REPORT OF LABORATORY TESTING

ASTM STANDARD TESTING PROTOCOL

COOLANT STANDARDS:

ASTM D6210-06
ASTM D 3306 – 03 (prerequisite)
TMC RP 329 (EG)
DDC 93K 217
Military CID A-A52624 A

PERFORMED FOR

OLD WORLD INDUSTRIES
FleetCharge 2790 in EG

Laboratory ID: 608179
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Introduction:

The ASTM D6210 specification covers the requirements for fully formulated glycol base coolants for cooling systems of heavy duty engines. When concentrates are used at 40 to 60 % glycol concentration by volume in water of suitable quality or when prediluted glycol base engine coolants (50 volume % minimum) are used without further dilution, they will function effectively during both winter and summer to provide protection against corrosion, cavitation, freezing, and boiling.

This specification is intended to cover the requirements for engine coolants prepared from virgin or recycled ethylene or propylene glycol. The coolants governed by this specification are categorized as follows:
Coolant Type Description

I-FF	Ethylene glycol base concentrate
II-FF	Propylene glycol base concentrate
III-FF	Ethylene glycol predilute (50 vol %)
IV-FF	Propylene glycol predilute (50 vol %)

Coolant concentrates meeting this specification do not require any addition of Supplemental Coolant Additive (SCA) until the first maintenance interval when a maintenance doses of SCA is required to continue protection in certain heavy duty engine cooling systems, particularly those of the wet cylinder liner-in-block design. The SCA additions are defined by and are the primary responsibility of the engine manufacturer or vehicle manufacturer. If they provide no instructions, follow the SCA supplier's instructions.

Concentrated and prediluted coolants shall meet all of the respective requirements of Specification D 3306.
The coolant concentrate mixed with water or the prediluted coolant, when maintained with maintenance doses of SCA in accordance with the engine manufacturer's recommendations, and those on the product label, shall be suitable for use in a properly maintained cooling system in normal service for a minimum of two years

The coolant concentrate or prediluted coolant additionally shall provide protection in operating engines against cavitation corrosion (also termed liner pitting) and against scaling of internal engine hot surfaces. Hot surfaces typically are within the engine head, head spacer, upper cylinder liner, or liquid cooled exhaust manifold.

Laboratory data or in-service experience demonstrating a positive influence on reducing cavitation corrosion in an operating engine is required. In-service qualification tests may consist of single or multiple-cylinder engine tests. At the option of the engine or vehicle manufacturer, such testing may be conducted in "loose
engines" or in engines fully integrated into an application, such as a vehicle, a power boat, or a stationary power source. One such test has been developed (the John Deere engine cavitation test). Several chemical compositions have been tested extensively by producers and users and satisfactorily minimize cylinder liner cavitation in actual test engines. Coolants meeting either of the following compositions are regarded as passing the requirements of D6210:

1. A minimum concentration of nitrite (as NO_2^-) of 1200 ppm in the 50 volume % predilute coolant, or
2. A minimum combined concentration of nitrite (as NO_2^-) plus molybdate (as MoO_4^{-2}) in the 50-volume % predilute coolant of 780 ppm. At least 300 ppm each of NO_2^- and MoO4−2 must be present.

The above concentrations are doubled for coolant concentrates.

Both concentrated and prediluted coolants under this specification must contain additives to minimize hot surface scaling deposits. Certain additives (polyacrylate and other types) minimize the deposition of calcium and magnesium compounds on heat rejecting surfaces. No specific chemical requirements for hot surface scaling and deposits resistance have been established at this time. A test procedure is under development and will be incorporated into the specification when ASTM approves a procedure.

The D3306 and D6210 specifications publish the following requirements for the physical and chemical tests:

Property	EG Concentrate	PG Concentrate	EG Predilute	PG Predilute	Test Method used at Amalgatech
Relative Density, 15.5/15.5°C (60 /60 °F)	1.110 –1.145	1.030-1.065	1.065 min.	1.025 min.	D1122
Freezing Point, °C (°F) 50% in DI water Undiluted	-37 (-34) max.	-32 (-26) max.	-37 (-34) max.	-32 (-26) max.	D1177
Boiling Point °C (°F)[A] 50% in DI water, Undiluted	108 (226) min 163 (325) min	104 (219) min 152 (305) min	108 (226) min	104 (219) min	D1120
Ash content, mass%	5 max.	5 max.	5 max.	5 max.	D1119
pH 50 vol% in DI water Undiluted	7.5 –11.0	7.5 –11.0	7.5 –11.0	7.5 –11.0	D1287
Chloride, ppm	25 max	25 max	25 max	25 max	D5827
Sulfate, ppm	50 max	50 max	50 max	50 max	D5827
Water, mass%	5 max.	5 max.	5 max.	5 max.	D1123
Reserve Alkalinity, ml[B]	report	report	report	report	D1121
Foaming Tendencies Vol/Break Time	150 ml 5.0 sec.	150 ml 5.0 sec.	150 ml 5.0 sec.	150 ml 5.0 sec.	D1881
Effect on Automotive Finish[C]	no effect	no effect	no effect	no effect	D1882

[A] Some precipitate may be observed at the end of the test. This is not a cause for rejection.
[B] Value as agreed between customer and supplier.
[C] Procedure and acceptance criteria should be agreed between customer and supplier

The coolant reported in this trial has the chemical profile in Table 1:

Table 1: Sample Analytical Identification

Test performed	This sample
Physical Data	
Color and Appearance *	Fucshia
pH by ASTM D1287	10.44
% Antifreeze from chart *	100
Freezing Point[2] by ASTM D3321	-37 C (-34 F)
Corrosion Inhibitors	
Boron (mg/l B) ASTM D 6130	351
Molybdenum (mg/l Mo) ASTM D 6130	0
Nitrites (mg/l) by ASTM D 5827	2265
Nitrates (mg/l) by ASTM D 5827	707
Phosphate (mg/l) by ASTM D 5827	0
Silicon (mg/l Si) by ASTM D 6130	235
Age and Wear Indicators	
Aluminum (mg/l Al) ASTM D 6130	0
Calcium (mg/l Ca) ASTM D 6130	0
Chloride (mg/l) ASTM D 5827	12
Copper (mg/l Cu) ASTM D 6130	0
Formate (mg/l) glycol degradation acid*	0
Glycolate (mg/l) glycol degradation acid*	0
Iron (mg/l Fe) ASTM D 6130	0
Magnesium (mg/l Mg) ASTM D 6130	0
Lead (mg/l Pb) ASTM D 6130	0
Sulfate (mg/l) ASTM D 5827	0
AZOLES AND CARBOXYLATES BY HPLC	
Mercaptobenzothiazole mg/l*	537
Benzotriazole mg/l*	549
Tolyltriazole mg/l*	0
Benzoate mg/l*	0
2 Ethylhexanoic acid mg/l*	0
Sebacic acid mg/l*	0

D3306 Table 2: Physical & Chemical Tests

Test Number & Description	Test Result
D-1122 Relative Density (aka Specific Gravity)	1.1240
D-1177 Freeze Point °C (°F) *50% with 50% DI Water v/v*	-40.2 C (-40.4 F)
D-1120 Boiling Point °C (°F) As received	178.9 C (354.0 F)
D-1120 Boiling Point °C (°F) *50% with 50% DI Water v/v*	108.0 C (226.4 F)
D-1882 Auto Finish Effect	No effect
D-1119 Ash Content, mass%	0.71
D-1287 pH: 50% vol. in distilled water	10.44
D-3634 Chloride ppm	12
D-1123 Water mass percent	1.86
D-1121 Reserve Alkalinity ML	6.4
D-1881 Foaming Tendencies	110 ml volume 4.2 seconds break time

ASTM D2809: **Cavitation Corrosion and Erosion-Corrosion Characteristics of Aluminum Pumps With Engine Coolants**

This test method consists of pumping an aqueous coolant solution at 113°C (235°F) through a pressurized 103-kPa (15-psig) simulated automotive coolant system. An aluminum automotive water pump, driven at 4600 r/min by an electric motor, is used to pump the solution and to serve as the object specimen in evaluating the cavitation erosioncorrosion effect of the coolant under test. The pump is examined to determine the extent of cavitation erosioncorrosion damage and is rated according to the system given in Table 3.

This test method can be used to distinguish between coolants that contribute to cavitation corrosion and erosioncorrosion of aluminum automotive water pumps and those that do not. It is not intended that a particular rating number, as determined from this test, will be equivalent to a certain number of miles in a vehicle test; however, limited correlation between bench and field service tests has been observed with single-phase coolants. Field tests under severe operating conditions should be conducted as the final test if the actual effect of the coolant on cavitation corrosion and erosion-corrosion is to be appraised. It is also possible, with proper control of the test variables, to determine the effect of pump design, materials of construction, and pump operating conditions on cavitation

TABLE 3: Rating System

10	No corrosion or erosion present; no metal loss. No change from original casting configuration. Staining permitted.
9	Minimal corrosion or erosion. Some rounding of sharp corners or light smoothing or both, or polishing of working surfaces.
8	Light corrosion or erosion may be generalized on working surfaces. Dimensional change not to exceed 0.4 mm (164 in.).
7	Corrosion or erosion with dimensional change not to exceed 0.8 mm (132 in.). Random pitting to 0.8 mm permitted.
6	Corrosion or erosion with dimensional change not to exceed 0.8 mm. Depressions, grooves, clusters of pits, or scalloping, or both, within 0.8 mm dimensional change limit permitted.
5	Corrosion or erosion with dimensional change not to exceed 1.6 mm (116 in.). Small localized areas of metal removal in high-impingement regions or random pits to 1.6 mm permitted.
4	Corrosion or erosion with dimensional change not to exceed 1.6 mm. Small localized areas of metal removal in high-impingement regions, clusters of pits within 1.6 mm dimensional change. Random pits to 2.4 mm (332in.) permitted.
3	Corrosion or erosion with dimensional change not to exceed 2.4 mm. Depressions, grooves, clusters of pits or scalloping, or both, permitted.
2	Corrosion or erosion with any dimensional change over 2.4 mm, and short of pump case failure
1	Pump case leaking due to corrosion or erosion.

ASTM D 2809 Test Results:

Pump Rating	Solution pH
10	Start 10.0 End 9.4
Comments: Darkened surface, otherwise “like new”	

Note: ASTM D-3306 requires a pump rating of 8 or higher on a scale of 10.

ASTM D4340: **Corrosion of Cast Aluminum Alloys in Engine Coolants Under Heat-Rejecting Conditions**

This test method covers a laboratory screening procedure for evaluating the effectiveness of engine coolants in combating corrosion of aluminum casting alloys under heat-transfer conditions that may be present in aluminum cylinder head engines.

In this test method, a heat flux is established through a cast aluminum alloy typical of that used for engine cylinder heads while exposed to an engine coolant under a pressure of 193 kPa (28 psi). The temperature of the aluminum specimen is maintained at 135°C (275°F) and the test is continued for 1 week (168 h). The effectiveness of the coolant for preventing corrosion of the aluminum under heat-transfer conditions (hereafter referred to as heat-transfer corrosion) is evaluated on the basis of the weight change of the test specimen.

ASTM D 4340 TEST RESULTS

	Run #1	Run #2	Average
Weight Loss (mg/cm^2/wk)	0.23	-0.05	**0.09**
pH After	8.10	8.04	**8.07**

Notes: ASTM places the maximum corrosion rate at **1.00** (mg/cm^2/wk).

ASTM D1384: **Corrosion Test for Engine Coolants in Glassware**

This test method covers a simple beaker-type procedure for evaluating the effects of engine coolants on metal specimens under controlled laboratory conditions. In this test method, specimens of metals typical of those present in engine cooling systems are totally immersed in aerated engine coolant solutions prepared with corrosive salts for 336 hours at 88°C (190°F). The corrosion inhibition properties of the test solution are evaluated on the basis of the weight changes incurred by the specimens. Each test is run in triplicate, and the average weight change is determined for each metal. This test method will generally distinguish between coolants that are definitely deleterious from the corrosion standpoint and those that are suitable for further evaluation. However, the results of this test method cannot stand alone as evidence of satisfactory corrosion inhibition. Only more comprehensive bench, dynamometer, and field tests can determine the actual service value of an engine coolant formulation.

Automobile manufacturers have accepted the specimens prescribed in this test method, but their composition may not be the same as that of alloys currently used for engine cooling system components. Therefore, specimens other than those designated in this test method may be used by mutual agreement of the parties involved. The following metal test specimens, 1 by 2 inches in size, representative of cooling system metals, were used:

1. ***Steel***, UNS G10200 (SAE 1020), Chemical composition of the carbon steel is as follows: carbon, 0.17 to 0.23 %; manganese, 0.30 to 0.60 %; phosphorus, 0.040 % maximum; sulfur, 0.050 % maximum.
2. ***Copper***, conforming to UNS C11000 (SAE CA110) or UNS C11300 (SAE CA113). Cold-rolled.
3. ***Brass***, conforming to Alloy UNS C26000 (SAE CA 260).
4. ***Solder***—A brass specimen as described in 6.1.3, coated with solder conforming to Alloy Grade 30A (SAE 3A)
5. ***Cast Aluminum***, conforming to Alloy UNS A23190 (SAE 329).

6. ***Cast Iron***, conforming to Alloy UNS F10007 (SAE G3500).

ASTM D 1384 TEST RESULTS

ASTM D 1384	Specimen Corrosion Weight Loss (mg)				
Specimen	#1	#2	#3	**Avg**	Max*
Copper	2	2	2	**2**	10
Solder	4	2	3	**3**	30
Brass	1	2	1	**1**	10
Steel	2	1	1	**1**	10
Cast Iron	1	1	0	**1**	10
Cast Aluminum	1	0	-1	**0**	30

* Maximum corrosion weight loss as specified by ASTM D3306

ASTM D2570: **Simulated Service Corrosion Testing of Engine Coolants**

This test method evaluates the effect of a circulating engine coolant on metal test specimens and automotive cooling system components under controlled, essentially isothermal laboratory conditions. This test method specifies test material, cooling system components, type of coolant, and coolant flow conditions that are considered typical of current automotive use. An engine coolant is circulated for 1064 h at 190°F (88°C) in a flow loop consisting of a metal reservoir, an automotive coolant pump, an automotive radiator, and connecting rubber hoses. Test specimens representative of engine cooling system metals are mounted inside the reservoir, which simulates an engine cylinder block. At the end of the test period, the corrosion-inhibiting properties of the coolant are determined by measuring the mass losses of the test specimens and by visual examination of the interior surfaces of the components. This test method, by a closer approach to engine cooling system conditions, provides better evaluation and selective screening of engine coolants than is possible from glassware testing (Test Method D 1384). The improvement is achieved by controlled circulation of the coolant, by the use of automotive cooling system components, and by a greater ratio of metal surface area to coolant volume. Although this test method provides improved discrimination, it cannot conclusively predict satisfactory corrosion inhibition and service life. If greater assurance of satisfactory performance is desired, it should be obtained from full-scale engine tests and from field-testing in actual service. The same coupons used in D1384 are also used in this test.

ASTM D 2570 Test Results

Specimen Corrosion Weight Loss (mg)					
Specimen	**#1**	**#2**	**#3**	**Avg.**	**Max***
Copper	1	1	1	**1**	20
30a Solder	6	6	5	**6**	60
Brass	2	2	2	**2**	20
Steel	0	3	2	**2**	20
Cast Iron	0	0	1	**0**	20
Cast Aluminum	1	2	0	**1**	60
	pH	**RA**	**Appearance**		
Before D 2570	9.9.	2.7	All exposed parts were in very good condition following the testing.		
After D 2570	7.80	2.0			

* Maximum corrosion weight loss as specified by ASTM D3306

Scaling Resistance of Engine Coolants on Hot Steel Surfaces

This test method circulates coolant at 190 degrees F pas a stainless steel heater rod that is heated to 400 degrees F for 96 hours. The test fluid may be engineered to contain hard water minerals or other hot surface depositing species. At the conclusion of the 96-hour exposure the heater rod is removed and dried. The weight of deposit is determined by comparing the weight of the prepared rod before exposure, and after.

Development of this test method is published as “Scale and Deposits in High Heat Rejecting Engines”, Engine Coolant Testing, Fourth Volume, STP 1335, ASTM International, 100 Barr Harbor Drive, West Conshohoshocken, PA 19428.

Scaling Test Results

Weight Before Exposure (g)	Weight After Exposure (g)	Net Weight Change (g)
305.397	308.228	**2.831**

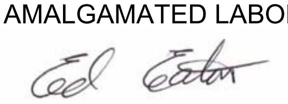
A negative number reflects a weight loss.

Performance in this test is by agreement between Supplier and Customer. There is not, as yet, any industry standard for pass/fain in hot surface scale testing.

Important note: Amalgatech is ISO 17025 accredited. Amalgatech receives samples that are identified by the customer/sender and takes these identifications in good faith, reporting data to the customer using the customer's identification. Our laboratory services are not intended for marketing and are not product certifications. We are accredited to perform most ASTM coolant tests. Any test performed for which Amalgatech is not accredited is identified with an asterisk (*). This report is © Amalgatech division, Amalgamated Laboratories, Inc. 2006. It may not be reproduced, altered, copied or disseminated except in whole. Use of the report is permitted, including copying, as long as the entire report, including this information section, is always provided in its entirety.

Respectfully submitted,

AMALGATECH DIVISION
AMALGAMATED LABORATORIES, INC.



Ed Eaton
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