

AUTOMOTIVE AND HEAVY-DUTY ENGINE COOLANT RECYCLING BY DISTILLATION

Technology Evaluation Report

by

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FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of materials that, if improperly dealt with, can threaten both public health and the environment. The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. These laws direct the EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Risk Reduction Engineering Laboratory is responsible for planning, implementing, and managing research, development, and demonstration programs to provide an authoritative, defensible engineering basis in support of the policies, programs, and regulations of the EPA with respect to drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes, Superfund-related activities, and pollution prevention. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

This report describes the results of field testing of a distillation process for recycling automotive and heavy-duty engine coolant. This recycling project supports the emphasis on reducing generation of hazardous and nonhazardous waste by encouraging study and development of methods to recover and reuse ethylene glycol coolant.

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ABSTRACT

This evaluation addresses the product quality, waste reduction, and economic issues involved in recycling automotive and heavy-duty engine coolants for a facility such as the New Jersey Department of Transportation garage in Ewing, New Jersey. The specific recycling unit evaluated is based on the technology of distillation. Coolant recycling was found to have good potential as a means of waste reduction and cost saving with a return on investment of greater than 300% in the first year. Product quality was evaluated by conducting selected performance tests recommended in ASTM D 3306 and ASTM D 4985 standards, and by chemical characterization of the spent, recycled, and virgin coolants. A good product quality of the recycled coolant was achieved by this unit. Boiling, freezing, and corrosion resistance functions of the coolant were restored and contaminant levels were considerably reduced in the coolant.

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SECTION 1

PROJECT DESCRIPTION

The objective of the Prototype Evaluation Program of the U.S. Environmental Protection Agency (U.S. EPA) and the New Jersey Department of Environmental Protection (NJDEP) is to evaluate, in a typical workplace environment, examples of prototype technologies that have potential for reducing waste. In general, for each technology to be evaluated, three issues should be addressed.

First, it must be determined whether the technology is effective. Since waste reduction technologies usually involve recycling or reusing materials, or using substitute materials or techniques, it is important to verify that the quality of the recycled product is satisfactory for the intended purpose. Second, it must be demonstrated that using the technology has a measurable positive effect on reducing waste. Third, the economics of the new technology must be quantified and compared with the economics of the existing technology. It should be clear, however, that improved economics is not the only criterion for the use of the new technology. There may be justifications other than saving money that would encourage adoption of new operating approaches. Nonetheless, information about the economic implications of any such potential change is important.

This evaluation addresses the issues involved in using a particular commercially available technology offered by a particular manufacturer for automotive and heavy-duty engine coolant recycling. The recycling unit used in this study is a distillation unit manufactured by Finish Thompson, Inc. Other recycling units and technologies (with varying capabilities) applicable to the same wastestream (coolant) are also commercially available.

1.1 PROJECT OBJECTIVES

The goal of this study was to evaluate a technology that could be used to recycle spent automotive and heavy-duty engine coolant for reuse in cars, trucks, buses, and heavy-duty vehicles. This study had the following critical objectives:

- Evaluate the effectiveness of the coolant recycling unit in generating a coolant that meets the automotive industry's performance standards
- Evaluate the waste reduction potential of this technology
- Evaluate the cost of recycling versus the cost of current practice (disposal).

In addition to the above critical objectives, an attempt was made to achieve the following additional objectives:

- Determine the chemical characteristics of the coolant that can affect its corrosivity and the number of times this coolant can be recycled
- Determine the hazardous/non-hazardous nature of the sidestreams from the recycling unit.

1.2 DESCRIPTION OF THE TECHNOLOGY

Technologies for recycling spent coolant include simple filtration, chemical filtration, ion exchange, and distillation. Distillation was selected for this evaluation because it appeared to have features suitable for regenerating spent coolant to acceptable quality standards. Distillation seemed better suited to removing dissolved solids, oily contaminants, etc., compared to the other technologies.

The coolant recycling unit in this study was manufactured by Finish Thompson, Inc. (FTI), Erie, Pennsylvania. The unit operates on up to 15 gallons of stored spent coolant per batch (see Appendix A.1 for manufacturer's literature). Spent coolant is poured into the distillation still (process vessel) through a cup-shaped inlet port (Figure 1-1). One bottle of FTI No-FoamTM, a foam suppressant, is added through the same port to control boiling. The first time the unit is run, five gallons of FTI Pump PrimerTM, which is basically pure ethylene glycol, is added to the pump tank on top of the unit. The primer liquid primes the vacuum pump, which operates by an aspirator effect. Future runs do not require fresh primer.

The unit is turned on and allowed to operate until water and ethylene glycol are distilled off into two separate clean drums outside the unit. This may take about 12 to 15 hours for a full 15-gallon load of spent coolant, depending upon the amount of water present. Water distills out first at atmospheric pressure. As the temperature rises, the vacuum pump switches on

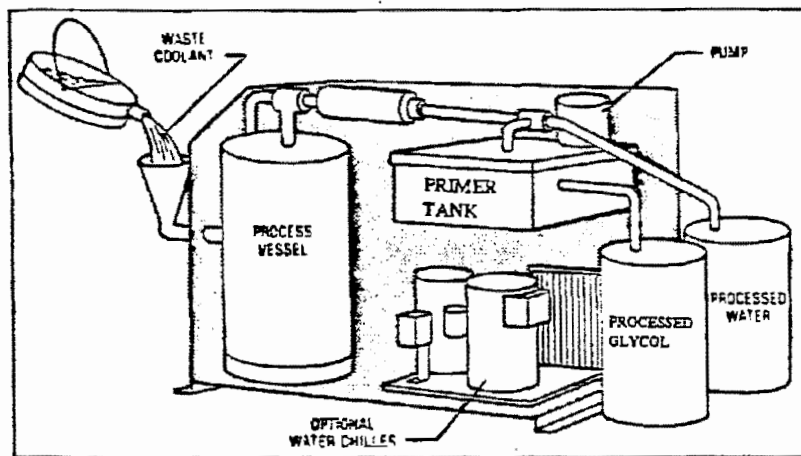


Figure 1-1. Coolant Distillation Process

automatically and starts drawing out the glycol. The vapors are condensed by using tap water as the heat exchanger fluid. A chiller is available as an option, but was not used in this study. The ethylene glycol distillate then enters the primer tank and mixes with the primer liquid (virgin ethylene glycol). The overflow from the primer tank is collected in the "processed glycol" drum.

Distillation continues until 3 gallons of residue are left in the still. At this point, the unit shuts off automatically. Note that until the 3-gallon residue is drained out (once in five batches is typical), the unit can process only 12 gallons of additional spent coolant. Each time a batch is run, this 3-gallon residue becomes more concentrated with contaminants such as oil and metals.

A measured amount of additive (FTI Engine Coolant Treatment™ in amounts previously calibrated by FTI) is poured into the processed (distilled) glycol drum before the condensate falls into this drum. As the glycol condensate drips into the drum, it gets mixed with the additive already there. Once the unit has shut off automatically, the processed ethylene glycol (including the additive) and the processed (distilled) water are available for preparing a 50:50 mix of the final recycled coolant when required.

The recommended mode of operation is that the unit be switched on at the end of the working day, so that the distilled batch is ready the next morning. Once a week, or after every five batches, the distillation residue is drained by gravity through a drain valve. Once a month, or after every twenty batches, the process tank (still) is cleaned by distilling 4 gallons of tap water through the process cycle.

1.3 DESCRIPTION OF THE SITE

The New Jersey Department of Transportation (NJDOT) vehicle maintenance and repair facility at Ewing, NJ, was the site of this project. The site houses many of the Department's functions, including administrative headquarters, sign making, signal installation and repair, roadway maintenance, and related activities. This facility is responsible for keeping automobiles, trucks, and motorized highway and roadway maintenance equipment in effective operating condition. Because of the number of vehicles serviced by the NJDOT garage, approximately 9,000 gallons of spent coolant is generated every year. Currently this coolant is being shipped to a waste disposal company. For this evaluation, one drum of spent coolant was shipped from NJDOT to the FTI location in Erie, Pennsylvania for processing.

1.4 SUMMARY OF APPROACH

A Quality Assurance Project Plan (QAPjP), prepared at the beginning of this study (Battelle 1991), describes the detailed approach and scientific rationale used to design the recycling unit evaluation.

1.4.1 Product Quality Evaluation

Virgin (new off-the-shelf) coolant is basically ethylene glycol which, when mixed in a 50:50 solution with water, provides the desired freezing and boiling characteristics for a vehicle's cooling system. The virgin coolant also contains corrosion inhibitors, foam controllers, and dyes to reduce corrosion, curb the coolant's foaming tendency, and impart a distinctive color to the product. During normal operation of the cooling system, the depletion products of these additives accumulate in the used coolant. The recycling process should remove the residual additives and depletion products and replenish the coolant with fresh additives in amounts specified by the manufacturer.

The used coolant also contains soluble and insoluble contaminants, which are either corrosion products or accumulated salts from the make-up water. The recycling process should remove these contaminants and restore the properties of the coolant to acceptable standards.

Product quality testing in this study involved a dual approach. The recycled coolant was subjected to a series of selected performance tests to evaluate its ability to meet the performance standards recommended in ASTM D 3306-89 and SAE J1034 (Appendix A.2) for automotive coolants and ASTM D 4985 and SAE J1941 (Appendix A.2) for heavy-duty coolants. The spent and recycled coolants were also analyzed to determine the degree to which chemical contaminants (metals, salts, etc.) were removed.

In addition to running batches of spent coolant (primary batches), test batches in which one or more characteristics of the coolant were intentionally altered (spiked batches) were run to test the limits of the recycling process.

1.4.2 Waste Reduction Evaluation

The waste reduction potential of this technology was measured in terms of the projected reduction in the amount of spent coolant generated by NJDOT if this technology were adopted. The only sidestream from the recycling process itself is the distillation residue, which was tested for hazardous metals (particularly lead).

1.4.3 Economic Evaluation

The economic analysis includes a comparison of operating costs for the new technology (recycling) with the costs for the current practice (disposal). Return on investment and payback period were also estimated.

SECTION 2

PRODUCT QUALITY EVALUATION

Engine coolants are intended to provide protection against boiling, freezing, and corrosion. Ethylene glycol-based coolants, which are the most common, contain mostly ethylene glycol, plus corrosion inhibitors (e.g., nitrates, nitrites, phosphates, silicates, molybdates, and benzoates), antifoam agents, and dyes. These additives are depleted during use and need to be replenished during recycling to restore the functional properties of the coolant.

A variety of contaminants accumulate in coolants during normal use. Suspended and dissolved metal particles may be present in the spent coolant as a result of corrosion of cooling system components. Calcium, magnesium, chloride, and sulfate may also accumulate in spent coolant through the make-up water. Depleted additives are another source of contamination. These contaminants contribute to increased corrosion and wear, fouling, scaling, and engine overheating. Ethylene glycol itself may degenerate into organic acids during use, thus lowering the pH and contributing to corrosion. These contaminants need to be removed during recycling.

The quality of ethylene glycol-based automotive coolant is specified in ASTM D 3306-89 and SAE J1034 (Appendix A.2). Heavy duty coolant standards are specified in ASTM D 4985 and SAE J1941 (Appendix A.2). These specifications cover the physical, chemical, and performance characteristics of coolants. The product quality tests conducted in this study were based on these specifications.

2.1 ON-SITE TESTING

Table 2-1 shows the coolant batches that were run on the recycling system and the samples that were collected from each batch. The spent coolant samples represent the stored used coolant before recycling. The recycled coolant samples represent the coolant after exiting the recycling system. Recycled coolant samples were collected after processing each batch for all batches that were run. Spent coolant samples were only collected from selected batches as shown in Table 2-1. Table 2-1 also indicates the source of the each coolant batch.

TABLE 2-1. DESCRIPTION OF THE COOLANT BATCHES RUN ON THE RECYCLING SYSTEM FOR PRODUCT QUALITY EVALUATION

Test Batch No. ^a	Coolant Batch Description	Source of Spent Coolant	Coolant Samples Collected ^b
1	Primary ^d	NJDOT ^f	1. Spent 2. Recycled 3. Processed Water
2	Primary ^d	NJDOT ^f	1. Recycled ^g
3/4 ^c	Salts & Acid Spiked ^e	NJDOT ^f	1. Spiked 2. Recycled 3. Processed Water
5	Primary ^d	Radiator Shop	1. Spent 2. Processed Glycol

- ^a Batches were run simultaneously on different machines.
- ^b Recycled samples were 50:50 processed glycol and processed water, plus additives.
- ^c Batches 3 and 4 were processed as separate batches; but the residues were combined and reprocessed to get enough volume for sampling.
- ^d Spent coolant as received.
- ^e Spent coolant, to which measured amounts of salts (chloride, sulfate, and bicarbonate), and glycolic acid were added.
- ^f New Jersey Department of Transportation garage.
- ^g No spent coolant sample collected for this batch. The spent coolant used came from the same source as Batch 1.

All batches, except Batch 5, consisted of spent coolant obtained from NJDOT. These batches represented coolants collected by NJDOT from several of their garages and car pools, and included coolants from cars, vans, and light- and heavy-duty trucks. Gasoline and diesel engine coolants were both represented. Batch 5 was spent coolant obtained from a local radiator shop. The five batches were run in five separate units at the same time.

Batches 3 and 4 were run at less-than-full capacity to conserve time and materials. Because both units shut off while 3 gallons of residue remained, as they are programmed to do, there was not enough recycled coolant for sampling from each individual batch. Hence, residue from Batches 3 and 4 was combined and rerun. This combined batch is henceforth referred to as Batch 3/4.

2.1.1 Primary Batches

Batches 1, 2, and 5 consisted of spent coolant (as received) without any alterations. These are referred to as the primary batches. A considerable amount of oil (in a thin film) was floating in the storage drums because used coolant from diesel engines often contains oily contaminants and the spent coolant had originally been stored in used motor-oil drums. This oil had formed a thin layer on top of the coolant. Therefore, when coolant test batches were drawn from the storage drums into the recycling unit, care was taken not to include this floating layer of oil. Emulsified (non-floatable) oil may still have been drawn into the test batches.

Table 2-2 shows the volume of all the batches run and amounts of fresh additive introduced into the recycled coolant. This table also shows the volume of processed ethylene glycol and water obtained from each run. The processed glycol was mixed with approximately equal amounts of the processed water from the same run to get the volumes of final recycled coolant recorded in Table 2-2.

Because Batch 1 was the only batch run at full unit capacity, the entire contents of one 500-mL additive bottle were introduced into the processed glycol (the recommended method for typical spent coolant batches). In all other batches, the measured amounts of additive were introduced in proportion to the volume of processed glycol generated, as recommended by FTI.

TABLE 2-2. ON-SITE RECYCLING MEASUREMENTS

Test Batch No.	Description of Batch	Initial Spent Coolant Volume (gallons)	Volume of Processed Ethylene Glycol ^a (gallons)	Volume of Processed Water	Total Volume of Recycled Coolant (gallons)	Amount of Additive Added ^b (mL)
1	Primary	15	3.5	8.5	7.0	500 ^d
2	Primary	10	1.3	6.5	2.6	150 ^e
3 ^c	Spiked	9.5	0.6	6.5	1.2	70 ^e
4 ^c	Spiked	9.5	0	6.5	0	0
5	Primary	10	2.5	5	5	280 ^e

- ^a Note that in each test batch (or each test unit), 3 gallons of ethylene glycol and contaminants are retained in the unit as residue. Subsequent batches on the same units would generate larger proportions of processed glycol and, hence, larger total amounts of final recycled coolant.
- ^b This only includes the FTI Engine CoolantTM additive package.
- ^c Batches 3 and 4 were both spiked with salts, water, and glycolic acid and processed separately; but the residues were combined and redistilled as completed Batch 3/4.
- ^d One full bottle (500 mL) was added based on vendor's recommendation.
- ^e Calculated amounts based on 60 mL of additive for every 4,000 mL of recycled coolant (glycol:water mix) were added. Only enough recycled coolant containing additive was mixed as was required to collect samples.

2.1.2 Spiked Batches

In addition to the primary batches, two spiked batches were recycled. The spiked batches were spent coolant batches that were altered to test the limits of the recycling process. Batches 3 and 4 were spiked with salts (chloride, sulfate, bicarbonate) and water, as well as glycolic acid. The spiked materials were intended to create an exaggerated corrosive environment, simulating extreme deteriorating conditions of the coolant.

The salts and water were introduced (spiked) in a manner similar to that recommended in ASTM Method D 1384 for preparing a test coolant solution with corrosive water. The added salts and water alter the freezing point of the spent coolant to approximately 0°F. A measured amount of glycolic acid was added to the spent coolant to simulate a situation in which ethylene glycol degenerates over time to form organic acids (glycolic, acetic, and formic). These organic acids are initially neutralized by the alkaline portion of the additive package to form organic salts (such as sodium glycolate). Once the additive is depleted, the acid continues to build up, contributing to a lower pH and hence a more corrosive environment.

2.2 PERFORMANCE TEST RESULTS

The samples collected during the on-site testing were analyzed in the laboratory for performance characteristics. The results are described below.

2.2.1 Boiling and Freezing Points

ASTM D 3306 standards for an approximately 50:50 mix of concentrate and distilled water are 226°F (or higher) boiling point and -34°F (or lower) freezing point. During on-site testing, the freezing point was adjusted to this level with a hand-held refractometer while adding the distilled water to the distilled glycol. The samples collected were later tested in the laboratory according to ASTM D 1120-89 (boiling point) and ASTM D 1177-88 (freezing point). The laboratory results in Table 2-3 show that in both primary batches, the boiling and freezing points were in agreement with the recommended standard.

TABLE 2-3. BOILING POINT (ASTM D 1120-89) AND FREEZING POINT (ASTM D 1177-88) AS MEASURED IN LABORATORY

SAE Standard for Boiling Point = 226°F or above
 SAE Standard for Freezing Point = -34°F or below

Batch No.	Description	Sample ^a	Boiling Pt. (°F)	Freezing Pt.(°F)
1,2	Primary	Spent	221	-11.2
1	Primary	Recycled	227	-35.2
2	Primary	Recycled	226.5	-39.3

^a Recycled samples were 50:50 distilled glycol and distilled water, plus additives.

2.2.2 pH and Corrosivity

The recommended pH range in SAE J1034 is between 7.5 to 11.0 to minimize the tendency towards corrosion. As seen in Table 2-4, the fresh additive restored the pH of all batches to the desired high levels.

Corrosivity test (ASTM D 1384) results and the D 3306 standard (acceptable range for results) are shown in Table 2-4. Corrosivity is measured in terms of the weight loss of metal test specimens exposed to the coolant for two weeks. This test is a screening test only and the results are significant only to the extent that they fall above or below the acceptable standard. The recycling process was able to restore the spent coolant to within specifications for both primary batches. It should be noted that the spent coolant sample was also within the acceptable range of the corrosivity test. Hence it is difficult to judge the level of improvement effected by the recycling process on the primary batches.

Spiked Batch 3/4 had been altered to ensure that the coolant was out of acceptable range for corrosivity. This was confirmed by the results of this test on the spiked coolant sample (Table 2-4), in which cast iron was out of acceptable range. After recycling, this spiked batch was restored to well within specifications for all metals, thus establishing the improvement in quality.

2.2.3 Corrosion of Cast Aluminum

ASTM D 4340-89 evaluates the effectiveness of the recycled coolant to inhibit corrosion of cast aluminum alloys under heat-transfer conditions that may be present in aluminum cylinder head engines. Corrosivity is measured in terms of the weight loss of an aluminum test specimen after one week of exposure to the coolant and a heat flux at 275°F and 28 psi. A coolant causing a weight loss of less than 1 mg/cm²/week is considered acceptable. This test is more demanding than ASTM D 1384 (discussed in Section 2.2) and is important because of the growing usage of aluminum instead of cast iron in automotive engines. As seen in Table 2-5, both primary batches were recycled to within the acceptable range, after starting with a spent coolant that was out of range. A virgin coolant solution (blank) prepared in tap water (to simulate real garage conditions) also passed this test. The numerical results are significant only to the extent that they fall above or below the acceptable standard.

TABLE 2-4. pH (ASTM D 1287-85) AND CORROSIVITY (ASTM D 1384-87)
AS MEASURED IN LABORATORY

SAE Standard for pH 7.5 to 11.0

ASTM D 3306 Standard for Corrosion:
(allowable weight loss per specimen)

Copper = 10 mg max Steel = 10 mg max
Solder = 30 mg max Cast Iron = 10 mg max
Brass = 10 mg max Cast Aluminum = 30 mg max

Batch No.	Description	Sample ^a	pH	Weight Loss per Specimen (mg) ^b					
				Copper	Solder	Brass	Steel	C. Iron	C. Al
1,2	Primary	Spent	8.3	0	2	1	0	4	1
1	Primary	Recycled	10.9	0	4	3	1	2	5
2	Primary	Recycled	11.0	0	6	1	0	0	1
3/4	Spiked	Spiked	8.7	0	4	2	0	72	1
		Recycled	10.7	0	6	2	0	1	0
5	Primary	Recycled	10.8	0	7	1	0	1	0

^a A recycled sample indicates 50:50 processed glycol and processed water, plus additives. No spent sample analyzed for Batch 5.

^b Average of triplicate results. Triplicates reported in Appendix B.2. An "NA" indicates not analyzed.

TABLE 2-5. CORROSION OF CAST ALUMINUM TEST (ASTM 4340-89) RESULTS

SAE Standard: Corrosion rate not greater than 1.0 mg/cm²/week

Batch No.	Description	Sample ^a	Corrosion Rate mg/cm ² /week
1,2	Primary	Spent	16.8
1	Primary	Recycled	0.8
2	Primary	Recycled	0.9
--	Blank	Virgin	0.9

^a A recycled sample indicates 50:50 processed glycol and processed water, plus additives.

2.2.4 Foaming Tendency

ASTM D 1881-86 evaluates the tendency of the recycled coolant to foam under controlled conditions of aeration and temperature. The volume of foam and the time (in seconds) for foam to break are measured, and should not be greater than 150 mL and 5 seconds, respectively.

The spent coolant was first confirmed to be well out of range (Table 2-6). This spent coolant continued to foam during the period of the test, and no breaking of the foam was observed. After recycling, Batch 2 was restored to within specifications. However, Batch 1 showed some tendency to foam and was slightly out of acceptable range, although considerable improvement from the spent coolant was observed. Ensuring that a processed batch receives appropriate amounts of fresh inhibitor (including anti-foam agents) could present some challenge. In Batch 1, one bottle (500 mL) of additive was introduced into the processed glycol drum before the glycol was collected, as recommended by the vendor. This may have caused too much or too little additive being introduced. In all other batches, additives were added in exact proportion to the amount of processed glycol generated, after collecting and measuring its volume. Therefore, no foaming problem was noticed in other batches.

2.3 CHEMICAL CHARACTERIZATION RESULTS

The physical and chemical requirements for coolant-grade ethylene glycol are given in ASTM E 1177-87 and ASTM D 3306-89. These are specifications for newly manufactured coolant and do not provide enough guidance on the quality of recycled coolant. Thus, the desirable level of removal of many typical contaminants from spent coolant and the way contaminant removal affects performance is currently a matter of judgment. A chemical characterization of the spent, virgin, and recycled coolants was conducted to see the relative differences in quality. The analytical methods used are listed in Appendix B.1.

It should be noted that the five batches processed in this evaluation were run on five different units, each of which was given a fresh charge of FTI Primer™. Because the primer is essentially pure ethylene glycol, and because distillate vapors are first drawn into the primer liquid before overflowing into the processed glycol drum, there is a dilution of the distillate in the primer. Hence, the chemical characterization in this section represents the lowest levels of contaminants possible in the processed glycol (and recycled coolant) for a given spent coolant.

TABLE 2-6. FOAMING TENDENCY TEST (ASTM D 1881-86) RESULTS

SAE Standard: Volume increase not greater than 150 mL
Foam break time not greater than 5 secs

Batch No.	Description	Sample ^a	Foam Vol. ^b (mL)			Foam Break Time (secs.)		
			1	2	3	1	2	3
1,2	Primary	Spent	>345	NA	NA	-- ^c	-- ^c	-- ^c
1	Primary	Recycled	185	185	190	8	7	6
2	Primary	Recycled	30	30	40	3	2	4

^a Recycled sample is 50:50 processed glycol and processed water, plus additives.

^b "NA" means not analyzed.

^c Foam continued to build.

2.3.1 Removal of Metal Contaminants

As a result of corrosion of cooling system components, suspended and dissolved metallic particles accumulate in the spent coolant. These particles have the potential to contribute to erosion and corrosion. Metals such as calcium and magnesium (from hard water) may also accumulate in the spent coolant and form scales that affect heat transfer characteristics. Sodium and potassium are present from residual inhibitor components; and, although these metals are not direct contributors to corrosion, they contribute to the level of dissolved solids in the coolant.

Table 2-7 provides an idea of the levels of these metals in the spent and recycled coolants, processed water, processed glycol, and distillation residue. The levels of calcium, magnesium, iron, and zinc were reduced considerably in the recycled coolant. Recoveries and precision in analysis of some metals were low due to low analyte levels and matrix interference. Hence, the capability of the unit to remove metals such as lead and aluminum (which were at low levels) was hard to judge. Processed water and processed glycol were analyzed separately (before adding inhibitors) and were found to be virtually free of metal contaminants.

The levels of some metallic contaminants in many spent coolants are higher (indicating greater deterioration) than the levels found in the NJDOT spent coolant used in this study. It would be desirable to test this recycling unit on such coolants to evaluate its metals removal capability. Results in Section 2.3.4 on some other metals (which were present at higher levels) do not indicate any significant carry over into the recycled coolant.

2.3.2 Removal of Other Inorganic Contaminants

The metallic contaminants discussed above, as well as anionic contaminants such as chlorides and sulfates, contribute to increased levels of dissolved solids. The dissolved solids levels of the spent and recycled coolants are given in Table 2-8. Dissolved solids are measured in terms of those particles that would pass through a 0.45 micron filter. The level of dissolved solids in the recycled coolant from the primary and spiked batches was considerably reduced. It should be noted that the levels of dissolved solids in the processed water and processed glycol were much lower than in the recycled coolant. Adding fresh additive to the processed glycol caused the dissolved solids level in the recycled coolant to increase slightly.

TABLE 2-7. CONCENTRATIONS OF METALLIC CONTAMINANTS IN COOLANT

Batch No.	Description	Sample ^a	ppm in Coolant ^b						
			Aluminum	Calcium	Copper	Iron	Lead	Magnesium	Zinc
1,2,3/4	Primary	Spent	<0.19	0.46	2.34	0.28	0.34	0.78	2.7
1	Primary	Recycled	0.63	<0.20	0.081	<0.04	2.88	<0.20	0.13
		Processed water	<0.19	<0.20	<0.036	<0.04	<0.2	<0.20	0.062
2	Primary	Recycled	0.88	<0.20	0.32	0.04	1.0	<0.20	0.83
3/4	Spiked	Recycled	1.01	<0.20	0.21	0.63	1.59	<0.20	0.35
5	Primary	Processed glycol	1.20	<0.20	0.15	0.098	2.9	<0.20	0.29

^a Recycled sample is 50:50 processed glycol and processed water, plus additives.

^b In succeeding batches on the same distillation unit, concentrations in the "recycled" and "processed glycol" streams may be slightly higher as the glycol primer in the primer tank starts accumulating contaminants present in the glycol distillate vapors. This increase is not likely to significantly affect coolant performance (see Section 2.4 of this report).

No specified standard for dissolved solids is currently available, although one engine manufacturer (Detroit Diesel, personal communication with S. L. Alexander, 1990) recommends that they be less than 3 percent of the coolant solution. Both the spent and recycled coolants in this study were well below this level.

Chloride and sulfate levels (Table 2-8) were considerably reduced in the recycled coolants. ASTM D 3306 and D 4985 recommend a chloride content of less than 25 ppm in undiluted virgin coolant. These ASTM standards also suggest that make-up water should not contain more than 40 ppm of chloride or 100 ppm of sulfate. It could, therefore, be inferred that a 50:50 solution of coolant concentrate and tap water could acceptably have 32 ppm chloride and 50 ppm sulfate. The chlorides in the processed glycol, processed water, and the final recycled coolant were well below these recommended levels. Even when salts (chloride, sulfate, and bicarbonate) were spiked into the spent coolant (Batch 3/4), the recycled coolant had very low levels of salts. In fact, the chloride and sulfate levels in the recycled coolants were lower than the levels in virgin coolant solution (blank-virgin sample in Table 2-8) prepared with tap water.

2.3.3 Removal of Organic Contaminants

The ability of the recycling unit to remove oil in the stored spent coolant was evaluated. Oily sludge can deposit on cooling system components, reduce heat transfer, and affect corrosion. The oil and grease analysis of spent and recycled coolants (Table 2-9) showed considerable reduction in the amount of oil in the recycled coolant. The oil remains in the distillation residue.

The level of glycolates in the spent and recycled coolants (Table 2-9) was measured by an ion chromatographic technique. Ethylene glycol in used coolant degenerates over time to form organic acids (glycolic, acetic, and formic). Initially, these acids are neutralized by the inhibitor components of the original virgin coolant into organic salts such as glycolates, acetates, and formates. As the inhibitor depletes, these acids continue to accumulate, reducing pH and contributing to an increasingly corrosive environment. The effect of organic salts in coolant is debatable, with opinions varying as to their possible deleterious effect.

Glycolates, acetates, and formates were reduced by recycling to levels comparable to those in the virgin coolant (blank) sample prepared with tap water. Even when glycolic acid was spiked into the spent coolant (Batch 3/4), the recycled coolant had relatively low levels of organic salts.

TABLE 2-8. CONCENTRATIONS OF INORGANIC CONTAMINANTS IN COOLANT

Batch No.	Description	Sample ^a	ppm in Coolant ^{b,c}		
			Chloride	Sulfate	Total Dissolved Solids
1,2	Primary	Spent	115	197	14,480
1	Primary	Recycled	3.41	5.39	5,980
		Processed water	<0.100	<0.500	120
2	Primary	Recycled	3.23	5.05	5,280
3/4	Spiked	Recycled	3.65	6.29	6,220
		Processed water	<0.100	<0.500	NA
5	Primary	Spent	37.2	217	NA
		Processed Glycol	<0.200	<1.00	80
--	Blank	Virgin	8.93	15.4	NA

^a A recycled sample indicates 50:50 processed glycol and processed water, plus additives.

^b An "NA" indicates "not analyzed".

^c In succeeding batches on the same distillation unit, concentrations in the "recycled" and "processed glycol" streams may be slightly higher as the glycol primer in the primer tank starts accumulating contaminants present in the glycol distillate vapors. This increase is not likely to affect the coolant performance significantly (see Section 2.4 of this report).

TABLE 2-9. CONCENTRATIONS OF ORGANIC CONSTITUENTS IN COOLANT

Batch No.	Description	Sample ^a	ppm in Coolant ^{b,c}			
			Oil and Grease	Glycolates	Acetates	Formates
1,2	Primary	Spent	105	600	140	180
1	Primary	Recycled	46.5	4.9	34	42
		Processed water	14.0	<5.0	<5.0	<5.0
2	Primary	Recycled	NA	3.2	18	19
3/4	Spiked	Recycled	NA	120	64	87
		Processed water	NA	<2.0	48	8.9
5	Primary	Spent	NA	710	75	200
		Processed Glycol	NA	<2.0	<2.0	5.0
--	Blank	Virgin	NA	25	732	48

^a A recycled sample is 50:50 processed glycol and processed water, plus additives. Virgin sample is 50:50 virgin concentrate and tap water.

^b An "NA" indicates "not analyzed".

^c In succeeding batches on the same distillation unit, concentrations in the "recycled" and "processed glycol" streams may be slightly higher as the glycol primer in the primer tank starts accumulating contaminants present in the glycol distillate vapors. This increase is not likely to affect the coolant performance significantly (see Section 2.4 of this report).

2.3.4 Additive Package Components

Table 2-10 indicates that the residuals of the old additive in the spent coolant were removed during recycling. Both processed water (Batch 1) and processed glycol (Batch 5) had very low or non-detectable levels of additive components. When fresh additive was added during recycling, the levels of nitrate, nitrite, boron, silicon, and sodium were raised in the final recycled coolant. Thus, there is no possibility of the old and new additives clashing. Removal of residual additives is important especially because NJDOT collects spent coolant from automotive and heavy-duty vehicles together. Automotive and heavy-duty vehicles often contain different types of additives, and not removing these residual additives could upset the chemical balance of the recycled coolant.

The recommendations of automotive manufacturers often vary for their specific cooling systems. For example, although phosphate inhibitors are acceptable to American and Japanese car manufacturers, European car manufacturers generally recommend low phosphate levels in their coolants. In this recycling process, the fresh additive package in the recycled coolant can be tailored to meet various specifications (such as low phosphate levels) by preparing different additive packages for different makes of cars.

Blank (virgin) sample results showed that the original virgin coolant contained high levels of phosphates, which were depleted to the levels found in the spent coolant.

Silicon levels (Table 2-10) were reduced considerably during recycling in the processed water and processed glycol samples. Silicon levels were raised again in the recycled coolants by introducing fresh additive (silicates are good corrosion inhibitors for aluminum). Removal of the residual silicate (from the original additive) is important before adding fresh silicate as a corrosion inhibitor. If the silicate level increases beyond its solubility in the coolant formulation, silica gel (commonly called "green goo") is formed. The gel can coat cooling system components, leading to reduced heat transfer and possible engine overheating.

2.4 PRODUCT QUALITY ASSESSMENT

The recycling unit restored the spent coolant to acceptable quality for the batches processed in this evaluation. Boiling and freezing points of the recycled coolant were within specifications. Corrosion inhibition function was restored, as was evident from the results of the ASTM D 1384 and 4340 tests. The recycled coolant showed a slight tendency to foam in one

TABLE 2-10. CHEMICAL CHARACTERIZATION RESULTS FOR ADDITIVE COMPONENTS IN COOLANT

Batch No.	Description	Sample ^a	ppm in Coolant ^{b,c}						
			Nitrate	Nitrite	Total Phosphate	Boron	Potassium	Silicon	Sodium
1,2	Primary	Spent	739	35.9	1,500	245	376	61.0	876
1	Primary	Recycled	321	686	1.85	80.8	1.66	231.0	946
		Processed water	<0.500	2.79	<0.500	1.86	<1.00	10.6	0.38
2	Primary	Recycled	328	680	1.81	75.3	1.56	217.0	940
3/4	Spiked	Recycled	368	705	2.18	84.7	1.46	246.0	944
		Processed water	.610	0.880	<0.500	NA	NA	NA	NA
5	Primary	Spent	951	18.1	1,710	NA	NA	NA	NA
		Processed glycol	<1.00	12.4	<1.00	3.8	<1.00	<9.7	1.64
--	Still Bottoms	Residue	NA	NA	NA	1,853	4,087	338	8,382
--	Blank	Virgin	<100	6.27	4,940	NA	NA	NA	NA

^a A recycled sample is 50:50 processed glycol and processed water, plus additives. Virgin sample is 50:50 virgin concentrate used by NJDOT and tap water.

^b An "NA" indicates "not analyzed".

^c In succeeding batches on the same distillation unit, concentrations in the "recycled" and "processed glycol" streams may be slightly higher as the glycol primer in the primer tank starts accumulating contaminants present in the glycol distillate vapors. This increase is not likely to affect the coolant performance significantly (see Section 2.4 of this report).

instance (Batch 1), but this could be addressed by properly calibrating the amount of additive required. The recycling unit is easy to install and operate, and requires no special expertise on the part of the operator.

The chemical characterization of the various process streams showed a high degree of contaminant removal. Chlorides and sulfates were reduced to levels lower than those found in virgin coolant-tap water solutions. Levels of metals and dissolved solids were lowered considerably. Oil and other organic contaminants (such as glycolates, acetates, formates) were reduced. Determination of overall coolant quality is difficult to judge based solely on levels of particular contaminants because the coolant is an integral product containing a variety of inhibitors and other additives. The amount and performance of these additives affects to a large extent the level of contaminants that can be tolerated in the recycled coolant. In this sense, performance tests (such as ASTM D 1384 and D 4340) may be the best measure of the overall quality of the coolant for a garage planning to purchase a recycling unit. The recycled coolant fared well in the selected performance tests conducted in this evaluation.

It should be noted that the recycled coolant tested in this evaluation was obtained from five batches that were processed in five separate distillation units. In each unit, fresh glycol primer was loaded into the primer tank. Ethylene glycol distillate vapors from the distillation still are diluted by this glycol primer before overflowing into the "processed glycol" drum. The concentration of contaminants in the glycol from the "processed glycol" drum (and hence in the final recycled coolant) is likely to increase slightly with each successive batch run on the same unit with the same primer. The upper limit on this increase is determined by the concentration of the contaminants in the ethylene glycol distillate vapor before it gets mixed with the primer. For example, the chloride level in Batch 1 recycled sample was 3.41 ppm. This chloride level could theoretically increase to 8.2 ppm after several batches. At this increased level, the chloride content of the recycled coolant would still be lower than that in the virgin solution prepared with tap water (Table 2-8). Hence, the increased levels are not expected to significantly affect the performance of the coolant. It would be a good adjunct to this study, however, to test the performance (corrosion tests, foaming, etc.) of recycled coolant over several batches processed on the same unit.

The basis for comparing the quality of recycled coolants is also important. The coolants of most cars are changed every 30,000 miles. Many heavy-duty diesel engines may not have their coolants changed during the first 150,000 miles. However, heavy-duty engine coolants are often fortified with supplemental coolant additives (SCA) initially, and after every 15,000 to

25,000 miles. Currently (without recycling), coolants are changed either by the drain-and-fill method or the flush-and-fill method. In the drain-and-fill method, as much as 40 to 60 percent of the spent coolant may still remain in the cooling system after draining. After refilling this system with a 50:50 virgin coolant solution, there may not be much improvement in the quality of this mixture of old and new coolants. In the flush-and-fill method, the cooling system is drained and then flushed with flowing water. Refilling with a virgin coolant solution yields a final coolant mixture containing lower levels of contaminants than that obtained by drain-and-fill.

Current opinion is divided on whether the basis for comparison for recycled coolants should be the drain-and-fill quality, the flush-and-fill quality, or, most stringent of all, virgin quality. Even if virgin quality were to be chosen as the basis for comparison, the quality of make-up water is still a variable.

The technology evaluated in this study is highly promising in terms of restoring coolant quality. Further testing could include tests such as cavitation and erosion (ASTM D 2809), simulated service corrosion test (ASTM D 2570), and effect on organic finishes (ASTM D 1882).

SECTION 3

WASTE REDUCTION POTENTIAL

Waste reduction potential was measured in terms of (a) volume reduction and (b) pollutant reduction. Volume reduction addresses the gross wastestream (such as spent coolant and spent filters). Pollutant reduction involves individual pollutants (such as ethylene glycol and heavy metals) in the gross wastestream. Volume reduction affects environmental resources (e.g., landfill space) expended during disposal. Pollutant reduction addresses the specific hazards of individual pollutants.

3.1 WASTE VOLUME REDUCTION

The waste volume reduction potential of this technology involves the amount of spent coolant prevented from being disposed of into the environment (e.g., by landfilling). This was estimated based on the amount of spent coolant generated by NJDOT per year. Information for this estimation was obtained from NJDOT's records and other industry sources as specified in this section. Table 3-1 compares the waste generated as a result of current practice (disposal) to the waste estimated to be generated if recycling were effectively implemented by NJDOT.

The various garages that NJDOT operates purchased 4,896 gallons (19,584 quarts) of virgin coolant concentrate in 1990, according to garage records. Assuming that this volume of concentrate goes into making a 50:50 solution of coolant in water, the amount of spent coolant would be expected to be twice the volume of the virgin coolant (or 9,792 gallons). However, some coolant is unavoidably lost to the environment from leaking hoses, radiators, and water pumps. This loss could not be quantified because there were no records of what percentage of purchased coolant was used for merely "topping off" the radiators as opposed to a complete coolant change. Assuming that 10 percent of spent coolant is lost to the environment, the waste volume reduction as a result of recycling would be 9,792 gallons, minus approximately 980 gallons, or 8,812 gallons.

TABLE 3-1. WASTE REDUCTION POTENTIAL

Wastestream Generated	Amount Per Year
<u>Current Practice^a</u>	
1. Spent Coolant	8,812 gallons
- ethylene glycol	4,406 gallons
- water	4,406 gallons
- oil	Variable ^b
2. Virgin Coolant Containers	4,406
<u>With Recycling^a</u>	
1. Distillation Residue	420 gallons
2. Virgin Coolant Containers	770
3. Oil	Variable ^b
4. Processed Water	Variable ^c

^a Note that some coolant is unavoidably lost to the environment due to leaks in the vehicles' cooling system.

^b If spent coolant is collected and stored in clean containers instead of used motor oil drums, this wastestream can be largely avoided.

^c Small amount of excess "processed water" not used for making up a 50:50 solution with the "processed glycol." This excess water can be reused for making up solutions with virgin coolant concentrate, if required.

Since virgin coolant is purchased by NJDOT in 1-gallon plastic containers, a large number of plastic containers are disposed of as waste. Recycling these plastic containers could be a possible source of waste reduction at NJDOT. In addition, recycling the coolant results in a reduction in the number of virgin coolant containers from over 4,000 to around 770.

With recycling, the discharge of spent coolant to the environment would be reduced to essentially zero, except for losses as a result of leakage in vehicles. However, other sidestreams of waste are generated during recycling; these are listed in Table 3-1. The main wastestream from recycling is the distillation residue in the still. Three gallons of residue (sludge) is generated for every 5 batches processed. Because the first batch is 15 gallons and succeeding batches are 12 gallons each, 3 gallons of residue are generated for every 63 gallons of spent coolant processed. This means that 420 gallons of residue would be generated annually if 8,812 gallons of spent coolant were processed.

Some amount of oil (about 1 quart) was skimmed off the top of the spent coolant storage (55-gallon) drum. For 8,812 gallons, the amount of oil skimmed off would be approximately 40 gallons. This oily waste could be avoided to a large extent if NJDOT were to store its spent coolant in clean drums instead of used motor oil drums.

As seen in Table 2-2, some amount of excess "processed water" will be available after making a 50:50 solution with "processed glycol." This processed water can be used for making 50:50 solutions with virgin coolant concentrate, if required. Any unused processed water could be disposed down the municipal drain, if testing shows that it does not contain regulated levels of volatiles or semi-volatiles and the local sewer district approves.

3.2 POLLUTANT REDUCTION

The measurable pollutant reduction from recycling is a result of the amount of ethylene glycol prevented from reaching the environment. From the first 15 gallons processed on the unit, an average of 20% (3 gallons) is recovered as glycol. From four subsequent 12-gallon batches (48 gallons total), an average of 47% (23 gallons) is recovered as glycol. Thus for every 63 gallons (five batches) of spent coolant processed, 26 gallons of ethylene glycol are recovered on average. After processing 8,812 gallons of spent coolant, approximately 3,637 gallons of glycol per year could be recovered.

It should be noted that spent coolant, besides containing ethylene glycol, water, and additives, also contains other contaminants, such as heavy metals. The mass of these individual contaminants is not considered part of the pollutant reduction because such contaminants eventually reach the environment -- through the spent coolant as a result of current practice or through the discarded distillation residue as a result of recycling.

Of interest, however, are the nature and leachable concentrations of the contaminants in the distillation residue, which affect their method of disposal. A sample of the distillation residue was collected and analyzed by the Toxicity Characteristic Leaching Procedure (TCLP) to determine the type of hazard. The residue sample was collected, not from the residue from the test batches, but from residue that FTI had previously collected after running five batches on the same unit. The source of spent coolants that were processed for generating this residue is unknown.

The TCLP results are shown in Table 3-2, along with the regulatory standards for each TCLP metal in the extract. Arsenic was the only TCLP metal detected above regulatory limits in the extract from the distillation residue. Hence, this distillation residue constitutes a hazardous waste. However, a generalization about residue disposal is not possible because the level of TCLP metals in the residue could vary depending on the levels present in the spent coolant processed. If analysis shows that none of the metals are above TCLP limits, the residue could be disposed according to state regulations for oily wastes.

3.3 WASTE REDUCTION ASSESSMENT

Ethylene glycol is considered a hazardous waste in some states. The California Department of Health Services (DHS) considers ethylene glycol toxic, based on its toxicity to animals (Section 66696(a)(6), Title 22, California Code of Regulations). DHS has determined that any waste which contains greater than 33% ethylene glycol is a hazardous waste. Ethylene glycol biodegrades readily in water (Rowe and Wolf 1982). It is also expected to biodegrade in soil. However, in water it can deplete some oxygen (BOD_5 is 0.47 g oxygen/g of ethylene glycol, Bridie et al. 1979) and can possibly cause localized fish kills. Ingesting ethylene glycol can be lethal to human beings as well (oral human LD_{50} is 1.56 g/kg, Rowe and Wolf 1982). Hazard data on coolant formulations containing ethylene glycol and additives are not readily available.

TABLE 3-2. TCLP (TOXICITY CHARACTERISTIC LEACHING PROCEDURE) ANALYSIS OF THE DISTILLATION RESIDUE

Item	Arsenic (mg/L)	Barium (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Lead (mg/L)	Mercury (mg/L)	Selenium (mg/L)	Silver (mg/L)
Regulatory Level ^a	5.0	100.0	1.0	5.0	5.0	0.2	1.0	5.0
Distillation Residue	3.86	<0.11	0.084	0.030	<0.20	<0.05	0.017	<0.56
Bias Corrected ^b	6.54	<0.11	0.112	0.027	<0.14	<0.05	0.030	<0.62

^a Toxicity Characteristic (TC) Rule, Federal Register, March 29, 1990.

^b Based on matrix spike recoveries in Table 5-2 for TCLP metals.

In the past, spent coolant could be dumped down the drain and the local POTW (publicly owned treatment works) could be expected to break the ethylene glycol down as part of its normal operation. When metals were found in the POTW sludge, restrictions began to be applied.

Spent coolant typically contains contaminants such as metals, dissolved solids, and organic acids. An ASTM subcommittee (D 15.15) was set up to address the issue of recycled coolants and has prepared frequency profiles (personal communication from Mark Filowitz, Wynn Oil Co.). These profiles show that over half the passenger cars surveyed had more than 5 ppm total lead (the regulatory level for defining a waste as RCRA hazardous). Over 50 ppm of total lead was found in the spent coolant from some cars.

The waste reduction potential of recycling engine coolants depends primarily on the volume of spent coolant prevented from entering the environment through disposal. Ethylene glycol can virtually be eliminated as a waste, except through some unavoidable losses in the form of leaks in a vehicle's cooling system. The waste reduction of individual contaminants (e.g., lead) in the spent coolant, however, is dependent mainly on the volume of waste containing these contaminants that has to be disposed of. With recycling, the volume of waste containing these contaminants can be potentially reduced to a few gallons of distillation residue. Disposing of this residue would consume much fewer resources (e.g., in terms of space in landfills) than hundreds of gallons of spent coolant. Coolant recycling, therefore, has great potential for reducing waste.

SECTION 4

ECONOMIC EVALUATION

The economic evaluation of this technology involved comparing the cost of recycling to the cost of the current practice (disposal).

4.1 OPERATING COSTS

Operating costs for the recycling process were obtained during on-site testing, from the records kept by NJDOT, and from the manufacturer of the units. Table 4-1 summarizes the information obtained from these sources.

Costs for the current practice (disposal) include the cost of 55-gallon storage drums for spent coolant, disposal charges, and labor. The amount of spent coolant (8,812 gallons) generated annually is obtained from Table 3-1. Labor involved in disposal was assumed to be 1 hour/drum. Disposal costs were estimated to be \$140/55-gallon drum of spent coolant and \$450/55-gallon drum of distillation residue (if hazardous), based on the charges of a local disposal company in New Jersey. If the distillation residue is analyzed and found to be non-hazardous, the disposal cost for the residue would be approximately \$165/55-gallon drum.

Operating costs (Table 4-1) for the recycling option were based on the following information. All costs were adjusted to an annual basis. The amount of spent coolant generated annually is about 8,812 gallons (Section 3.1). Processing time is approximately 12 hours per batch of spent coolant and about 5 hours per flush. The capacity of the unit is 15 gallons for the first batch and 12 gallons for the next four batches, after which the residue is drained and the same sequence repeated. After every 20 batches processed, the unit is flushed by processing 4 gallons of tap water.

The number of batches processed on the unit per year would be approximately 700 for 8,812 gallons of coolant. Thus, 700 bottles each of FTI No FoamTM and FTI Engine Coolant TreatmentTM (additive) would be consumed annually. The water requirement is based on (a) cooling water required for the condenser (0.5 gallons per minute for 12 hours/batch and 5 hours/flush) and (b) water required for flushing itself (4 gallons/flush).

TABLE 4-1. MAJOR OPERATING COSTS

Item	Quantity/yr	Unit Cost, \$	Total Cost, \$/yr
<u>Current Practice</u>			
Disposal:			
- Coolant	8,812 gal	\$140/ 55 gal drum	22,431
- Drums	160	30	4,800
- Labor (no overheads)	160 hrs	15	<u>2,400</u>
			Total 29,631 ^a
<u>Recycling</u>			
No-Foam™	700 bottles	1.86	1,302
FTI Treatment™	700 bottles	8.60	6,020
Water (for condenser, flush)	252,140 gal	.0011	277
Electricity	35,990 kwh	.12	4,319
Labor (no overheads)	257 hrs	15/hr	3,855
Residue Disposal	420 gal	\$450/ 55 gal drum	3,436
Drums	8	30	<u>240</u>
			Total 19,449 ^a

^a This total does not include maintenance costs or overheads. For complete operating costs, see Table 4-3 and 4-4.

Labor costs were tracked by noting the operator time required for recycling. Note that the operator does not have to watch the unit all the time. Based on observation of the process, a typical batch would take approximately 12 hours with actual operator involvement of 20 minutes. Additionally, operator time is involved for draining the residue (5 minutes) after every five batches, and for flushing the unit (20 minutes) after every twenty batches. The base labor rate (without overhead) was assumed to be \$15/hr.

Energy costs were estimated from the electricity consumption of the heater for the distillation unit, which rated at 220 volts, 19 amperes for 12 hours per batch, resulting in a consumption of 50 kilowatt-hours per batch. Assuming that flushing the unit after every 20 batches involves about 5 hours, there is an additional energy requirement of 21 kilowatt-hours per flush.

4.2 REVENUE FROM RECYCLED PRODUCT

If recycling were instituted at NJDOT, the amount of recycled coolant would result in savings (or revenue) from reduced virgin coolant purchase. The annual volume of recycled coolant produced (marketable by-product) was obtained (a) from Table 2-2, which shows that during the first run in each cycle, for every 15 gallons of spent coolant processed (based on the three primary batches only), approximately 6 gallons of recycled coolant were obtained, and (b) on the basis that, in subsequent runs of each cycle, approximately 11 gallons of recycled coolant would be obtained. Thus for 8,812 gallons of spent coolant processed per year, 6,994 gallons of recycled coolant (containing 3,497 gallons of concentrate and 3,497 gallons of water) can potentially be obtained.

NJDOT currently pays \$6.20 per gallon for virgin coolant concentrate. Because recycled coolant is a 50:50 solution, its value includes \$6.20 per gallon of concentrate and \$0.001 per gallon of water (based on the cost of water in the Ewing area). Annual revenue from the unit would include 3,497 gallons of concentrate at \$6.20 per gallon and 3,497 gallons of water at \$0.001 per gallon, or a total \$21,685.

4.3 ECONOMIC ANALYSIS

The return on investment and payback period for recycling were calculated based on the worksheets provided in the Waste Minimization Opportunity Assessment Manual (U.S. EPA 1988).

4.3.1 Capital Costs

Table 4-2 provides the capital cost inputs used in the worksheet.

- . Equipment costs are purchase price (\$5,115 including the pump primer), plus 10% for taxes, shipping, etc.
- . Installation costs are 4 hours of operator time at \$15/hr.
- . Plant engineering costs are 2 hours of engineer time at \$50/hr.
- . Contingency costs are assumed to be \$500.
- . Working capital is based on one month's supply of FTI No-Foam™ and FTI Engine Coolant Treatment™.
- . Start-up costs are based on 2 hours of engineer time and 4 hours of operator time.
- . 100% equity is assumed; that is, NJDOT would not borrow money to buy the unit. If a loan were taken, the percent debt and interest rate would have been entered here.
- . Because NJDOT does not incur taxes, no depreciation period or tax rate are included.
- . Escalation (inflation) rate is assumed to be 5 percent.

4.3.2 Operating Cost/Revenue

Table 4-3 provides the operating cost/revenue inputs used.

- . Raw material costs are based on an annual supply FTI No-Foam™ and FTI Engine Coolant Treatment™.
- . Utility costs are based on the energy and water costs in Table 4-1.
- . Operating labor costs are based on the operating labor costs in Table 4-1.
- . Operating supply costs are based on the air filters (that have to be changed on the unit).
- . Maintenance costs are based on a percentage of capital costs.

TABLE 4-2. CAPITAL COSTS FOR THE ECONOMICS WORKSHEET

INPUT		OUTPUT	
		CAPITAL REQUIREMENT	
Capital Cost			
		Construction Year	1
Capital Cost			
Equipment	\$5,627	Capital Expenditures	
Materials	\$0	Equipment	\$5,627
Installation	\$60	Materials	\$0
Plant Engineering	\$100	Installation	\$60
Contractor/Engineering	\$0	Plant Engineering	\$100
Permitting Costs	\$0	Contractor/Engineering	\$0
Contingency	\$500	Permitting Costs	\$0
Working Capital	\$610	Contingency	\$500
Start-up Costs	\$160	Start-up Costs	\$160
		Depreciable Capital	\$6,447
% Equity	100%	Working Capital	\$610
% Debt	0%	Subtotal	\$7,057
Interest Rate on Debt, %	0.00%	Interest on Debt	\$0
Debt Repayment, years	0	Total Capital Requirement	\$7,057
Depreciation period	10	Equity Investment	\$7,057
Income Tax Rate, %	0.00%	Debt Principal	\$0
		Interest on Debt	\$0
Escalation Rates, %	5.0%	Total Financing	\$7,057
Cost of Capital	15.00%		

TABLE 4-3. ANNUAL OPERATING COST/REVENUE INPUTS TO THE ECONOMICS WORKSHEET

Operating Cost/Revenue			
Marketable By-products		Operating Labor	
Recycled Coolant	\$21,685	Operator hrs/batch	1.61
Total \$/yr.	\$21,685	Batches/year	160
		Wage rate, \$/hr.	\$15.00
Utilities		Operating Supplies	
Water	277	Total \$/yr.	\$10
Electric	\$4,576		
Total \$/yr.	\$4,853		
Raw Materials		Maintenance Costs	
No-Foam	\$1,302	(% of Capital Costs)	
Extender	\$6,020	Labor	2.00%
Total, \$/yr.	\$7,322	Materials	1.00%
		Supervision	
Waste Disposal Savings		(% of O&M Labor)	10.0%
Offsite Fees, \$	\$18,995	Overhead Costs	
labor cost, \$	\$2,400	(% of O&M Labor + Super.)	
Storage Drums \$	\$4,560	Plant Overhead	25.0%
Total Disposal Savings	\$25,955	Home Office	0.0%
		Labor Burden	28.0%

- Overhead costs are based on supervision costs (10% of O&M labor costs), plant overhead (25% of O&M labor and supervision), and labor burden (28% of O&M labor and supervision).
- Revenue is based on the value of the recycled coolant as discussed in Section 4.2.

4.3.3 Results of Economic Analysis

Tables 4-4 and 4-5 indicate the results of the economic analysis. A return on investment (ROI) greater than 15% (which is the cost of capital) is obtained in the very first year of recycling. This implies that the payback period for NJDOT is much less than one year. The high return on investment (over 300% in the first year) occurs because, at the end of the very first year of operation of the unit, disposal costs can be reduced by \$27,253 and recycled coolant worth \$22,769 (\$21,685 plus 5% inflation in Year 1) is available for re-use. These savings would more than offset the purchase price of the recycling unit and its operating costs.

Figure 4-1 describes how the ROI varies depending on the amount of spent coolant generated annually by the user. If a user generates 100 gallons of spent coolant annually, the initial investment may not be recoverable. A slightly larger generator, with 500 gallons/year of spent coolant, would have a payback period of approximately seven years (ROI greater than 15%). The ROI improves as the amount of spent coolant generated becomes larger. The manufacturer has improved the economics of the technology by reducing the heating energy requirement of the unit and by eliminating the No Foam™ additive in the 1992 version of this unit (personal communication from Don Guillard, FTI, 1991).

4.4 ECONOMIC ASSESSMENT

Effective coolant recycling has considerable potential for reducing disposal and virgin coolant purchase costs. Repair shops that generate 500 gallons or more of coolant may find this recycling unit most economically beneficial. However, disposal costs can be expected to grow as more states start regulating spent coolant and even smaller generators may eventually find it economically attractive to recycle. Also, a valuable resource can be recovered by implementing coolant recycling.

TABLE 4-4. INCREASED ANNUAL REVENUES AND OPERATING SAVINGS FROM RECYCLING

REVENUE AND COST FACTORS				
Operating Year Number			1	2
Escalation Factor		1.000	1.050	1.103
INCREASED REVENUES				
Increased Production			\$0	\$0
Marketable By-products			\$22,769	\$23,908
Annual Revenue			\$22,769	\$23,908
OPERATING SAVINGS (Numbers in parentheses indicate net expense) *				
Raw Materials			(\$7,688)	(\$8,073)
Disposal Costs			\$27,253	\$28,615
Maintenance Labor			(\$119)	(\$125)
Maintenance Supplies			(\$60)	(\$63)
Operating Labor			(\$4,057)	(\$4,260)
Operating Supplies			(\$11)	(\$11)
Utilities			(\$5,096)	(\$5,350)
Supervision			(\$418)	(\$439)
Labor Burden			(\$1,286)	(\$1,351)
Plant Overhead			(\$1,149)	(\$1,206)
Home Office Overhead			\$0	\$0
Total Operating Savings			\$7,370	\$7,738

* End of the year savings (or expenses) are listed based on 5% annual inflation.

TABLE 4-5. RETURN ON INVESTMENT (ROI)

RETURN ON INVESTMENT				
Construction Year		1		
Operating Year			1	2
Book Value		\$6,447	\$5,158	\$4,126
Depreciation (by straight-line)			\$645	\$645
Depreciation (by double DB)			\$1,289	\$1,032
Depreciation			\$1,289	\$1,032
Cash Flows				
Construction Year		1		
Operating Year			1	2
Revenues			\$22,769	\$23,908
+ Operating Savings			\$7,370	\$7,738
Net Revenues			\$30,139	\$31,646
– Depreciation			\$1,289	\$1,032
Taxable Income			\$28,849	\$30,614
– Income Tax			\$0	\$0
Profit after Tax			\$28,849	\$30,614
+ Depreciation			\$1,289	\$1,032
After-Tax Cash Flow			\$30,139	\$31,646
Cash Flow for ROI		(\$7,057)	\$30,139	\$31,646
Net Present Value		(\$7,057)	\$19,151	\$43,079
Return on Investment			327.08%	414.27%

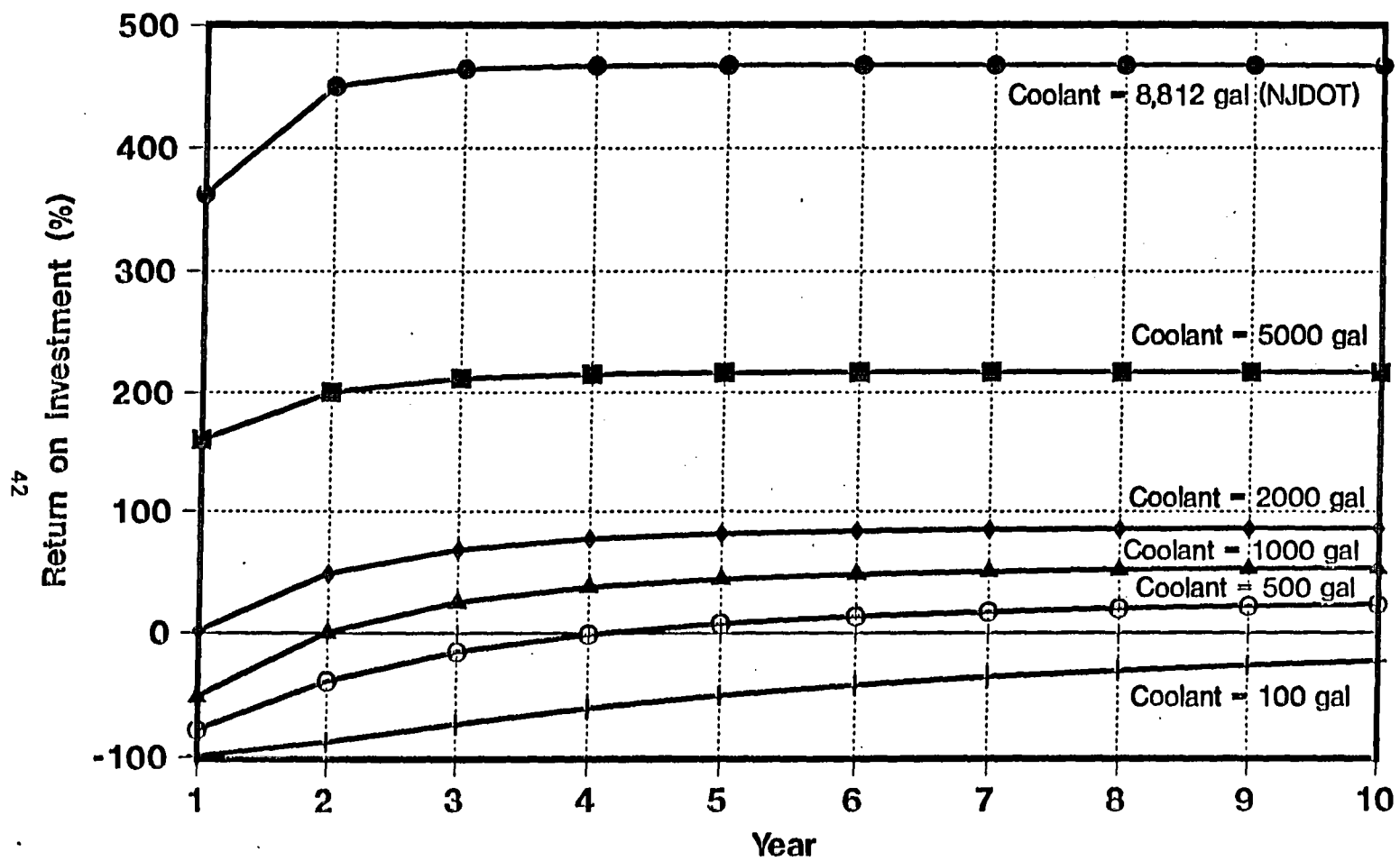


Figure 4-1. Summary of ROI for Various Sizes of Shops Generating Spent Coolant

SECTION 5

QUALITY ASSURANCE

A Quality Assurance Project Plan (QAPjP) was prepared and approved by the EPA before testing began (Battelle 1991). This QAPjP contains a detailed design for conducting this study. The experimental design, field testing procedures, and laboratory analytical procedures are covered. The QA objectives outlined in this QAPjP are discussed below.

5.1 ON-SITE TESTING

On-site testing was conducted as planned, with the following variations. Two primary and two spiked batches were planned in the QAPjP. However, one extra batch was processed (Batch 5) with spent coolant obtained by FTI from a radiator shop.

Batches 3 and 4 were initially processed in separate units, but neither unit produced enough distilled glycol to enable sampling. Hence, the contents of the two units were combined and processed. Only one set of samples was taken from Batches 3 and 4. Batch 5 (extra batch) was sampled instead.

5.2 LABORATORY ANALYSIS FOR COOLANT PERFORMANCE

All analysis was performed as planned. One additional ASTM D 4340 test was conducted on the blank-virgin solution (Batch 9) as a comparison.

Table 5-1 describes the QA data on the performance tests. Precision of the corrosivity test (ASTM D 1384) results was evaluated as requested in the standard method, which says that triplicate results for a sample that have "a single weight change that appears out of line" should be considered suspect. The method does not define "out of line." Table 2-4 shows the averages of triplicate results on each sample. Appendix B.2 shows the actual triplicate values. In most cases, all triplicates were either above or below the standard (e.g., the copper standard is 10 mg/week). In some cases, triplicates fell on either side of the standards; but none of the triplicates appeared to be "out of line."

TABLE 5-1. LABORATORY QA DATA FOR PERFORMANCE TESTS

Parameter	Precision Requirement for this Study	Duplicate Results	Precision Acceptable
Boiling point	Duplicates should not differ from mean by more than $\pm 0.5^{\circ}\text{F}$.	227.0, 227.5 $^{\circ}\text{F}$	Yes
Freezing point	Duplicates should not differ from mean by more than $\pm 0.5^{\circ}\text{F}$.	-35.2, -35.9 $^{\circ}\text{F}$	Yes
pH	Duplicates should not differ by more than ± 0.1 .	10.9, 10.9	Yes
Corrosivity	Any one triplicate should not be "out of line" with the other two.	Triplicates are consistent (see Appendix B.2).	Yes
Foaming Tendency	Any one triplicate result should not be "out of line" with the other two.	Triplicates are consistent (see Table 2-6).	Yes
Corrosion of Aluminum	The two recycled samples should both pass or both fail.	Both passed.	Yes

5.3 LABORATORY ANALYSIS FOR CHEMICAL CHARACTERIZATION

All analyses were performed as planned except for the following variations. The anion analysis (nitrate, nitrite, phosphate, chloride, and sulfate) was performed by an ion chromatographic technique (similar to EPA Method 300.0). Ion chromatography is used routinely by coolant manufacturers to test for anions. The results of this ion chromatographic analysis are shown in Section 2. Analysis by ion chromatography determines the concentration of available inorganic anions, e.g., chloride, sulfate. Colorimetric methods, on the other hand, are usually preceded by a sample preparation step that involves acid digestion. This step creates the potential for releasing organic (or otherwise unavailable chloride or sulfate), with the resulting spectrophotometric method detecting both organic and inorganic forms of chloride as Cl^- . Since ionic forms of these anions are more important in corrosion or corrosion inhibition, the ion chromatographic analysis is more appropriate.

The coolant was additionally analyzed for glycolates, acetates, and formates since some coolant manufacturers expressed concern about its presence in coolant. The initial ion chromatographic peak for glycolate using bicarbonate eluant showed a slight shoulder. The eluant was changed to borate on the recommendation of the instrument manufacturer to get better resolution of the peak. The shoulder was thereby identified as caused by formates and acetates, and the glycolate peak was isolated and quantified. The coolant was additionally analyzed for oil and grease content because oil was noticed floating in the spent coolant.

Holding times mentioned in the QAPjP for dissolved solids and anions (phosphate, sulfate, nitrate, and nitrite) were exceeded. However, coolants have a fairly long shelf life and results are not expected to be affected significantly by exceeding the holding times normally prescribed for wastewater.

Tables 5-2 and 5-3 list the QA data on accuracy, precision, and method blanks. All the data in these tables are within the limits specified in the QAPjP, except for the data on some of the metals analyzed. Due to matrix effects and the very low concentrations of these metals in the samples, precision and accuracy were out of specified limits. The matrix spike recoveries for aluminum, copper, lead, zinc, potassium, and sodium were out of range. Duplicate precision was out of range for aluminum, zinc, boron, lead, and silicon. For the organic salts analysis, a matrix spike was conducted only for glycolate to demonstrate adequate recovery. Acetates and formates analysis of the samples was done as an additional piece of information.

TABLE 5-2. ACCURACY DATA FOR CHEMICAL CHARACTERIZATION
AND TCLP TESTING

[Acceptable accuracy is 75-125% recovery,
except TCLP for which 50-150% is acceptable]

Parameter	Sample No.				
Chloride	DOT-S4	8.9	10.0	17.3	84
Sulfate	FTI-R3	6.296	2.5	8.799	100
Aluminum	FTI-S3	<0.19	0.50	0.299	60
Calcium	FTI-S1	0.46	1.00	1.40	94
Copper	FTI-R1	0.081	0.05	0.118	74
Iron	FTI-R1	<0.04	0.20	0.162	81
Lead	FTI-S1	0.34	1.00	0.72	38
Magnesium	FTI-S1	0.78	2.00	2.78	100
Zinc	-- ^a	0.03	0.20	0.125	48
Oil and Grease	FTI-W1	13.5	1065	1121	104
Glycolates	FTI-W3	<2.0	10.0	11.377	114
Nitrate	FTI-W3	0.88	0.5	1.37	98
Nitrite	FTI-W3	0.612	2.5	3.39	111
Phosphate	FTI-W1	<0.5	2.500	2.080	83
Boron	-- ^a	1.39	1.00	2.51	112
Potassium	FTI-W1	<1.0	2.00	1.46	73
Silicon	FTI-N5	<0.10	1.0	1.0	100
Sodium	FTI-N5	1.64	2.00	2.88	62

TABLE 5-2. (CONTINUED)

Parameter	Sample No.				
<u>TCLP-Coolant</u>					
Arsenic	FTI-DR1	<0.007	0.03	0.0176	59
Barium	FTI-DR1	<0.053	1.0	1.038	104
Cadmium	FTI-DR1	0.028	0.02	0.043	75
Chromium	FTI-DR1	0.013	0.02	0.035	110
Lead	FTI-DR1	<0.1	1.00	1.48	148
Mercury	FTI-DR1	<0.01	1.00	0.92	92
Selenium	FTI-DR1	0.0055	0.01	0.0111	57
Silver	FTI-DR1	<0.007	0.20	0.018	90

^a Spike was done on a diluted sample.

^b Accuracy = $\frac{(\text{matrix spike measured}) - (\text{regular sample})}{\text{matrix spike level}} \times 100$

TABLE 5-3. PRECISION DATA FOR CHEMICAL CHARACTERIZATION

Parameter	Sample No.	Regular Sample (ppm)	Duplicate (ppm)	Precision % ^a	Method Blank
Dissolved Solids	FTI-S1	2,987	2,964	0.8	1
Chloride	FTI-S1	122	108	12.2	<0.1
Sulfate	FTI-R3	6.326	6.266	0.96	<0.5
Aluminum	FTI-N5	1.2	<0.4	100	-- ^c
Calcium	FTI-S1	0.46	0.56	19.6	-- ^c
Copper	FTI-N5	0.15	0.12	22	-- ^c
Iron	FTI-N5	0.098	0.078	23	-- ^c
Lead	FTI-N5	2.9	<1.0	51	-- ^c
Magnesium	FTI-N5	<0.2	<0.2	NC	-- ^c
Zinc	FTI-N5	0.29	<0.1	97	-- ^c
Oil and Grease	FTI-W1	14.0	13.5	3.6	<1.0
Glycolates ^b	FTI-W3	11.377	11.622	2.1	<1.0
Formates	FTI-R2	18.600	17.982	3.4	<1.0
Acetates	FTI-R2	17.702	15.582	12.7	<1.0
Nitrate	FTI-W3	0.627	0.597	4.9	<0.5
Nitrite	FTI-W3	0.902	0.857	5.1	<0.1
Phosphate	FTI-S1	1,609	1,403	13.7	<0.5
Boron	FTI-N5	3.8	1.36	95	-- ^c
Potassium	FTI-N5	<1	<1	NC	-- ^c
Silicon	FTI-N5	<0.1	0.192	63	-- ^c
Sodium	FTI-N5	1.64	1.76	7.1	-- ^c

^a Precision = $\frac{(\text{regular}) - (\text{duplicate})}{(\text{regular} + \text{duplicate})/2} \times 100$; if analyte is not detected in

regular or duplicate precision is marked not calculable or "NC".

^b Glycolate precision calculated on matrix spike and matrix spike duplicate.

^c Analysis done by method of standard additions.

5.4 LIMITATIONS AND QUALIFICATIONS

Based on the above QA data, the results of the on-site and laboratory testing can be considered as a valid basis for drawing conclusions about product quality and waste reduction. As mentioned in Section 5.3, metal recoveries and precision were not very good, especially for low values. In most cases, metal recoveries and precision were poor when the original sample values were in the <1 ppm range. At these levels, the analytical variability is not expected to affect the results of the evaluation.

One limitation of the product quality evaluation is that all five batches were run on five separate recycling units due to time constraints. It would be desirable to evaluate the technology further by running five or more batches on the same unit with the same primer to see the difference in quality of the coolant from the fifth or later batch versus that from the very first batch. The same performance tests (corrosion, foaming, etc.) could be conducted on the recycled coolant from the first and fifth batches.

Data for economic analysis were mostly obtained from NJDOT's records. Any assumptions made are specified so that the readers can adjust them to their own case.

SECTION 6

DISCUSSION

This evaluation shows that the potential for waste reduction with automotive coolant recycling is good. The NJDOT facility where this evaluation was conducted could potentially reduce spent coolant waste volume from over 8,000 gallons per year to approximately 400 gallons per year. The recycling unit is easy to install and operate and requires no special expertise on the part of the operator. The recycled product fared very well in the ASTM performance tests and the chemical characterization. Boiling point, freezing point, pH, and corrosion resistance functions of the coolant were restored to specifications. Levels of metals, salts, and organic contaminants were considerably reduced in the recycled coolant. The performance of the recycling unit over several batches processed on the same unit with the same primer was not evaluated but, in general, the technology looks promising. Recycling was found to be economically viable for the NJDOT facility, with a return on investment of over 300% in the very first year.

Shops generating as little as 400 to 500 gallons per year of spent coolant would also find this unit economically attractive. Improvements planned by the manufacturer of this recycling unit for the year 1992 include a heating element which draws 15 amperes instead of 19 amperes (thus lowering energy requirement) and elimination of the anti-foaming (No-Foam™) agent from the process (personal communication from Don Guillard, FTI, 1991). These improvements are expected to further reduce operating costs.

One difficulty encountered during evaluation of many recycled products is the lack of sufficient guidance on quality requirements. Most existing specifications are designed for newly manufactured products. Such specifications, when they were formulated, did not have to take into account contaminants that might be found in used products. Therefore, acceptable levels of such contaminants in the recycled product remain a matter of opinion. However, the technology evaluated reduced contaminants to levels comparable to those in a virgin coolant solution in tap water.

To issue guidance on recycled coolant quality, ASTM has established a subcommittee (D 15.15) to set performance standards for recycled car and heavy-duty coolants. This subcommittee hopes to establish performance standards, as well as physical/chemical requirements, for recycled coolant based on laboratory data and technical literature (personal communication from Mark Filowitz, Wynn Oil, 1990).

An extensive study of various recycling technologies is being conducted by General Motors (personal communication from Wayne Bradley, General Motors, 1991). Several other automotive and heavy-duty engine manufacturers are also beginning to look at recycling. Such studies involve relatively expensive testing, which may be very costly for small repair shops to conduct on their own. Some repair shops have already undertaken recycling based on information provided by vendors to address the increasing cost of disposal. But, in general, initial reaction to recycling coolants in the automotive industry has been cautious, given the demanding nature of the application.

Several commercial coolant recycling units are currently available. All recycling units are based on simple filtration, chemical filtration, ion exchange, distillation, or combinations of these. Recycling units are either bulk units or single vehicle hook-up (portable) units. Some vendors also provide on-site or off-site recycling as a service, charging the generator a fixed fee per gallon of spent coolant. Some recycling vendors offer limited warranties on their recycled products.

Substituting propylene glycol for ethylene glycol is also being explored, especially in Europe. Propylene glycol is similar to ethylene glycol in many ways. However, propylene glycol is claimed to have lower toxicity, lower biodegradation time, and higher resistance to cavitation (Dobrovolny 1990). On the other hand, ethylene glycol is claimed to be a better solvent for corrosion inhibitors, to provide more freeze protection, and to cost less (personal communication from Dr. John Conville, BASF, 1990).

For further information on waste reduction, see Appendix C for a list of agencies offering technical and/or financial assistance.

SECTION 7
REFERENCES

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APPENDIX A

COOLANT STANDARDS AND MANUFACTURER'S LITERATURE

A.1 MANUFACTURER'S LITERATURE ON THE RECYCLING UNIT

Turn Waste Coolants Into Profits

OUR REVOLUTIONARY TECHNOLOGY MEANS:

- Recovered coolant meets highest purity standards.
- Elimination of waste disposal liabilities.

Make Spent Coolant Pay For Itself!

Engine coolants are primarily a mixture of 50% pure ethylene glycol and 50% water. As engine coolant is used within the cooling system, it gradually becomes contaminated and weakened.

Improper disposal of spent coolant is a violation of the *Clean Water Act*. This factor, combined with the rising costs of new antifreeze and disposal, has forced a search for an economic and environmental solution . . . It's here! **Bad Ethyl: the Coolant Reclaimer.**

Clear Advantages:

- Recover and reuse all of your used engine coolants.
- Removes *all* contaminants, both suspended and dissolved.
- Meets *all* performance and protection specifications for new coolants.
- Eliminates used coolant disposal costs and liabilities.
- Easily installed in your facility.
- Self-cleaning, simple to use, and no labor to operate.
- Saves money by eliminating the need to purchase new coolants and reducing high waste disposal costs.

New coolant for just over \$1.00 per gallon.

Superior Process...Super Results

Recovery systems that rely on filters cannot remove dissolved contaminants, particularly hazardous metals. Fortunately, vacuum distillation removes *all* suspended and dissolved contaminants. Utilizing this new technological breakthrough, **Bad Ethyl** does not require you to buy, replace or dispose of filters.

FTI Vacuum Distillation Technology

- Same process used to manufacture the original coolant.
- Full corrosion protection by removing dissolved solids.
- The *only* coolant recovery process recommended by major auto and heavy equipment manufacturers.
- Exclusive FTI self-cleaning feature means very low maintenance.
- "Distillation: the Difference is Clear"

Simple Operation Makes Money While You Sleep

Bad Ethyl will not tie up your valuable time or service bays. Simply pour dirty coolant into **Bad Ethyl** and push the "On" button. An automatic shut down is provided. Run day and night. If you run it overnight, you will have pure concentrated engine coolant ready for use in the morning.

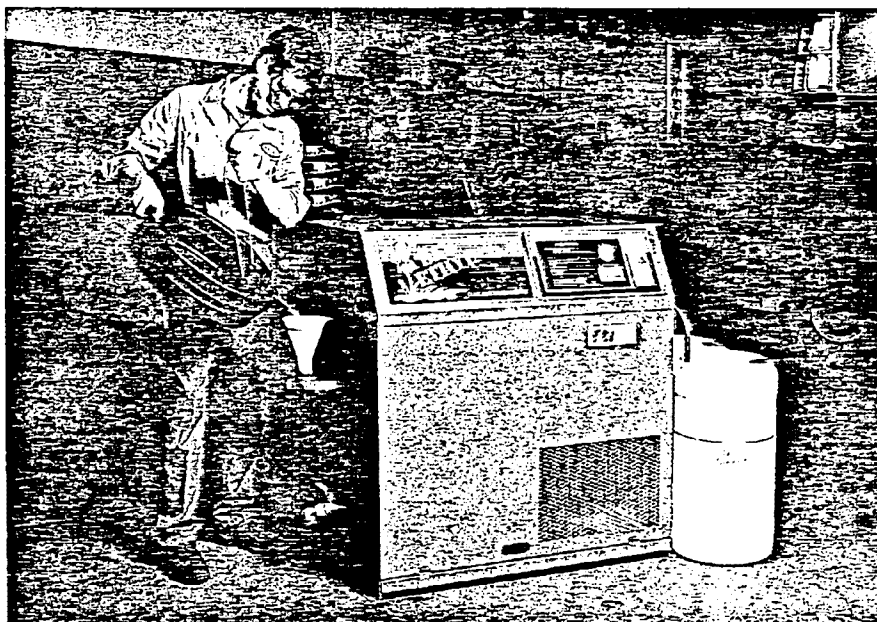
Results of Independent Laboratory Analysis of Reclaimed Coolant

Component	Dirty Coolant	Filtered Coolant*	Bad Ethyl Distilled Coolant*
Sodium (Na)	880 ppm	770 ppm	0.1 ppm
Potassium (K)	880 ppm	820 ppm	0.1 ppm
Phosphorus (P)	370 ppm	370 ppm	1 ppm
Chloride (Cl)	100 ppm	140 ppm	3 ppm
Sulfate (SO ₄)	260 ppm	250 ppm	5 ppm
Nitrate (NO ₃)	10 ppm	10 ppm	2 ppm
Iron (Fe)	4.0 ppm	15 ppm	0.5 ppm
Aluminum (Al)	2.5 ppm	3.7 ppm	1 ppm
Copper (Cu)	5.3 ppm	4.8 ppm	0.6 ppm

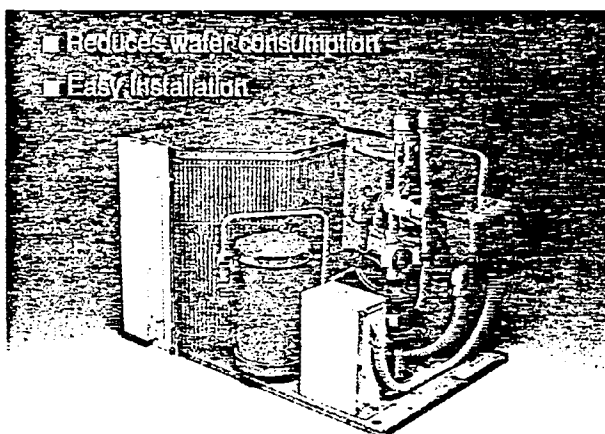
*Before adding corrosion inhibitors

Applications for BAD ETHYL Coolant Reclaimer

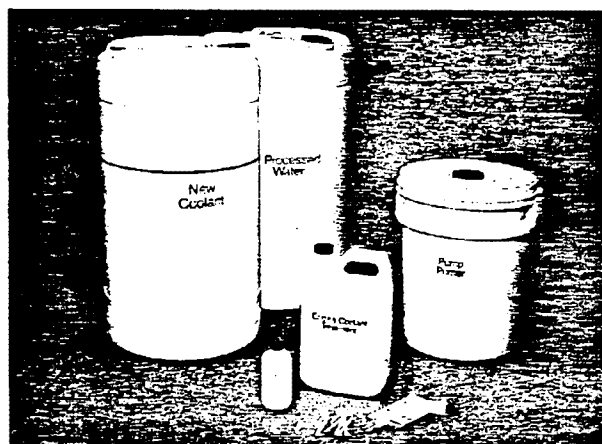
Auto Service Centers
 Radiator Repair Shops
 Truck Stops
 Construction Companies
 Government Fleets
 Auto Dealerships
 Service Stations
 Heavy Equipment Dealers
 Independent Fleet Operators
 Military Bases



Optional Water Chiller



Accessories



Specifications

Size:	Length 41 $\frac{1}{4}$ "	104.78 cm
	Height: 48 $\frac{3}{4}$ "	123.96 cm
	Depth: 25 $\frac{1}{8}$ "	63.94 cm
Weight:	390 lbs.	175.5 kg
Capacity:	15 gallons	56.85 liters
Distillation Rate:	1 gph	3.79 liters per hour
Process Time:	12 to 14 hours	
Electrical Requirements:	220 volts, single phase, 60 Hz, 19 amps	

FTI FINISH THOMPSON INC.

WARNING: The BE-15 Coolant Reclaimer is manufactured to safely reclaim engine coolants. Attempts to reclaim any other materials may cause personal injury and equipment damage.

A.2 COOLANT STANDARDS

1. SAE J 1034. Engine Coolant Concentrate - Ethylene-Glycol Type. Revised July 1988. Society of Automotive Engineers, Inc., Warrendale, Pennsylvania.
2. SAE J 1941. Ethylene-Glycol Type Requiring an Initial Charge of Supplemental Coolant Additive for Heavy-Duty Engines. April 1990. Society of Automotive Engineers, Inc., Warrendale, Pennsylvania.
3. ASTM Designation D 3306-89. Standard Specification for Ethylene Glycol Base Engine Coolant for Automobile and Light-Duty Service. Annual Book of The American Society for Testing and Materials (ASTM) Standards, Volume 15.05.
4. ASTM Designation D 4985-89. Standard Specification for Low Silicate Ethylene Glycol Base Engine Coolant for Heavy-Duty Engines Requiring an Initial Charge of Supplemental Coolant Additive (SCA). Annual Book of The American Society for Testing and Materials (ASTM) Standards. Volume 15.05.

APPENDIX B

TESTING AND ANALYSIS

APPENDIX B.1. ANALYTICAL METHODS FOR CHEMICAL CHARACTERIZATION

Analyte	Method
Dissolved Solids	EPA 601.1
Potassium	EPA 6010
Calcium	EPA 6010
Boron	EPA 6010
Silicon	EPA 6010
Iron	EPA 6010
Aluminum	EPA 6010
Copper	EPA 6010
Magnesium	EPA 6010
Zinc	EPA 6010
Lead	EPA 6010
Oil and Grease	EPA 413.2
Chloride	Modified EPA 300.0
Sulfate	Modified EPA 300.0
Nitrate	Modified EPA 300.0
Nitrite	Modified EPA 300.0
Phosphate	Modified EPA 300.0
Glycolate	Modified EPA 300.0
Acetate	Modified EPA 300.0
Formate	Modified EPA 300.0

APPENDIX B.2. CORROSIVITY (ASTM D 1384-87) AS MEASURED IN LABORATORY (TRIPPLICATE RESULTS)

ASTM D 3306 Standard for Corrosion: Copper = 10 mg max Steel = 10 mg max
 Solder = 30 mg max Cast Iron = 10 mg max
 Brass = 10 mg max Cast Aluminum = 30 mg max

Batch No.	Description	Sample	Weight Loss per Specimen (mg) ^a								
			Copper			Solder			Brass		
1	Primary	Spent Recycled	0	0	1	1	2	2	1	2	1
			0	0	0	4	4	4	3	1	4
2	Primary	Recycled	0	0	0	6	6	6	1	0	2
3/4	Primary	Spent Recycled	0	1	0	6	5	2	2	3	2
			1	0	-1	6	6	6	2	2	1
5	Primary	Recycled	0	0	1	7	7	7	1	1	1

^a Averages are shown in Table 2-4.

APPENDIX B.2. (Continued)

ASTM D 3306 Standard for Corrosion: Copper = 10 mg max Steel = 10 mg max
 Solder = 30 mg max Cast Iron = 10 mg max
 Brass = 10 mg max Cast Aluminum = 30 mg max

Batch No.	Description	Sample	Weight Loss per Specimen (mg) ^a								
			Steel			Cast Iron			Cast Aluminum		
1	Primary	Spent Recycled	0	1	0	3	4	5	-1	0	-3
			1	1	0	0	4	1	-3	-3	-8
2	Primary	Recycled	0	0	0	0	0	1	4	0	0
3/4	Primary	Spent Recycled	0	0	0	48	95	73	0	0	-3
			0	0	0	4	-1	0	0	0	1
5	Primary	Recycled	0	0	0	0	0	2	1	0	0

^a Averages are shown in Table 2-4.

APPENDIX C

TECHNICAL/FINANCIAL ASSISTANCE PROGRAMS

APPENDIX C

TECHNICAL/FINANCIAL ASSISTANCE PROGRAMS

The following agencies can provide additional information on pollution prevention.

U.S. EPA Pollution Prevention Office
401 M Street S.W. (PM-219)
Washington, D.C. 20460
(202) 382-4335

U.S. EPA Solid Waste Office
401 M Street SW
Washington, D.C. 20460
(703) 308-8402

U.S. EPA Office of Research & Development
Center for Environmental Research Information
26 Martin Luther King Drive
Cincinnati, OH 45268
(513) 569-7562

The following states have programs that offer technical and/or financial assistance in the areas of pollution prevention (waste reduction).

Alabama

Hazardous Material Management
and Resource
Recovery Program
University of Alabama
P.O. Box 6373
Tuscaloosa, AL 35487-6373
(205) 348-8401

Department of Environmental
Management
1751 Federal Drive
Montgomery, Alabama 36130
(205) 271-7914

Alaska

Alaska Health Project
Waste Reduction Assistance Program
431 West Seventh Avenue, Suite 101
Anchorage, AK 99501
(907) 276-2864

Arizona

Arizona Department of Economic Planning
and Development
1645 West Jefferson St.
Phoenix, AZ 85007
(602) 255-5705

Arkansas

Arkansas Industrial Development
Commission
One State Capitol Mall
Little Rock, AR 72201
(501) 371-1370

California

Alternative Technology Section
Toxic Substances Control Division
California State Department of
Health Services
714/744 P Street
Sacramento, CA 94234-7320
(916) 324-1807

Pollution Prevention Program
San Diego County Department of
Health Services
Hazardous Materials
Management Division
P.O. Box 85261
San Diego, Ca 92186-5261
(619) 338-2215

Colorado
Division of Commerce and
Development Commission
500 State Centennial Building
Denver, CO 80203
(303) 866-2205

Connecticut
Connecticut Hazardous Waste
Management Service
Suite 360
900 Asylum Avenue
Hartford, CT 06105
(203) 244-2007

Connecticut Department of
Economic Development
210 Washington Street
Hartford CT 06106
(203) 566-7196

Delaware
Delaware Dept. of Community Affairs
& Economic Development
630 State College Rd.
Dover, DE 19901
(302) 736-4201

D.C.
U.S. Department of Energy
Conservation and Renewable Energy
Office of Industrial Technologies
Office of Waste Reduction,
Waste Material Management Division
Bruce Cranford CE-222
Washington D.C. 20585
(202) 586-9496

Pollution Control Financing Staff
Small Business Administration
1441 "L" Street N.W., Room 808
Washington, D.C. 20416
(202) 653-2548

Florida
Waste Reduction Assistance Program
Florida Department of
Environmental Regulation
2600 Blair Stone Road
Tallahassee, FL 32399-2400
(904) 488-0300

Georgia
Hazardous Waste Technical
Assistance Program
Georgia Institute of Technology
Georgia Technical Research Institute
Environmental Health and Safety Division
O'Keefe Building, Room 027
Atlanta, GA 30332
(404) 894-3806

Environmental Protection Division
Georgia Department of Natural Resources
205 Butler Street S.E. Room 1154
Atlanta, GA 30334
(404) 656-2833

Guam
Solid and Hazardous Waste
Management Program
Guam EPA
IT&E Harmon Plaza Complex
Unit D-107
130 Rojas Street
Harmon, Guam 96911
(671) 646-8863-5

Hawaii
Department of Planning &
Economic Development
Financial Management and
Assistance Branch
P.O. Box 2359
Honolulu, HI 96813
(808) 548-4617

Idaho

IDHW-DEQ
Hazardous Materials Bureau
450 W. State Street
3rd Floor
Boise, ID 83720
(208) 334-5879

Illinois

Hazardous Waste Research and
Information Center
Illinois Department of Energy and
Natural Resources
One E. Hazelwood Drive
Champaign, Illinois 61820
(217) 333-8940

Illinois Waste Elimination
Research Center
Pritzker Department of
Environmental Engineering
Illinois Institute of Technology
3201 South Dearborn
Room 103 Alumni Memorial Hall
Chicago, IL 60616
(312) 567-3535

Indiana

Environmental Management and
Education Program
School of Civil Engineering
Purdue University
2129 Civil Engineering Building
West Lafayette, IN 47907
(317) 494-5036

Indiana Department of
Environmental Management
Office of technical Assistance
P.O. Box 6015
105 South Meridian Street
Indianapolis, IN 46206-6015
(317) 232-8172

Iowa

Iowa Department of Natural Resources
Air Quality and Solid Waste
Protection Bureau
Wallace State Office Building
900 East Grand Avenue
Des Moines, IA 50319-0034
(515) 281-8690

Center for Industrial Research and Service
Iowa State University Research Center
Suite 500
2501 N. Loop Drive
Building 1
Ames, IA 50010-8286
(515) 294-3420

Waste Management Authority
Iowa Department of Natural Resources
Henry A. Wallace Building
900 East Grand
Des Moines, IA 50319
(515) 281-8489

Iowa Waste Reduction Center
University of Northern Iowa
75 Biology Research Complex
Cedar Falls, Iowa 50614
(319) 273-2079

Kansas

Bureau of Waste Management
Department of Health and Environment
Forbes Field, Building 730
Topeka, KS 66620
(913) 296-1607

Kentucky

Division of Waste Management
Natural Resources and Environmental
Protection Cabinet
18 Reilly Road
Frankfort, KY 40601
(502) 564-6716

Kentucky Partners
Room 312 Ernst Hall
University of Louisville
Speed Scientific School
Louisville, KY 40292
(502)588-7260

Louisiana

Department of Environmental Quality
Office of Solid and Hazardous Waste
P.O. Box 44307
Baton Rouge, LA 70804
(504) 342-1354

Maine

State Planning Office
184 State St.
Augusta, ME 04333
(207) 289-3261

Maryland

Maryland Hazardous Waste
Facilities Siting Board
60 West Street, Suite 200A
Annapolis, MD 21401
(301) 974-3432

Massachusetts

Office of Technical Assistance
Executive Office of
Environmental Affairs
100 Cambridge Street, Room 1904
Boston, MA 02202
(617) 727-3260

Source Reduction Program
Massachusetts Department of
Environmental Quality Engineering
1 Winter Street
Boston, MA 02108
(617) 292-5982

Michigan

Resource Recovery Section
Department of Natural Resources
P.O. Box 30028
Lansing, MI 48909
(517) 373-0540

Minnesota

Minnesota Pollution Control Agency
Solid and Hazardous Waste Division
520 Lafayette Road
St. Paul, MN 55155
(612) 296-6300

Minnesota Technical
Assistance Program

1313 5th Street S.E. Suite 207
Minneapolis, MN 55414
(612) 627-4646
(800) 247-0015 (in Minnesota)

Mississippi

Waste Reduction & Minimization Program
Bureau of Pollution control
Department of Environmental Quality
P.O. Box 10385
Jackson, Mississippi 39289-0385
(601) 961-5190

Missouri

State Environmental Improvement
and Energy
Resources Agency
P.O. Box 744
Jefferson City, MO 65102
(314) 751-4919

Waste Management Program
Missouri Department of Natural Resources
Jefferson Building, 13th Floor
P.O. Box 176
Jefferson City, MO 65102
(314) 751-3176

Nebraska

Land Quality Division
Nebraska Department of Environmental
Control
Box 98922
State House Station
Lincoln, Nebraska 68509-8922
(402) 471-2186

Hazardous Waste Section
Nebraska Department of Environmental
Control
P.O. Box 98922
Lincoln, Nebraska 68509-8922
(402) 471-2186

New Jersey

New Jersey Hazardous Waste
Facilities Siting Commission
Room 614
28 West State Street
Trenton, NJ 08608
(609) 292-1459
(609) 292-1026

Hazardous Waste Advisement Program
Bureau of Regulation and Classification
New Jersey Department of
Environmental Protection
401 East State Street
Trenton, NJ 08625
(609) 292-8341

Risk Reduction Unit
Office of Science and Research
New Jersey Department of
Environmental Protection
401 East State Street
Trenton, NJ 08625
(609) 292-8341

New Mexico

Economic Development Department
Bataan Memorial Building
State Capitol Complex
Santa Fe, NM 87503
(505) 827-6207

New York

New York Environmental Facilities
Corporation
50 Wolf Road
Albany, NY 12205
(518) 457-4222

North Carolina

Pollution Prevention Pays Program
Department of Natural Resources and
Community Development
P.O. Box 27687
512 North Salisbury Street
Raleigh, NC 27611
(919) 733-7015

Governor's Waste Management Board
P.O. Box 27687
325 North Salisbury Street
Raleigh, NC 27611-7687
(919) 733-9020

Technical Assistance Unit
Solid and Hazardous Waste
Management Branch
North Carolina Department of
Human Resources
P.O. Box 2091
306 North Wilmington Street
Raleigh, NC 27602
(919) 733-2178

North Dakota

North Dakota Economic
Development Commission
Liberty Memorial Building
State Capitol Grounds
Bismarck, ND 58505
(701) 224-2810

Ohio

Division of Solid and Hazardous
Waste Management
Ohio Environmental Protection Agency
P.O. Box 1049
1800 Watermark Drive
Columbus, OH 43265-1049
(614) 644-2917

Oklahoma

Industrial Waste Elimination Program
Oklahoma State Department of Health
P.O. Box 53551
Oklahoma City, OK 73152
(405) 271-7353

Oregon

Oregon Hazardous Waste
Reduction Program
Department of Environmental Quality
811 Southwest Sixth Avenue
Portland, OR 97204
(503) 229-5913
(800) 452-4011 (in Oregon)

Pennsylvania

Pennsylvania Technical
Assistance Program
501 F. Orvis Keller Building
University Park, PA 16802
(814) 865-0427

Center of Hazardous Material Research
Subsidiary of the University of

Pittsburgh Trust

320 William Pitt Way
Pittsburgh, PA 15238
(412) 826-5320
(800) 334-2467

Puerto Rico

Government of Puerto Rico,
Economic Development Administration
Box 2350
San Juan, PR 00936
(809) 758-4747

Rhode Island

Hazardous Waste Reduction Section
Office of Environmental Management
83 Park Street
Providence, RI 02903
(401) 277-3434
(800) 253-2674 (in Rhode Island)

South Carolina

Center for Waste Minimization
Department of Health and
Environmental Control
2600 Bull Street
Columbia, SC 29201
(803) 734-4715

South Dakota

Dept. of State Development
P.O. Box 6000
Pierre, SD 57501
(800) 843-8000

Tennessee

Center for Industrial Services
226 Capitol Blvd.
Building #401
University of Tennessee
Nashville, TN 37219-1804
(615) 242-2456

Bureau of Environment
Tennessee Department of Health
and Environment
150 9th Ave. North
Nashville, Tennessee 37219-5404
(615) 741-3657

Tennessee Hazardous Waste
Minimization Program
Tennessee Department of Economic and
Community Development
Division of Existing Industry Services
7th Floor, 320 6th Ave. North
Nashville, TN 37219
(615) 741-1888

Texas

Texas Economic Development Authority
410 E. Fifth St.
Austin, TX 78701
(512) 472-5059

Utah

Utah Division of Economic Development
6150 State Office Building
Salt Lake City, UT 84114
(801) 533-5325

Vermont

Economic Development Department
Pavilion Office Building
Montpelier, VT 05602
(802) 828-3221

Virginia

Office of Policy and Planning
Virginia Department of
Waste Management
11th Floor, Monroe Building
101 North 14th Street
Richmond, VA 23219
(804) 225-2667

Washington

Hazardous Waste Section
Mail Stop PV-11
Washington Department of Ecology
Olympia, WA 98504-8711
(206) 459-6322

West Virginia

Governor's Office of Economics
and Community Development
Building G, Room B-517
Capitol Complex
Charleston, WV 25305
(304) 348-2234

Wisconsin

Bureau of Solid Waste Management
Wisconsin Department of
Natural resources
P.O. Box 7921
101 South Webster Street
Madison, WI 53707
(608) 267-3763

Wyoming

Solid Waste Management Program
Wyoming Department of
Environmental Quality
Herschler Building, 4th Floor,
West Wing
122 West 25th Street
Cheyenne, Wy 82002
(307) 777-7752