, © ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA

<sup>ii</sup> Hudgens, R.D. and Hercamp R.D., "Filtration of Coolants for Heavy Duty Engines", SAE Technical Paper Series 881270 ©1988 SAE International Society of Automotive Engineers, Inc.

<sup>iii</sup> Eaton, E, Boone, W. and Smith C. "A Chemical Base for Engine Coolant / Antifreeze with Improved Thermal Stability Properties", SAE Technical Paper Series 2001-01-1182 ©2001 SAE International Society of Automotive Engineers, Inc.

<sup>iv</sup> Hudgens, page 5