EXTENDED LIFE COOLANT TESTING

INTERIM REPORT
TFLRF No. 478

by
Gregory A. T. Hansen
Edwin A. Frame

U.S. Army TARDEC Fuels and Lubricants Research Facility
Southwest Research Institute® (SwRI®)
San Antonio, TX

for
Mr. Zackery Schroeder
U.S. Army TARDEC
Force Projection Technologies
Warren, Michigan

Contract No. W56HZV-09-C-0100 (WD35)

June 2016

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UNCLASSIFIED: Distribution Statement A. Approved for public release

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Approved by:

Gary B. Bessee, Director
U.S. Army TARDEC Fuels and Lubricants
Research Facility (SwRI®)

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188
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1. REPORT DATE *(DD-MM-YYYY)* 06-06-2016	**2. REPORT TYPE** Interim Report		**3. DATES COVERED** *(From - To)* June 2014 – June 2016
4. TITLE AND SUBTITLE Extended Life Coolant Testing Simulated Service Corrosion Testing of Traditional and Extended Life Coolants			**5a. CONTRACT NUMBER** W56HZV-09-C-0100 **5b. GRANT NUMBER** **5c. PROGRAM ELEMENT NUMBER**
6. AUTHOR(S) Hansen, Gregory A. T.; Frame, Edwin A.			**5d. PROJECT NUMBER** SwRI 08.20495.01.101 **5e. TASK NUMBER** WD 35 **5f. WORK UNIT NUMBER**
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army TARDEC Fuels and Lubricants Research Facility (SwRI®) Southwest Research Institute® P.O. Drawer 28510 San Antonio, TX 78228-0510			**8. PERFORMING ORGANIZATION REPORT NUMBER** TFLRF No. 478
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army RDECOM U.S. Army TARDEC Force Projection Technologies Warren, MI 48397-5000			**10. SPONSOR/MONITOR'S ACRONYM(S)** **11. SPONSOR/MONITOR'S REPORT NUMBER(S)**
12. DISTRIBUTION / AVAILABILITY STATEMENT UNCLASSIFIED: Dist A Approved for public release; distribution unlimited			
13. SUPPLEMENTARY NOTES			
14. ABSTRACT The U.S. Army has a desire to understand the interaction of traditional and extended life coolants with the goal to reduce the logistical burden of providing vehicle specific coolants. Several laboratory corrosion tests were performed according to ASTM D1384 and D2570, but with a 2.5x extended time length. While the results of testing showed little corrosion, some negative interactions with the corrosive water mixture were observed.			
15. SUBJECT TERMS Coolant, ASTM D1384, ASTM D2570, Extended Life			

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**		28	19b. TELEPHONE NUMBER *(include area code)*

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

EXECUTIVE SUMMARY

The use of extended life coolant (ELC) has become a priority to the U.S. Army in order to maintain parity amongst its fleet of military vehicles. Newer vehicles come factory-filled with ELC, while the Army continues to use traditional supplemental coolant additives (SCA)-based coolant (hereafter referred to as traditional coolant) with a shorter use and shelf-life. It is unknown if traditional coolant and ELC can be mixed, or if the entire coolant system needs to be flushed and refilled during routine maintenance. TARDEC intends to evaluate identified ELCs, traditional coolant and the mixtures thereof via a multitude of ASTM and Commercial Item Description (CID) test methods. If the Army can determine the viability of recycled/virgin ELC or ELC/traditional coolant mixtures, logistical burdens can be significantly reduced.

The objective of this effort was to run modified versions (to extend the testing to be representative of five years of use) of ASTM D2570 Simulated Service Corrosion and ASTM D1384 Glassware Corrosion in a closed environment with several coolant formulations and mixtures in order to analyze coolant performance characteristics. This analysis may provide insight into corrosion performance of ELCs and ELC/traditional coolant mixtures in a laboratory testing environment that provides a closer approach to actual engine coolant systems.

The two ASTM tests chosen for this effort were run for two and a half (2.5x) times their standard length. While it was anticipated that time would be an important factor in discrimination of coolant performance, the results were inconclusive. It is recommended that for future testing, other variables such as temperature, flow rate, or corrosive water concentration might have a larger impact on performance.

FOREWORD/ACKNOWLEDGMENTS

The U.S. Army TARDEC Fuel and Lubricants Research Facility (TFLRF) located at Southwest Research Institute (SwRI), San Antonio, Texas, performed this work during the period June 2014 through June 2016 under Contract No. W56HZV-09-C-0100. The U.S. Army Tank Automotive RD&E Center, Force Projection Technologies, Warren, Michigan administered the project. Mr. Eric Sattler served as the TARDEC contracting officer's technical representative. Mr. Zackery Schroeder of TARDEC served as project technical monitor.

The authors would like to acknowledge the contribution of the TFLRF technical staff in running the ASTM tests and the administrative staff for report-processing support.

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ACRONYMS AND ABBREVIATIONS

ASTM – American Society for Testing and Materials

CID – Commercial Item Description

ELC – Extended Life Coolant

SCA – Supplemental Coolant Additive

SOW – Scope of Work

SwRI – Southwest Research Institute

TARDEC – Tank Automotive Research, Development, and Engineering Center

TFLRF – TARDEC Fuels and Lubricants Research Facility

1.0 BACKGROUND & INTRODUCTION

The use of extended life coolant (ELC) has become a priority to the U.S. Army in order to maintain parity amongst its fleet of military vehicles. Newer vehicles come factory-filled with ELC, while the Army continues to use traditional supplemental coolant additives (SCA)-based coolant (hereafter referred to as traditional coolant) with a shorter use and shelf-life. It is unknown if traditional coolant and ELC can be mixed, or if the entire coolant system needs to be flushed and refilled during routine maintenance. TARDEC intends to evaluate identified ELCs, traditional coolant and the mixtures thereof via a multitude of ASTM and Commercial Item Description (CID) test methods. If the Army can determine the viability of recycled/virgin ELC or ELC/traditional coolant mixtures, logistical burdens can be significantly reduced. This report covers extended length ASTM coolant tests (ASTM D1384 and ASTM D2570) which were performed over two years. Testing was conducted at the U.S. Army TARDEC Fuels and Lubricants Research Facility (TFLRF), located at Southwest Research Institute (SwRI), San Antonio TX.

2.0 OBJECTIVE

The objective of this effort was to run modified versions (to extend the testing to be representative of five years of use) of ASTM D2570 Simulated Service Corrosion and ASTM D1384 Glassware Corrosion in a closed environment with several coolant formulations and mixtures in order to analyze coolant performance characteristics. This analysis provided insight into corrosion performance of ELCs and ELC/traditional coolant mixtures in a testing environment that is a closer approximation of field testing.

3.0 APPROACH

Both ASTM D1384 and ASTM D2570 were run for two and a half times their normal length. This resulted in ASTM D1384 tests that ran for 840 hours each, and ASTM D2570 tests that ran for 2660 hours each. While each ASTM D1384 test is run in triplicate for repeatability, there are no repeatability limits or duplicate runs for the ASTM D2570 test.

4.0 COOLANTS TESTED

Table 1 and Table 2 list the coolant formulations tested in this program. According to their listed ASTM methods, the coolant formulations were mixed with a certain percentage of corrosive water which was made from a solution of de-ionized water and anhydrous salts: sodium sulfate, sodium chloride, and sodium bicarbonate.

Table 1. Coolants run in ASTM D1384

ASTM D1384	
Coolant Formulation	SwRI Lab Code
60% Ethlyene Glycol #1 40% H2O	CL14-6565
60% Proplyene Glycol 40% H2O	CL14-6566
60% Extended Life Coolant #1 40% H2O	CL14-6567
50% Ethlyene Glycol #1 50% H2O	CL14-6568
50% Proplyene Glycol 50% H2O	CL14-6569
50% Extended Life Coolant #1 50% H2O	CL14-6570
50% Extended Life Coolant #2 50% H2O	CL14-6571
100% Extended Life Coolant #1	CL14-6572
100% Ethlyene Glycol #1	CL14-6573
100% Proplyene Glycol	CL14-6574
50% Ethlyene Glycol #2 50% H2O	CL15-7308
50% Extended Life Coolant #2 50% H2O	CL15-7352
50% Ethlyene Glycol #1 50% H2O	CL15-7564
30% Proplyene Glycol 70% Extended Life Coolant #1	CL15-8129
30% Ethlyene Glycol 70% Extended Life Coolant #2	CL15-8130

Table 2. Coolants run in ASTM D2570

ASTM D2570	
Coolant Formulation	SwRI Lab Code
50% Ethlyene Glycol #1 50% H2O	CL15-7564
50% Extended Life Coolant #1 50% H2O	CL15-8131
5% Ethlyene Glycol #1 45% Extended Life Coolant #1 50% H2O	CL15-8350
15% Ethlyene Glycol #1 35% Extended Life Coolant #1 50% H2O	CL15-8926
5% Proplyene Glycol #1 45% Extended Life Coolant #1 50% H2O	CL15-8927
15% Proplyene Glycol #1 35% Extended Life Coolant #1 50% H2O	CL15-8928

5.0 RESULTS AND DISCUSSION

ASTM D3306 defines the coupon mass loss limits for the glassware corrosion and simulated service corrosion tests. The values in Table 3 are the limits, in milligrams, for the standard length tests.

Table 3. Mass Loss Limits (milligrams) for ASTM D1384 and D2570

ASTM D1384			ASTM D2570	
Material	Loss Limit		Material	Loss Limit
Copper	10		Copper	20
Solder	30		Solder	60
Brass	10		Brass	20
Steel	10		Steel	20
Cast Iron	10		Cast Iron	20
Aluminum	30		Aluminum	60

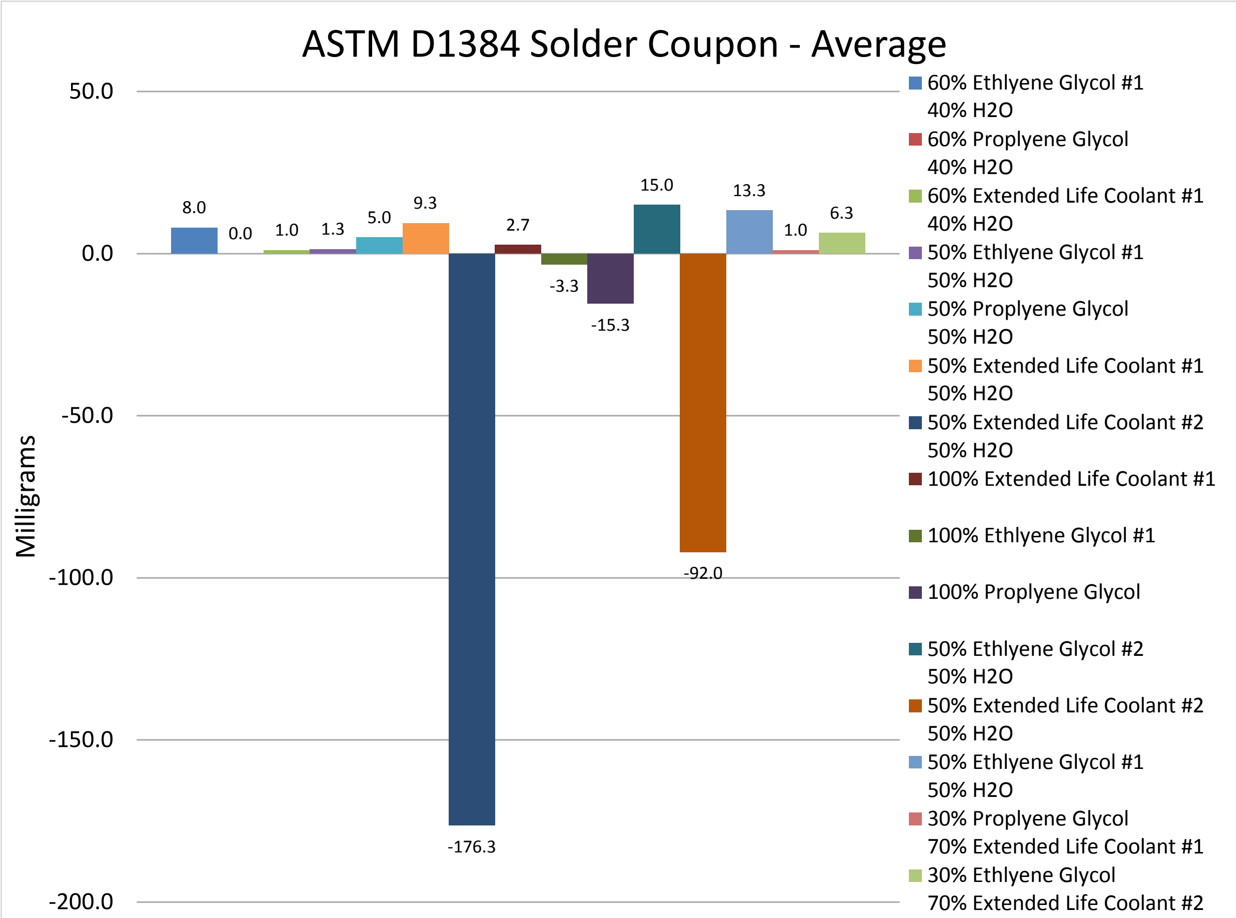

Figure 1. ASTM D1384 Solder Coupon Mass Loss

For all of the tests run in the glassware corrosion test, only the solder coupons in the Extended Life Coolant #2 tests showed questionable results. In total, none of the coupons were beyond the proscribed limits for mass loss, but since there is no limit for mass gain, the results are open to interpretation. The two solder coupons with high mass gain (as seen in Figure 1), indicated by a large negative value, were heavily plated with salt at the end of the tests. Some of the salt flaked off during the approved cleaning procedure, and so the values would have been even more negative pre-cleaning. Images of the coupons for those two tests can be seen in Figure 2 and Figure 3.

Figure 2. ASTM D1384 Coupons for Test CL14-6571 Extended Life Coolant #2

The solder coupons in Figure 2 showed an average weight gain of 176.3 grams. The cleaning process for the solder involved brushing the coupons with a soft bristle brush to remove any loose deposits. Then they were immersed for 5 minutes in a 1% solution of glacial acetic acid. The coupons were then rinsed in deionized water and brushed again. This cleaning procedure, which is outlined in the ASTM D1384 method, removed some of the salt crust that formed, but not all.

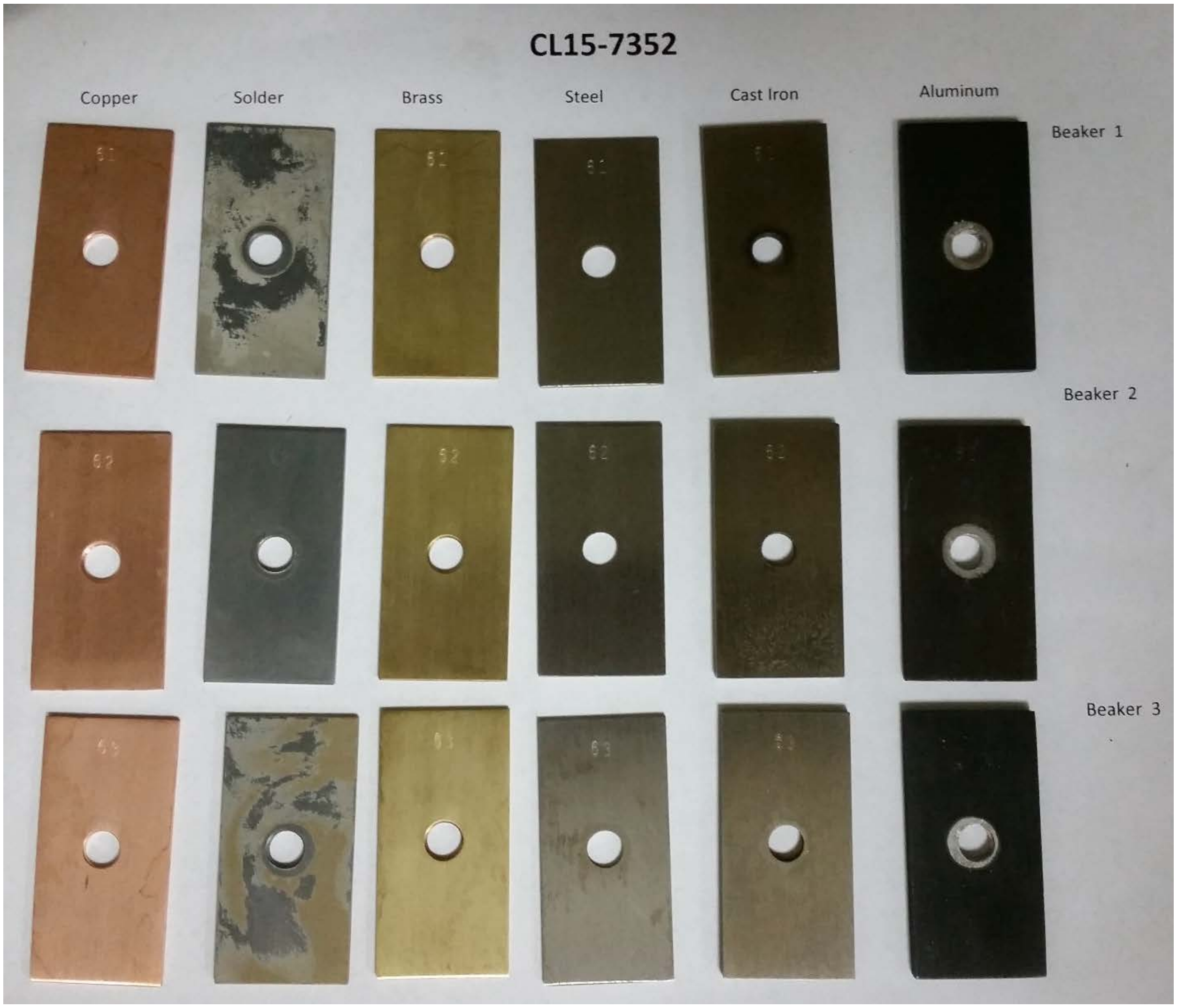

Figure 3. ASTM D1384 Coupons for Test CL15-7352 Extended Life Coolant #2

The solder coupons in Figure 3 showed an average weight gain of 92 grams. This was a re-run of the previous test to make certain the salt crust accumulation on the coupons was repeatable, and not due to a laboratory error. For an unknown reason, one of the glass beakers (each test is run in triplicate) did not allow any accumulation on the solder coupon. So for the six glass beakers that ran this coolant, five of them showed very high salt accumulation on the solder coupon.

All data tables for ASTM D1384 can be found in APPENDIX A.

In the simulated service corrosion tests, two of the six tests had copper coupons (as seen in Figure 4) had mass loss higher than the limit of 20 milligrams.

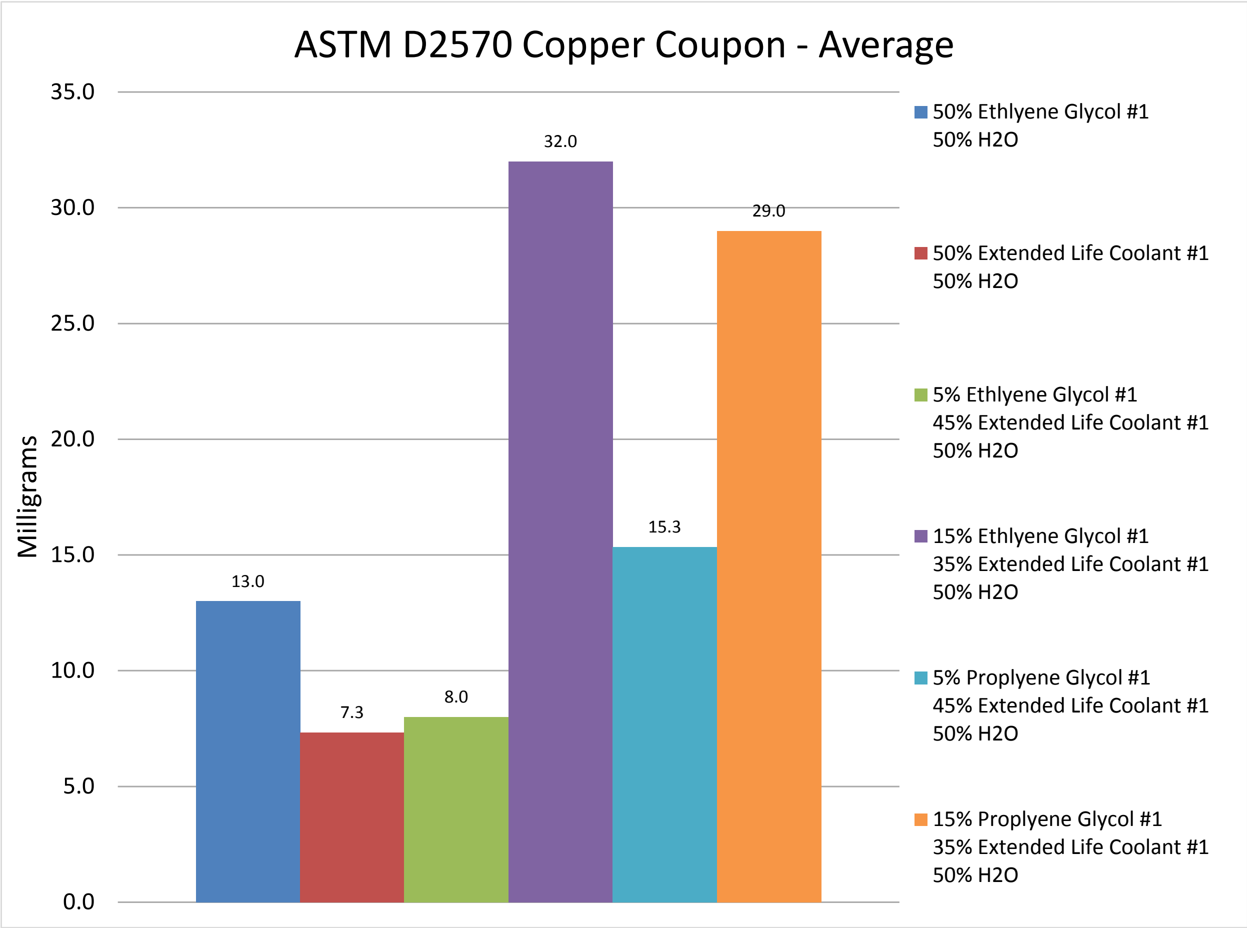

Figure 4. ASTM D2570 Copper Coupon Mass Loss

In both of the tests exhibiting higher than allowed copper mass loss, the coolant formulations were a mix of either 15% ethylene or propylene glycol and 35% extended life coolant #1 (ELC1) with a balance of water. At a higher ELC1 content of 45% or 50%, the mass loss results were within acceptable bounds. This may warrant further study at lower ELC1 concentrations in various coolant mixtures as there could be some competitive chemistry at work in the additive packages.

There was an issue with mass gain during this testing as well, although the cast aluminum coupons showed the evidence as opposed to the solder coupons mentioned previously. For the third test which was a mixture of 5% ethylene glycol, 45% ELC1, and 50% water, there was significant material accumulation on the aluminum coupons as seen in Figure 5 and Figure 6.

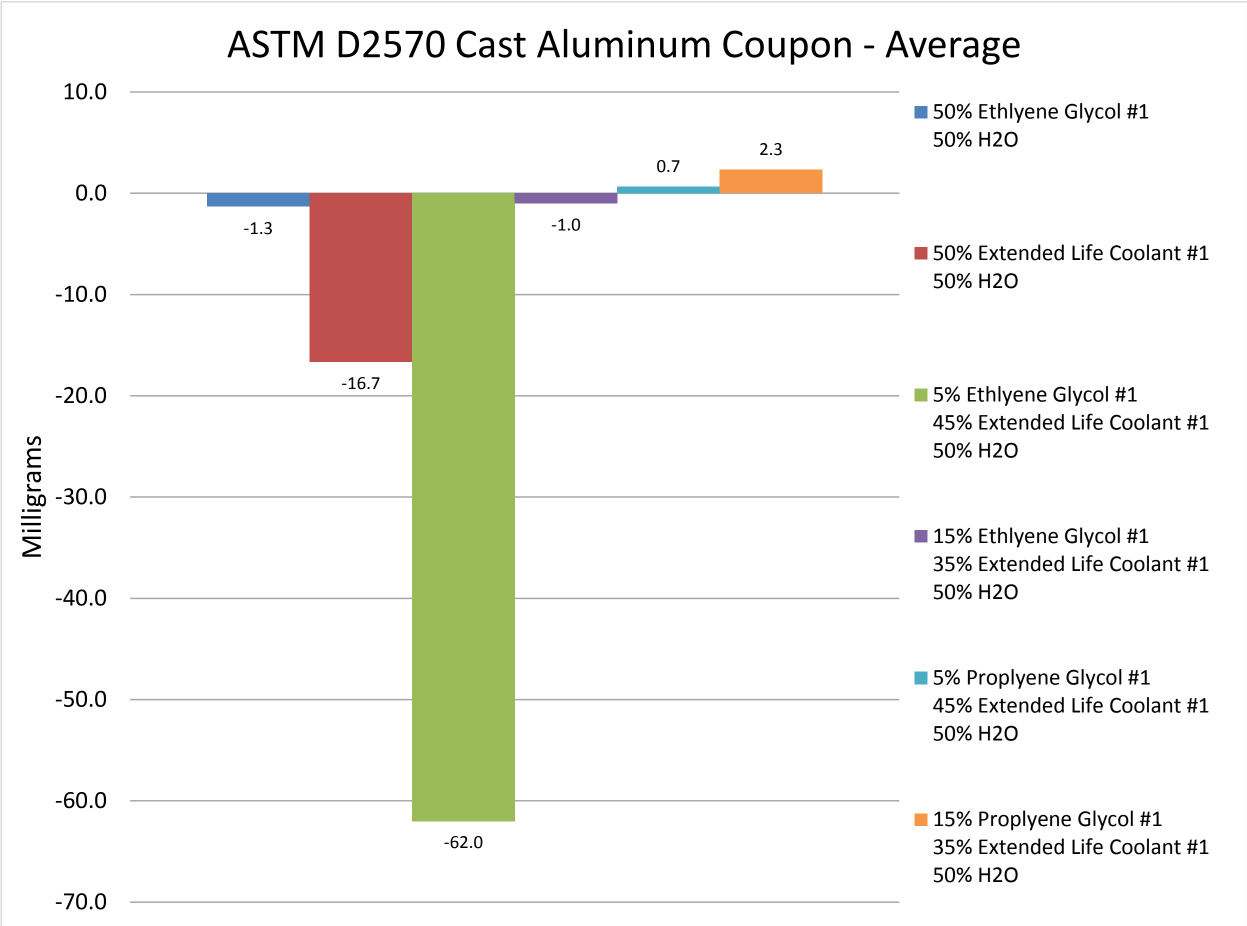

Figure 5. ASTM D2570 Cast Aluminum Coupon Mass Loss

The cause of these deposits may be due to a series of pump failures that occurred during the test. Typically pump failures occur due to the design age (1987 Buick Skylark, per the method), but it is uncommon to have more than 1 per test. The procedure for continuing the test is to drain the fluid, replace the pump, put all of the fluid back in and top off if necessary. The first pump failure in the test was an internal bearing rupture, which was only discovered during post-test investigations. This caused some of the bearing grease to be washed out into the coolant system.

Figure 6. ASTM D2570 Coupons for Test CL15-8350, 5% EG & 45% ELC1

Although no samples were analyzed, pictures were taken of the heavy deposits inside the cast iron vessel and of the 'grease' that was collected from the system, Figure 7 and Figure 8.

Figure 7. Cast iron vessel after test that had multiple pump failures

Figure 8. 'Grease' found at bottom of cast iron vessel

It is possible that there was some chemical reactions occurring between the corrosive water and the grease that was leaked into the system. In terms of corrosion, the third test still passed by not exceeding any of the mass loss limits, but since water pump failures can and do occur in the field, it may be of interest to further investigate the interaction of coolant mixtures and bearing greases typically found in the coolant pumps. This could ensure that the coolant system would not clog up and still be serviceable after replacement of a failed pump.

All of the other test images of the coupons in the ASTM D2570 testing are available upon request but are not included in this document due to their un-remarkable nature. All data tables for ASTM D2570 can be found in APPENDIX B.

6.0 SUMMARY AND RECOMMENDATIONS

In total, 15 glassware corrosion and 6 simulated service corrosion tests were run. The glassware test did not show any significant differences in corrosion protection between the coolants. It did indicate that there was a negative interaction between ELC#2 and the corrosive water mixture, with heavy salt deposits on the solder coupons. The simulated service test did show some increased copper corrosion for some of the ELC#1 coolant mixtures but not all. There were also some increased salt deposits on the aluminum coupons. When compared to the baseline SCA glycol coolants, the ELC coolants and ELC mixtures were unable to show increased corrosion protection. This result demonstrates that extending the test time was not a significant variable. In future testing other variables such as temperature (or temperature differential), flow rate, corrosive concentration, or even 3rd party contaminants may have a larger impact and be better able to distinguish differences in coolant performance.

Appendix A
ASTM D1384 Results

Sample Name		CL14-6573	CL14-6566	CL14-6570	CL14-6568	CL14-6574
Copper 1	**mg**	1	13	2	2	4
Copper 2	**mg**	1	8	3	3	3
Copper 3	**mg**	1	7	4	3	3
Solder 1	**mg**	9	1	0	1	5
Solder 2	**mg**	7	-3	2	2	5
Solder 3	**mg**	8	2	1	1	5
Brass 1	**mg**	0	11	2	2	1
Brass 2	**mg**	0	0	2	1	2
Brass 3	**mg**	0	1	4	1	3
Steel 1	**mg**	1	-1	-1	2	-4
Steel 2	**mg**	1	-1	0	2	-4
Steel 3	**mg**	0	-3	0	1	-2
Cast Iron 1	**mg**	-4	-8	-7	0	-1
Cast Iron 2	**mg**	-4	-9	-6	-1	-10
Cast Iron 3	**mg**	-5	-9	-3	0	-3
Cast Aluminum 1	**mg**	37	21	8	4	6
Cast Aluminum 2	**mg**	-3	23	9	6	7
Cast Aluminum 3	**mg**	15	16	8	12	7

Sample Name		CL14-6565	CL14-6571	CL14-6569	CL14-6572	CL14-6567
Copper 1	**mg**	2	3	6	-10	5
Copper 2	**mg**	2	3	6	-6	6
Copper 3	**mg**	2	5	5	-6	4
Solder 1	**mg**	8	-147	1	-3	-12
Solder 2	**mg**	10	-233	4	-4	-20
Solder 3	**mg**	10	-149	3	-3	-14
Brass 1	**mg**	2	5	3	-6	-2
Brass 2	**mg**	2	4	5	-3	-3
Brass 3	**mg**	1	4	6	-3	-2
Steel 1	**mg**	0	-1	0	-1	0
Steel 2	**mg**	0	0	-1	0	-1
Steel 3	**mg**	0	0	0	-4	0
Cast Iron 1	**mg**	-4	0	-9	-3	-5
Cast Iron 2	**mg**	-1	-6	-7	-5	-6
Cast Iron 3	**mg**	-2	-5	-6	-4	-2
Cast Aluminum 1	**mg**	-4	1	14	2	-1
Cast Aluminum 2	**mg**	-5	0	35	1	-5
Cast Aluminum 3	**mg**	-4	2	24	-1	-2

Sample Name		CL15-7308	CL15-7352	CL15-7564	CL15-8129	CL15-8130
Copper 1	**mg**	3	1	3	4	2
Copper 2	**mg**	3	1	4	5	3
Copper 3	**mg**	3	1	3	5	2
Solder 1	**mg**	16	-149	15	0	6
Solder 2	**mg**	12	-1	12	2	6
Solder 3	**mg**	17	-126	13	1	7
Brass 1	**mg**	3	1	4	3	0
Brass 2	**mg**	3	0	3	2	1
Brass 3	**mg**	3	-1	3	3	2
Steel 1	**mg**	0	-3	1	0	0
Steel 2	**mg**	1	-1	1	0	0
Steel 3	**mg**	1	-2	1	0	1
Cast Iron 1	**mg**	-3	-5	-5	0	-3
Cast Iron 2	**mg**	-5	-4	-2	0	-3
Cast Iron 3	**mg**	-3	-2	-3	0	-3
Cast Aluminum 1	**mg**	3	4	-1	1	1
Cast Aluminum 2	**mg**	3	3	-3	4	5
Cast Aluminum 3	**mg**	2	4	0	3	3

Appendix B

ASTM D2570 Results

Sample Name		CL15-7564	CL15-8131	CL15-8350
Copper 1	**mg**	12	7	7
Copper 2	**mg**	13	7	7
Copper 3	**mg**	14	8	10
Solder 1	**mg**	22	8	6
Solder 2	**mg**	14	3	3
Solder 3	**mg**	18	6	6
Brass 1	**mg**	10	7	7
Brass 2	**mg**	9	7	8
Brass 3	**mg**	9	8	9
Steel 1	**mg**	4	2	0
Steel 2	**mg**	3	1	0
Steel 3	**mg**	4	1	0
Cast Iron 1	**mg**	-1	-2	0
Cast Iron 2	**mg**	-2	-1	0
Cast Iron 3	**mg**	-5	-2	0
Cast Aluminum 1	**mg**	-1	-21	-74
Cast Aluminum 2	**mg**	-1	-31	-72
Cast Aluminum 3	**mg**	-2	2	-40
New Freeze Point	**deg F**	-15	-20	-21
New pH	**.**	10.1	8.5	8.5
New Reserve Alkalinity	**ml HCl**	1.6	2.2	2.9
New Color	**.**	Green	Pink	Red
New Precipitate	**.**	None	N/A	None
New Clarity	**.**	Translucent	Translucent	Translucent
Used Freeze Point	**deg F**	-15	-20	-19
Used pH	**.**	8	9.3	9.2
Used Reserve Alkalinity	**ml HCL**	1.2	2	3.4
Used Color	**.**	Green	Pink	Dark Red
Used Precipitate	**.**	None	N/A	Sediments
Used Clarity	**.**	Translucent	Translucent	Translucent

Sample Name		CL15-8926	CL15-8927	CL15-8928
Copper 1	mg	30	20	28
Copper 2	mg	33	14	30
Copper 3	mg	33	12	29
Solder 1	mg	7	14	20
Solder 2	mg	8	6	24
Solder 3	mg	8	5	27
Brass 1	mg	8	18	8
Brass 2	mg	6	9	8
Brass 3	mg	8	10	8
Steel 1	mg	1	0	-2
Steel 2	mg	1	0	-1
Steel 3	mg	1	0	-1
Cast Iron 1	mg	-1	0	-5
Cast Iron 2	mg	-1	-1	-4
Cast Iron 3	mg	-1	-1	-5
Cast Aluminum 1	mg	-1	0	3
Cast Aluminum 2	mg	-1	1	3
Cast Aluminum 3	mg	-1	1	1
New Freeze Point	deg F	-23	-20	-25
New pH	.	8.12	8.11	9.03
New Reserve Alkalinity	ml HCl	1.6	1.4	1.7
New Color	.	Red	Red	Red
New Precipitate	.	None	None	None
New Clarity	.	Translucent	Translucent	Translucent
Used Freeze Point	deg F	-25	-23	-28
Used pH	.	8.41	8.56	8.85
Used Reserve Alkalinity	ml HCL	1.8	1.6	1.8
Used Color	.	Red	Red	Red
Used Precipitate	.	None	None	None
Used Clarity	.	Translucent	Translucent	Translucent