



# Standard Specification for Recycled Prediluted Aqueous Glycol Base Engine Coolant (50 Volume % Minimum) for Automobile and Light-Duty Service<sup>1</sup>

This standard is issued under the fixed designation D6471; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope\*

1.1 This specification covers the requirements for a recycled prediluted aqueous ethylene glycol (50 volume % minimum) base engine coolant and recycled prediluted aqueous propylene glycol (50 volume % minimum) base engine coolant for use in automobiles and light-duty vehicles. Committee D15 has developed this specification using experience, knowledge and research from recycling used aqueous base engine coolant and blends of used aqueous base engine coolant and virgin glycol. This standard does not apply to coolant produced from other glycol sources such as medical waste, distillation bottoms, airplane/airport deicers and polyester production waste. This specification provides a procedure for evaluating engine coolant recycling technologies through the recycling of a reference synthetic used engine coolant. It also specifies the chemical, physical, and performance requirements for the recycled prediluted aqueous glycol base engine coolant that is produced from that procedure. When used without further dilution, this product functions effectively during both winter and summer. This material is intended to provide protection against freezing, boiling, and corrosion in automobile or other light-duty service cooling systems.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are approximate equivalents and provided for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

---

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee D15 on Engine Coolants and is the direct responsibility of Subcommittee D15.15 on Recycled Engine Coolant.

Current edition approved April 1, 2010. Published May 2010. Originally approved in 1999. Last previous edition approved in 2006 as D6471-06. DOI: 10.1520/D6471-10.

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

- D512 Test Methods for Chloride Ion In Water
- D516 Test Method for Sulfate Ion in Water
- D1119 Test Method for Percent Ash Content of Engine Coolants
- D1120 Test Method for Boiling Point of Engine Coolants
- D1121 Test Method for Reserve Alkalinity of Engine Coolants and Antirusts
- D1122 Test Method for Density or Relative Density of Engine Coolant Concentrates and Engine Coolants By The Hydrometer
- D1126 Test Method for Hardness in Water
- D1176 Practice for Sampling and Preparing Aqueous Solutions of Engine Coolants or Antirusts for Testing Purposes
- D1177 Test Method for Freezing Point of Aqueous Engine Coolants
- D1193 Specification for Reagent Water
- D1287 Test Method for pH of Engine Coolants and Antirusts
- D1293 Test Methods for pH of Water
- D1384 Test Method for Corrosion Test for Engine Coolants in Glassware
- D1881 Test Method for Foaming Tendencies of Engine Coolants in Glassware
- D1882 Test Method for Effect of Cooling System Chemical Solutions on Organic Finishes for Automotive Vehicles
- D2570 Test Method for Simulated Service Corrosion Testing of Engine Coolants
- D2809 Test Method for Cavitation Corrosion and Erosion-Corrosion Characteristics of Aluminum Pumps With Engine Coolants
- D2847 Practice for Testing Engine Coolants in Car and Light Truck Service

---

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

\*A Summary of Changes section appears at the end of this standard

- D3306 Specification for Glycol Base Engine Coolant for Automobile and Light-Duty Service
- D3634 Test Method for Trace Chloride Ion in Engine Coolants
- D4327 Test Method for Anions in Water by Suppressed Ion Chromatography
- D4340 Test Method for Corrosion of Cast Aluminum Alloys in Engine Coolants Under Heat-Rejecting Conditions
- D5827 Test Method for Analysis of Engine Coolant for Chloride and Other Anions by Ion Chromatography
- D5931 Test Method for Density and Relative Density of Engine Coolant Concentrates and Aqueous Engine Coolants by Digital Density Meter
- D6129 Test Method for Silicon in Engine Coolant Concentrates by Atomic Absorption Spectroscopy
- D6130 Test Method for Determination of Silicon and Other Elements in Engine Coolant by Inductively Coupled Plasma-Atomic Emission Spectroscopy
- D6208 Test Method for Repassivation Potential of Aluminum and Its Alloys by Galvanostatic Measurement
- D6472 Specification for Recycled Glycol Base Engine Coolant Concentrate for Automobile and Light-Duty Service
- D6660 Test Method for Freezing Point of Aqueous Ethylene Glycol Base Engine Coolants by Automatic Phase Transition Method

#### 2.2 Other Documents:

- Federal Method 2540B Total Dissolved Solids Dried at 103–105°C<sup>3</sup>
- GM 6043M—Automotive Engine Coolant Concentrate—Ethylene Glycol Type<sup>4</sup>
- GM 1825M—Automotive Engine Coolant Concentrate—Ethylene Glycol; §3.11 Storage Stability and Compatibility<sup>5</sup>

### 3. Reagents and Materials

3.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society where such specifications are available.<sup>6</sup> Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

3.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean reagent water as defined by Type IV of Specification D1193.

### 4. Procedure

4.1 In order to properly evaluate a coolant recycling technology, a reference synthetic used coolant (Annex A1) is to

be used as the feed stock. The reference synthetic used coolant shall be prepared in accordance with Annex A1. An appropriately sized batch of reference synthetic used coolant is to be prepared and used to purge the recycling process components and yield enough consistent product to complete the testing specified within this specification.

4.2 Prepare the coolant recycling equipment or technology according to the manufacturer's directions and recommendations.

4.3 Vigorously stir or mix the reference synthetic used coolant using appropriate vessels and mixing equipment immediately prior to and during the processing through the coolant recycling process.

4.4 Recycle the reference synthetic used coolant according to the manufacturer's directions and recommendations.

4.5 Evaluate the recycled coolant per the requirements listed in this specification.

### 5. General Requirements

5.1 The recycled prediluted aqueous glycol base engine coolant shall consist essentially of water and ethylene glycol or propylene glycol obtained from the processing of light, medium or heavy duty engine coolant products. The recycled prediluted aqueous glycol base engine coolant can in part contain virgin glycol. It also shall contain suitable corrosion inhibitors and a foam suppressor.

5.1.1 Recycled prediluted aqueous ethylene glycol base engine coolant may contain glycols other than ethylene glycol up to 7.5 % provided the chemical and physical properties of Table 1 are met.

5.1.2 Recycled prediluted aqueous propylene glycol base engine coolant may contain glycols other than propylene glycol up to 0.5 % provided the chemical and physical properties of Table 1 are met.

5.2 The recycled prediluted aqueous glycol base engine coolant shall conform to the chemical and physical properties in Table 1. If the recycled prediluted aqueous glycol base engine coolant contains chloride or sulfate, or both, at levels greater than the requirements specified in Table 1, fleet testing requirements described in Section 6 shall be met. If the chloride and sulfate requirements in Table 1 are met, fleet testing is not required.

NOTE 1—The intention of conducting fleet testing is to verify that the effects of residual contaminants left in the recycled glycol base engine coolant are neutralized through real world application in a fleet test. Due to the fact that there are not enough industry field test data available to support setting hard specification limits, the fleet test requirements in Section 6 specify a protocol and limits based on comparing the recycled glycol base engine coolant to an industry standard reference engine coolant that is known to adequately protect modern day cooling systems from corrosion.

5.3 The recycled prediluted aqueous glycol base engine coolant shall conform to the general requirements in Table 2.

5.4 The recycled prediluted aqueous glycol base engine coolant shall be in accordance with the performance requirements in Table 3.

<sup>3</sup> Standard Method for the Examination of Water and Wastewater. American Public Health Association, et al, 1015 15th Street, N.W. Washington, DC 20005.

<sup>4</sup> Applicable rewrite available in Annex A2.

<sup>5</sup> Applicable rewrite available in Annex A3.

<sup>6</sup> *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the United States Pharmacopeia and National Formulary, U.S. Pharmacopeial Convention, Inc., (USPC), Rockville, MD.

**TABLE 1 Physical and Chemical Requirements of the Recycled Prediluted Product**

| Property   | Ethylene Glycol Base Specific Values | Propylene Glycol Base Specific Values | ASTM Test Method           |
|--|--------------------------------------|---------------------------------------|----------------------------|
| Relative density, 15.5°C (60/60°F)   | 1.0650 min                           | 1.0250 min                            | D1122, D5931               |
| Freezing point, °C (°F)  | -36.4 (-33.5) max or lower           | -31 (-23.8) max or lower              | D1177, D6660               |
| Boiling point, °C (°F)   | 107.8 (226) min                      | 104 (219) min                         | D1120                      |
| Effect on automotive finish (use clear coat thermoset urethane or acrylic urethane finish) | no effect                            | no effect                             | D1882 <sup>A</sup>         |
| Ash content, mass %  | 2.5 max                              | 2.5 max                               | D1119                      |
| pH, 50 volume % in distilled water   | 7.5 to 11.0                          | 7.5 to 11.0                           | D1287                      |
| Chloride, ppm  | 33 max                               | 33 max                                | D3634 <sup>B</sup> , D5827 |
| Sulfate, ppm   | 140 max                              | 140 max                               | D5827                      |
| Reserve alkalinity, mL   | report <sup>C</sup>                  | report <sup>C</sup>                   | D1121                      |

<sup>A</sup>Currently, many vehicle manufacturers prepare test panels using the specific paint finishes employed on their actual product. Coolant suppliers and vehicle manufacturers should agree on the exact test procedures and acceptance criteria on an individual basis.

<sup>B</sup>In case of dispute, D3634 shall be the preferred test method.

<sup>C</sup>Agreed value between the supplier and the customer.

**TABLE 2 General Requirements of the Recycled Prediluted Product**

| Property            | Specified Values         | ASTM Test Method |
|---------------------|--------------------------|------------------|
| Color               | distinctive <sup>A</sup> | —                |
| Effect on nonmetals | no adverse affect        | —                |

<sup>A</sup>Commonly used color: green to blue-green.

5.5 This product, when installed in accordance with the recommendations of the manufacturer of the vehicle, or the coolant recycling process, and those on the product label, shall be suitable for use in a properly maintained cooling system (see [Appendix X1](#)) in normal light-duty or passenger car service for a minimum of one year without adversely affecting fluid flow and heat transfer.

## 6. Fleet Testing Requirements

6.1 *Engine Coolants*—Reference engine coolant concentrate ([Annex A2](#)) and recycled prediluted engine coolant shall be used to conduct the fleet testing.

6.2 *Vehicles*—A minimum of fourteen vehicles is recommended to start the test: seven containing reference engine coolant concentrate (control vehicles) and seven containing recycled prediluted engine coolant (test vehicles). A minimum of five control vehicles and five test vehicles shall finish the test. Starting with fourteen vehicles allows for vehicles to drop out of the test for various reasons, that is, mechanical failure, coolant contamination, etc.

6.2.1 *Vehicle Selection*—All vehicle cooling systems should be inspected prior to selection. Vehicles with corroded cooling systems should not be used for testing purposes. Vehicle selection shall be made as follows:

6.2.1.1 Control vehicles and test vehicles shall be matched pairs and be new or have similar low mileage accumulation.

6.2.1.2 Same year, make, and model.

6.2.1.3 Similar mileage and cooling system condition.

6.2.1.4 Same cooling system and power train configuration.

6.2.1.5 Aluminum head(s), aluminum radiator, aluminum heater core and aluminum water pump (housing).

6.2.1.6 Cast iron block (optional).

NOTE 2—Vehicles equipped with cast iron heads may be tested in addition to those specified above. A minimum of five control vehicles and

**TABLE 3 Performance Requirements of the Recycled Prediluted Product**

| Property  | Specific Values                     | ASTM Test Method   |
|---|-------------------------------------|--------------------|
| Corrosion in glassware; Weight loss, mg/specimen  |                                     | D1384 <sup>A</sup> |
| Copper  | 10 max                              |                    |
| Solder  | 30 max                              |                    |
| Brass   | 10 max                              |                    |
| Steel   | 10 max                              |                    |
| Cast iron   | 10 max                              |                    |
| Cast aluminum   | 30 max                              |                    |
| Simulated service test; Weight loss, mg/specimen  |                                     | D2570 <sup>B</sup> |
| Copper  | 20 max                              |                    |
| Solder  | 60 max                              |                    |
| Brass   | 20 max                              |                    |
| Steel   | 20 max                              |                    |
| Cast iron   | 20 max                              |                    |
| Cast aluminum   | 60 max                              |                    |
| Corrosion of cast aluminum alloys at heat-rejecting Surfaces; Weight loss, mg/cm <sup>2</sup> /week | 1.0 max                             | D4340 <sup>C</sup> |
| Foaming   |                                     | D1881              |
| Volume, mL  | 150 max                             |                    |
| Break time, s   | 5 max                               |                    |
| Cavitation-erosion rating for pitting, cavitation, or Erosion of the water pump                     |                                     | D2809 <sup>D</sup> |
| 8 min   |                                     |                    |
| Aluminum galvanostatic pitting potential, V v SHE   | -0.40 min                           | D6208 <sup>E</sup> |
| Fleet test  | see 6.8 and appropriate subsections |                    |

<sup>A</sup>The recycled product shall be mixed with the proper quantity of ASTM Type IV reagent water (Specification D1193) to result in a 33-1/3 volume % coolant test solution. To each liter of test solution add 99 mg of sodium sulfate, 110 mg of sodium chloride and 92 mg sodium bicarbonate.

<sup>B</sup>The recycled product shall be mixed with the proper quantity of ASTM Type IV reagent water (Specification D1193) to result in a 44 volume % coolant test solution. To each liter of test solution add 83 mg of sodium sulfate, 92 mg of sodium chloride and 77 mg of sodium bicarbonate.

<sup>C</sup>The adjusted recycled product shall be mixed with an equal volume of ASTM Type IV reagent water (Specification D1193). To each liter of test solution add 165 mg of sodium chloride.

<sup>D</sup>One volume of the recycled product shall be mixed with two volumes of ASTM Type IV reagent water (Specification D1193). To each liter of test solution add 123 mg of sodium sulfate, 137 mg of sodium chloride and 115 mg of sodium bicarbonate.

<sup>E</sup>The test solution is to be prepared as follows: 50 volume % of the prediluted coolant to be tested, 25 volume % of the corrosive water specified in Test Method D6208, and the remainder deionized or distilled water.

five test vehicles, equipped with aluminum heads, shall complete the test and be included in the conclusive analysis report.

6.2.2 *Vehicle Setup*—All vehicles shall be set up in accordance with Practice D2847 unless otherwise specified within this specification.

6.2.2.1 All vehicles shall be set up with a new aluminum head(s), aluminum radiator, aluminum water pump, thermostat, hoses, belts and radiator/cooling system cap. Installation of new heater cores is recommended. New aluminum heads and radiators are required as they will be sectioned for evaluation at the end of the test.

6.2.2.2 Each vehicle shall be set up with six coupon bundles in the bypass heater circuit coupon bundle capsule(s). Once the test has been started, no additional or replacement corrosion coupon bundles can be added to any of the vehicle cooling systems. The coupon bundle capsule(s) should be arranged in the cooling system to minimize the amount of coolant spillage when coupon bundles are removed throughout the testing period. More than one coupon bundle capsule may be used in the bypass heater circuit in series if the vehicle design does not accommodate the incorporation of a single capsule.

NOTE 3—Additional coupon bundles may be added to the cooling system prior to starting the test for informational purposes.

6.3 *Reference Coolant Solution*—Prepare the reference coolant solution with reference engine coolant concentrate and corrosive water described in Test Method **D1384**. The glycol concentration should give a freeze point of  $-36.4 \pm 1^\circ\text{C}$  ( $-33.5 \pm 2^\circ\text{F}$ ) for a 50 volume % ethylene glycol base reference coolant solution or a freeze point of  $-31 \pm 1^\circ\text{C}$  ( $-23.8 \pm 2^\circ\text{F}$ ) for a 50 volume % propylene glycol base reference coolant solution. Enough reference coolant solution should be prepared to allow for additions to the vehicle cooling systems throughout the test duration and for individual vehicle test restarts.

6.4 *Test Coolant Solution*—Prepare the test coolant solution with recycled prediluted engine coolant and corrosive water contaminants described in Test Method **D1384** (see **Note 4**). The glycol concentration should give a freeze point of  $-36.4 \pm 1^\circ\text{C}$  ( $-33.5 \pm 2^\circ\text{F}$ ) for a 50 volume % ethylene glycol base test coolant solution or a freeze point of  $-31 \pm 1^\circ\text{C}$  ( $-23.8 \pm 2^\circ\text{F}$ ) for a 50 volume % propylene glycol base test coolant solution. Enough test coolant solution should be prepared to allow for additions to the vehicle cooling systems throughout the test duration and for individual vehicle test restarts.

NOTE 4—If necessary, the recycled prediluted engine coolant shall be adjusted with the proper quantity of ASTM Type IV reagent water (Specification **D1193**) to result in a 50 volume % test coolant solution. To each litre of balanced recycled prediluted engine coolant add 74 mg of sodium sulfate, 83 mg of sodium chloride, and 69 mg of sodium bicarbonate.

#### 6.5 *Vehicle Test Parameters:*

6.5.1 *Preparation and Testing*—All vehicles shall be tested in accordance with Practice **D2847**, unless otherwise specified within this specification.

6.5.2 *Duration*—One year, 48,280 km (30,000 miles) minimum, and 4,828 km (3,000 miles) per month maximum.

6.5.3 *Driving Conditions*—All vehicles shall undergo similar driving conditions. A minimum of 40 % of the test duration shall be city driving (stop and go).

6.5.4 *Duty Cycle*—All vehicles shall be turned off and allowed to cool for a minimum of eight hours per day.

6.5.5 *Coolant Solution Additions*—Coolant solution additions are not to exceed 10 volume % of the vehicle cooling system capacity within the fleet test duration for top-off or to

replace lost coolant solution. Coolant solution used to top-off the cooling system shall be from the same batch that was initially prepared and put into that vehicle.

6.5.6 *Number of Vehicles to Finish*—A minimum of five control vehicles containing the reference coolant solution and a minimum of five test vehicles containing the test coolant solution shall finish the fleet test and have valid results.

6.6 *Vehicle Exclusion Criteria*—Criteria for vehicle exclusion from the fleet test evaluation are:

6.6.1 If the fleet testing requirements are not followed.

6.6.2 If cooling system leakage exceeds 10 volume % or cooling system failure occurs.

6.6.3 If the vehicle becomes disabled, that is, accident, engine failure, vehicle becomes inoperable, etc.

6.6.4 If the cooling system becomes contaminated with oil.

6.6.5 If the cooling system is topped off or the coolant solution was replaced with a coolant solution volume greater than 10 volume % of the vehicle cooling system capacity.

6.6.6 Coolant solutions or chemicals other than those prepared for that vehicle are added to the cooling system.

6.6.7 If the coolant solution has to be drained or removed for major vehicle repairs, for example milling or warped heads, engine overhaul, etc.

6.6.8 If the vehicle coolant solution properties significantly change, that is, cooling system contamination, coolant solution dilution, addition of cooling system additives, etc.

NOTE 5—If a vehicle falls out of the fleet testing requirements, that same vehicle can be rebuilt and restarted providing the fleet is not more than 8,047 km (5,000 miles) into the test. Replacement or additional matched vehicles conforming to the requirements specified previously may be added to the fleet test provided the original fleet is not more than 8,047 km (5,000 miles) into the test. Vehicles run together in a fleet test should be started at the same time so that all the vehicles in the test experience similar environmental and driving conditions.

#### 6.7 *Fleet Test Evaluation:*

6.7.1 *Beginning of Test*—Sample coolant solutions from each vehicle (60 mL [2 oz]) and conduct coolant analysis. The coolant analysis for each vehicle shall include pH, reserve alkalinity, glycol weight %, glycol corrosion inhibitor content, contaminants (chloride, sulfate, etc.), and corrosion metal levels. Analysis for glycol degradation products is optional. The reference and test coolant solutions in the vehicles shall have a glycol concentration near 50 volume %. Report the results.

6.7.2 *Middle of Test (24,140 km [15,000 miles])*—Conduct mid-test coolant and coupon bundle analysis as follows:

6.7.2.1 Remove two coupon bundles from each vehicle cooling system, clean the coupons, and measure weight losses or gains and report the average weight losses or gains for each coupon type.

6.7.2.2 Sample the coolant solutions from each vehicle (60 mL [2 oz]) and conduct coolant analysis. The coolant analysis for each vehicle shall include pH, reserve alkalinity, glycol weight %, corrosion inhibitor content, contaminants (chloride, sulfate, etc.), and corrosion metal levels. Analysis for glycol degradation products is optional. The reference and test coolant solutions in the vehicles shall have a glycol concentration near 50 volume %. Report the results.

6.7.2.3 Coolant samples and extra coupon bundles placed in the cooling system for information purposes may be removed at intervals more frequently than that specified within this specification but shall not be more frequent than 8,047 km (5,000 miles) intervals. If excessive amounts of coolant solution are removed from control or test vehicle cooling systems for analysis purposes or otherwise, the maximum allowable amount of coolant to top-off the cooling systems may be exceeded.

NOTE 6—The intended application of conducting mid-test analysis is to determine the status of the fleet test. If the reference or test coolant solutions are performing outside the expected performance levels, vehicles can be withdrawn from the test, saving considerable amounts of time and expenses.

6.7.3 *End of Test (48,280 km [30,000 miles])*—Conduct end of test coolant, coupon, and vehicle component analysis on all vehicles that finish the fleet test as follows:

6.7.3.1 Remove the remaining four coupon bundles from each finishing vehicle cooling system, clean the coupons, measure the weight losses or gains and report the results as described in Practice **D2847**. Results shall be reported on all finishing vehicles with a minimum of five vehicles being from the control vehicle group and five from the test vehicle group. Report the average weight loss or gain for each coupon type for each vehicle. Report the control vehicle group average coupon weight losses or gains from the individual control vehicle average coupon weight losses or gains. Also report the test vehicle group average coupon weight losses or gains from the individual test vehicle average coupon weight losses or gains. Conduct statistical analysis on the coupon weight losses or gains for the fleet test and report the results at the 95<sup>th</sup> percentile confidence level. The T-test and F-test may be used to conduct statistical analysis on the fleet test results.

6.7.3.2 Sample the coolant solutions from each test vehicle (60 mL [2 oz] min) and conduct coolant sample analysis. The coolant analysis for each vehicle shall include pH, reserve alkalinity, glycol weight %, corrosion inhibitor content, contaminants (chloride, sulfate, etc.), and corrosion metal levels. Analysis for glycol degradation products is optional. The reference and test coolant solutions in the vehicles shall have a glycol concentration near 50 volume %. Report the results.

6.7.3.3 Evaluate each of the control and test vehicle cooling system components in accordance with Practice **D2847**. Additional to Practice **D2847**, the cooling system components of each finishing vehicle, unless otherwise specified, shall be photographed and evaluated as described in the following subsections.

(a) *Radiator*—Section each radiator, visually evaluate and report on the tube and tube-end deposits, erosion/corrosion, tube pitting and header crevice corrosion.

(b) *Water Pump*—Disassemble each water pump and rate the pump impeller and housings in accordance with Practice **D2809** water pump rating system. Average the ratings for the test vehicles and report the result. Average the ratings for the control vehicles and report the result.

(c) *Cylinder Head(s)*—Section each head from a minimum of three control vehicles and three test vehicles near an exhaust port and a valve bridge. The sectioning of each head shall be in

the same location for comparison evaluation purposes. Evaluate each head for deposits, pitting, corrosion and discoloration on the coolant side of the exhaust valve ports and valve bridge areas. Also, evaluate each head for general corrosion. In this context, corrosion means pitting, etching, copper plating, metal surface phenomena, erosion, cavitation, or crevice corrosion.

#### 6.8 *Fleet Test Performance Specifications:*

6.8.1 *Metal Coupons*—For each metal test coupon type, the test vehicle group average coupon weight loss shall be less than or equal to the maximum weight losses specified in the following subsections or shall be less than or equal to the average coupon weight losses obtained from the control vehicle group, whichever is greater for each coupon type (see **Note 7**).

6.8.1.1 *Copper Weight Loss:* 20 mg/coupon max.

6.8.1.2 *Solder Weight Loss:* 40 mg/coupon max.

6.8.1.3 *Brass Weight Loss:* 20 mg/coupon max.

6.8.1.4 *Steel Weight Loss:* 20 mg/coupon max.

6.8.1.5 *Cast Iron Weight Loss:* 20 mg/coupon max.

6.8.1.6 *Cast Aluminum Weight Loss:* 40 mg/coupon max.

NOTE 7—If the average weight loss for one or more coupon types in the control vehicle group is higher than the maximums specified in **6.8.1.1-6.8.1.6**, then the average weight loss obtained for the control vehicle group for that metal coupon or coupons takes precedence and becomes the maximum allowed weight loss for that metal coupon type. Otherwise, the maximums specified in **6.8.1.1-6.8.1.6** apply.

6.8.2 *Radiator*—The radiators from the test vehicle group shall exhibit similar or less deposit formation in the radiator tubes and at the tube ends, erosion/corrosion, and header crevice corrosion than radiators from the control vehicle group.

6.8.3 *Water Pump Cavitation/Erosion Rating*—The average rating for test vehicle water pumps shall be a minimum of eight or shall be equal to or greater than the obtained average control vehicle water pump rating.

6.8.4 *Cylinder Heads*—The cylinder heads from the test vehicle group shall exhibit similar or lesser amounts of deposits, pitting, and corrosion on the coolant side of the exhaust ports and valve bridges than the heads from the control vehicle group. They also shall exhibit similar or less general corrosion in the head cooling system passageways than that generated in the heads from the control vehicle group. Report any head surface discoloration on the coolant side of the exhaust ports and valve bridges.

6.9 *Fleet Testing Coordinator*—Either the fleet test managing company or coordinator name, or both, as well as the contact information, shall be reported and included with fleet testing results and documentation.

NOTE 8—Inclusion of either the fleet test managing company or coordinator information, or both, provides a means for the customer to verify and validate test results provided by the supplier. It is generally the supplier's responsibility to locate qualified parties to coordinate the fleet test and conduct evaluations; however, this may be negotiated and agreed upon between the customer and supplier.

6.10 *Fleet Test Cooling System Component Evaluation*—The cooling system components that require evaluation (radiators, water pumps, and heads) within Section 6 shall be

evaluated and reported on by an independent laboratory with automotive and ASTM coolant testing and evaluation experience.

6.11 *Fleet Test Cooling System Component Storage*—The cooling system components that are evaluated in this fleet test protocol shall be kept for a minimum of one year for reference purposes. The components shall be kept in a suitable location or environment that prevents or minimizes component deterioration or degradation beyond that obtained from testing.

## 7. Other Requirements

7.1 The recycled prediluted glycol base engine coolant shall visually provide a similar or smaller amount of precipitate than the reference coolant concentrate (see [Annex A2](#)) in the test

method for storage stability and compatibility (see [Annex A3](#)). The comparison evaluation of the reference coolant concentrate versus the recycled prediluted coolant specified within this section takes precedence over limits or specifications detailed in [Annex A3](#).

NOTE 9—When conducting testing for purposes of approval by a customer, generally it is recommended to have the testing conducted or supervised by an independent laboratory where reference materials are produced by a qualified laboratory or manufacturer.

## 8. Keywords

8.1 glycol base; light-duty engine coolant; recycled prediluted aqueous engine coolant; reference engine coolant concentrate; reference synthetic used coolant

# ANNEXES

## (Mandatory Information)

### A1. REFERENCE SYNTHETIC USED COOLANT

A1.1 The reference synthetic used coolant described in the following is predilute and represents a synthetic used coolant feedstock. An equivalent used coolant may be used in the evaluation of a coolant recycling process; however, it shall meet the requirements specified in [Section A1.3](#).

A1.2 *Preparation of the Reference Synthetic Used Coolant*—The Reference Synthetic Used Coolant is to be prepared by blending the components listed in [Table A1.1](#) in an appropriately sized stainless steel or plastic vessel with aggressive mixing or agitation capabilities. Blending vessels, tanks, mixing equipment, transfer pumps, hoses and lines shall be clean, free of contaminants and rinsed with deionized or distilled water prior to blending and use.

A1.2.1 Blend an appropriately sized batch with all the components listed in [Table A1.1](#) in the order that the components are listed, with the exception of the SAE 5W30 engine oil.

A1.2.2 Once all of the components listed in [Table A1.1](#) have been blended together, with the exception of the SAE 5W30 engine oil, adjust the pH of the solution to  $8.0 \pm 0.2$  with sodium hydroxide (50 weight % aqueous sodium hydroxide may be used).

A1.2.3 Add the SAE 5W30 engine oil to the blend and vigorously mix. Complete emulsification of the engine oil is not necessary and it is expected that oil will rise to the surface of the final blend.

A1.3 Blended batches of Reference Synthetic Used Coolant shall be tested for ingredient presence and quality by conforming to the parameters listed below after being filtered through a 0.7 micron filter.

A1.4 Reference Synthetic Used Coolant conforming to the above specification is suitable for use to evaluate a coolant

**TABLE A1.1 Reference Synthetic Used Coolant Components<sup>A</sup>**

| Material   | Ethylene Glycol Base Weight, % | Propylene Glycol Base Weight, % |
|--|--------------------------------|---------------------------------|
| Glycol <sup>B</sup>  | 52.5250                        | 50.7236                         |
| Water <sup>C</sup>   | 47.0972                        | 48.8986                         |
| Sodium tetraborate (Na <sub>2</sub> B <sub>4</sub> O <sub>7</sub> · 5H <sub>2</sub> O) |                                | 0.0140                          |
| Sodium sulfate (Na <sub>2</sub> SO <sub>4</sub> )                                      |                                | 0.0419                          |
| Glycolic acid (C <sub>2</sub> H <sub>4</sub> O <sub>3</sub> )                          |                                | 0.1100                          |
| Formic acid (CH <sub>2</sub> O <sub>2</sub> )  |                                | 0.0300                          |
| Acetic acid, glacial (C <sub>2</sub> H <sub>4</sub> O <sub>2</sub> )                   |                                | 0.0100                          |
| Sodium chloride (NaCl)   |                                | 0.0324                          |
| Sodium Nitrate (NaNO <sub>3</sub> )  |                                | 0.0110                          |
| Copper chloride (CuCl <sub>2</sub> · 2H <sub>2</sub> O)                                |                                | 0.0009                          |
| Iron sulfate (FeSO <sub>4</sub> · 7H <sub>2</sub> O)                                   |                                | 0.0050                          |
| Aluminum nitrate (Al(NO <sub>3</sub> ) <sub>3</sub> · 9H <sub>2</sub> O)               |                                | 0.0028                          |
| Lead nitrate (Pb(NO <sub>3</sub> ) <sub>2</sub> )                                      |                                | 0.0008                          |
| Silicate stabilizer (Dow Corning Q1-6083) <sup>D</sup>                                 |                                | 0.0100                          |
| Sodium metasilicate (Na <sub>2</sub> SiO <sub>3</sub> · 5H <sub>2</sub> O)             |                                | 0.0140                          |
| Surfactant (BASF Pluronic L61) <sup>D</sup>  |                                | 0.0100                          |
| SAE 5W30 Engine Oil <sup>E</sup>   |                                | 0.0850                          |

<sup>A</sup>Materials listed are to be ACS Reagent Grade or equivalent unless otherwise specified. Materials may be substituted for alternative species materials provided the ionic concentrations of importance are maintained. [Section A1.3](#) lists the ionic species minimums and maximums allowed.

<sup>B</sup>A high quality technical grade ethylene or propylene glycol shall be used.

<sup>C</sup>Water quality shall conform to [Specification D1193](#) Type IV water requirements.

<sup>D</sup>Chemical equivalents may be used.

<sup>E</sup>A commercially available SAE 5W30 engine oil may be used. The engine oil concentration represents oil contamination in used coolants and was arrived at by surveying coolant recyclers in the industry.

recycling process. To evaluate a coolant recycling process or technology, the reference synthetic used coolant shall be recycled within 30 days from when it was made and shall be thoroughly agitated immediately prior to recycling.

NOTE A1.1—The Reference Synthetic Used Coolant has been and is currently being used by industry to evaluate coolant recycling processes. This coolant significantly exceeds corrosion weight loss specification limits when tested according to Test Methods [D1384](#) and [D4340](#). A research report presenting the test data shall be generated after the

**TABLE A1.2 Reference Synthetic Used Coolant Property Requirements**

| Property or Material                                       | Ethylene Glycol Base Parameter   | Propylene Glycol Base Parameter | Suggested Analysis Method |
|--|--|---------------------------------|---------------------------|
| Chloride (Cl)  | 200 mg/L min   |                                 | D5827                     |
| Sulfate (SO <sub>4</sub> <sup>-2</sup> )                   | 300 mg/L min   |                                 | D5827                     |
| Glycolic acid  | 1100 mg/L min  |                                 | D5827                     |
| Formic acid  | 300 mg/L min   |                                 | D5827                     |
| Acetic acid  | 100 mg/L min   |                                 | D5827                     |
| Tetraborate (B <sub>4</sub> O <sub>7</sub> <sup>-2</sup> ) | 300 mg/L max   |                                 | D5827, D6129, D6130       |
| Nitrate (NO <sub>3</sub> )                                 | 400 mg/L max   |                                 | D5827                     |
| Silicate (SiO <sub>3</sub> <sup>-2</sup> )                 | 50 mg/L max  |                                 | D5827, D6129, D6130       |
| Iron (Fe)  | 10 mg/L min  |                                 | D6129, D6130              |
| Copper (Cu)  | 3 mg/L min   |                                 | D6129, D6130              |
| Aluminum (Al)  | 2 mg/L min   |                                 | D6129, D6130              |
| Lead (Pb)  | 5 mg/L min   |                                 | D6129, D6130              |
| pH   | 8.0 ± 0.2 max  |                                 | D1287                     |
| Visual   | May have some cloudiness or phase separation due to the oil. No solids precipitation is permitted. |                                 | visual                    |
| Freeze point   | -36.4 (-33.5) or lower   | -31 (-23.8) or lower            | D1177, D6660              |

specification has been adopted by ASTM. When the research report has been generated, this note will be revised.

## A2. REFERENCE ENGINE COOLANT CONCENTRATE—ETHYLENE GLYCOL FOR LIGHT DUTY SERVICE<sup>7</sup>

### A2.1 Scope

A2.1.1 This specification covers a reference ethylene glycol type engine coolant intended to protect automotive engine cooling systems from corrosion and freezing. The requirements are intended to insure that coolants give satisfactory performance when used at recommended concentrations. This specification also provides a coolant concentrate that is to be used as reference coolant in performance testing listed earlier in this specification.

### A2.2 Formulation

A2.2.1 The coolant concentrate shall be prepared by mixing the materials in the weight percent indicated in [Table A2.1](#)

A2.2.2 *Stability*—The reference coolant concentrate shall be used within one year of being made and should be mixed prior to use if let standing for long periods of time.

### A2.3 Properties

A2.3.1 The coolant concentrate, when formulated as specified, shall meet the following properties as determined by methods listed in [Table A2.2](#).

A2.3.2 Sampling shall be performed in accordance to Test Method [D1176](#).

NOTE A2.1—Propylene glycol may be substituted for the ethylene glycol in the reference engine coolant concentrate. A maximum of 1 % of

<sup>7</sup> GM 6043M *Automotive Engine Coolant Concentrate—Ethylene Glycol Type*, General Motors Engineering Standards, Revision: December 1984.

**TABLE A2.1 Reference Engine Coolant Concentrate Formulation<sup>A</sup>**

| Material   | Weight % |
|--|----------|
| Ethylene Glycol <sup>B</sup>   | 95.53    |
| Sodium Nitrate (NaNO <sub>3</sub> )  | 0.10     |
| Sodium Molybdate (Na <sub>2</sub> MoO <sub>4</sub> ·2H <sub>2</sub> O)                               | 0.20     |
| Sodium Tetraborate (Na <sub>2</sub> B <sub>4</sub> O <sub>7</sub> ·5H <sub>2</sub> O)                | 0.40     |
| Sodium Silicate (Liquid SiO <sub>3</sub> ), SiO <sub>2</sub> /Na <sub>2</sub> O weight ratio of 3.22 | 0.30     |
| Phosphoric Acid (85 % H <sub>3</sub> PO <sub>4</sub> ) <sup>C</sup>                                  | 0.15     |
| Sodium Mercaptobenzothiazole (50 % solution)   | 0.50     |
| Sodium Tolytriazole (50 % solution)  | 0.20     |
| Sodium Hydroxide   | 0.235    |
| Water  | 2.30     |
| Silicate Stabilizer (Dow Corning Q1-6083) <sup>D</sup>   | 0.06     |
| Surfactant (BASF Pluronic L61) <sup>D</sup>  | 0.02     |
| Green Dye <sup>E</sup>   | 0.005    |

<sup>A</sup>The values specified for chemical additives are intended as target values, as a subsequent analysis of a formulated product should provide values that are equal to or greater than those shown. Sodium hydroxide is used to adjust pH and the concentration may have to be varied to satisfy the pH requirements of the specification. The stabilizer improves storage stability of the silicate, allowing sufficient time between additions to obtain complete mixing.

<sup>B</sup>A high quality technical grade ethylene or propylene glycol shall be used. A maximum of 15 % of the ethylene glycol can be replaced with other glycols, provided the formulated product satisfies the requirements of [A2.3](#). A maximum of 1.0 percent of the propylene glycol can be replaced with other glycols, provided the formulated product satisfies the requirements of [A2.3](#).

<sup>C</sup>Alternatively, sodium phosphate dibasic or tribasic may be used with equivalent PO<sub>4</sub> content and appropriate adjustment of sodium hydroxide and water additions.

<sup>D</sup>Chemical equivalents may be used.

<sup>E</sup>0.002 percent Fluorescein (Uranine-C) and 0.003 percent Alizarine Cyanone Green B Extra (Acid Green 2.5).

the propylene glycol can be replaced with other glycols. If propylene glycol is substituted for ethylene glycol, the acceptable range for relative density is 1.030 to 1.065 and the freezing point requirement is -31°C (-23.8°F) or lower. All other property requirements shall be met.

TABLE A2.2 Reference Coolant Concentrate Properties

| Property  | Acceptable Range       | ASTM Test Method   |
|---|------------------------|--------------------|
| Relative density 15.5°C (60/60°F)   | 1.120 to 1.130         | D1122, D5931       |
| Reserve alkalinity, mL  | 10.0 min               | D1121              |
| Chloride, ppm   | 25 max                 | D3634, D5827       |
| Freezing point, °C (°F)<br>at 50.0 volume % in distilled H <sub>2</sub> O | -36.4 (-33.5) or lower | D1177, D6660       |
| pH at 50.0 volume % in distilled H <sub>2</sub> O                         | 10.0 to 11.0           | D1287 <sup>A</sup> |

<sup>A</sup>The pH is subject to a slight change with time. As the concentrate ages, the pH measured immediately after dilution of a sample may be higher than it was when the concentrate was first made; however, the pH of a diluted sample may decrease with elapsed time after dilution.

### A3. TEST METHOD FOR STORAGE STABILITY AND COMPATIBILITY<sup>8</sup>

#### A3.1 Samples

A3.1.1 Samples of the coolant concentrate shall show no separation or precipitation when diluted with a synthetic hard water and tested as follows: Prepare the hard water by adding 275 mg of CaCl<sub>2</sub> to 1 L of the synthetic hard water described in Test Method D1384. Mix 100 mL of the coolant concentrate plus 100 mL of the synthetic hard water (room temperature) in a 250-mL beaker, and allow to stand in the dark 24 h. Make a second mixture, as above, heat to 82°C (179.6°F) and allow to cool to room temperature and to stand in the dark 24 h. Slight cloudiness is permitted, but an excessive amount of precipitate is considered to interfere with bulk storage and use of the mixtures.

A3.1.2 Compatibility with other mixtures shall be similarly determined at the request of the purchaser.

A3.1.3 Allow an undiluted sample of the coolant to stand for 24 h. Any separation into phases shall disqualify the engine coolant concentrate for factory-fill but does not prevent its use as a package item, provided the package states that it should be shaken before adding to the cooling system. Some minor separation, not sufficient to form a continuous film over the entire surface, is to be considered normal.

NOTE A3.1—This test method is an exact quotation from the General Motors engine coolant concentrate engineering standards and has not been modified from its original form for copyright and usage permission purposes. Evaluation of the reference engine coolant versus the recycled engine coolant is specified in 7.1, which takes precedence over the limits and specifications detailed within this annex. To perform testing on a recycled predilute aqueous glycol base engine coolant (50 volume % minimum) prepare the engine coolant test solution as follows: to each liter of recycled aqueous glycol base engine coolant, add 74 mg of sodium sulfate, 83 mg of sodium chloride, 69 mg sodium bicarbonate and 138 mg of calcium chloride.

<sup>8</sup> GM 1825M Automotive Engine Coolant Antifreeze Concentrate—Ethylene Glycol, General Motors Engineering Standards, Revision: April 1985.

## APPENDIXES

### (Nonmandatory Information)

#### X1. COOLING SYSTEM MAINTENANCE

##### X1.1 Cooling System Maintenance

X1.1.1 Dilution of this product is not recommended; however, if circumstances require the addition and prediluted aqueous engine coolant is not available, use a coolant concentrate of the same glycol base as the prediluted product and dilute to 50 volume % with water of at least the quality outlined in Table X1.1.

X1.1.2 It is recommended that products meeting this specification shall have the following information on the package label:

X1.1.2.1 Recycled prediluted engine coolant,

TABLE X1.1 Suggested Water Quality Limits<sup>A</sup>

| Property                         | Specific Values | ASTM Test Method     |
|----------------------------------|-----------------|----------------------|
| Total solids, ppm (grains/gal)   | 340 (20) max    | Federal Method 2540B |
| Total hardness, ppm (grains/gal) | 170 (10) max    | D1126                |
| Chloride, ppm (grains/gal)       | 40 (2.4) max    | D512, D4327          |
| Sulfate, ppm (grains/gal)        | 100 (5.9) max   | D516, D4327          |
| pH                               | 5.5–9.0         | D1293                |

<sup>A</sup>Adopted by a survey by the D-15 Water Quality Task Force.

X1.1.2.2 Do not add water,

X1.1.2.3 Meets Specification D6472, and



X1.1.2.4 **Warning**—The freezing point of the final coolant in the cooling system is determined by the extent of dilution of this product with any liquid remaining in the cooling system at the time of filling.

X1.1.3 *Cooling System Maintenance*—Before installing recycled engine coolant, the cooling system should be inspected and necessary service work completed. Essential spring and fall cooling system service includes the following:

X1.1.3.1 Check coolant concentration, 50 % minimum<sup>9</sup>.

X1.1.3.2 Check coolant level and cleanliness. Replace coolant at service intervals recommended by engine manufacturer, vehicle manufacturer, or designated service organization. Follow recommended practices.

X1.1.3.3 Pressure test the cooling system for leaks (preferably when cold).

X1.1.3.4 Test pressure cap, inspect radiator filler neck.

---

<sup>9</sup> It is recommended that coolant concentration be determined by use of a refractometer.

X1.1.3.5 Inspect hoses and tighten hose connections.

X1.1.3.6 Inspect drive belts and check for proper tension.

X1.1.3.7 Test thermostat if engine is running too hot or too cold. Replace with the thermostat recommended by the manufacturer.

X1.1.4 Additions to the cooling system should be done with a prediluted aqueous glycol base engine coolant complying with this specification, Specification **D3306** (coolant Type III or IV) or a 50/50 mixture of a glycol base engine coolant concentrate meeting the requirements of Specification **D3306** (coolant Type I or II) or Specification **D6472** and water, meeting at least the requirements outlined in this appendix. (**Warning**—Do not remove radiator pressure cap when engine is hot. Cooling system is likely to be under pressure. When the engine has cooled, carefully turn to the first notch to vent the system pressure, then remove the cap. If coolant overflows when the cap is vented, immediately retighten and permit the system to cool further.)

## X2. DETERMINATION OF FREEZE POINT

X2.1 If propylene glycol (PG) base coolants and ethylene glycol (EG) base coolants are mixed in a cooling system, problems may result when attempting to determine freezing point in the field. The hydrometers used in North America are calibrated to the higher relative density of ethylene glycol base coolants. These hydrometers cannot be used to determine the freeze point of propylene glycol base engine coolants or mixtures of PG and EG coolants. Using this type of hydrometer to determine the freeze point of a PG base coolant is likely to result in a high coolant to water mix ratio (80/20), which in turn may cause engine and cooling system problems. A hydrometer specifically calibrated to the relative density of propylene glycol shall be used to determine the freezing point of propylene glycol base coolants. A convenient and preferred

means of determining the freeze points for PG coolants or mixtures of PG and EG coolants is by refractometer. Test strips may also be used. **Table X2.1** lists methods for determining the freeze point of propylene glycol base engine coolants when used either alone or when mixed with ethylene glycol base coolants. A refractometer provides an accurate method for measuring freezing points. Dip-and-read test strips will provide only an approximation of freeze points.

X2.2 It is recommended that propylene glycol base coolant containers be labeled with an appropriate cautionary statement to alert the user to the differences described in **X2.1**. It is also recommended that a peel-off label be attached to the filler-neck of the cooling system to advise the user that the system has been charged with a propylene glycol base coolant.

**TABLE X2.1 Methods for Determining Freezing Points**

| Method        | Base Glycol      |                  |                  |
|---------------|------------------|------------------|------------------|
|               | Ethylene         | Propylene        | Mixture          |
| Hydrometer    | yes <sup>A</sup> | yes <sup>B</sup> | no               |
| Refractometer | yes              | yes <sup>C</sup> | yes <sup>D</sup> |
| Test Strips   | yes              | yes              | yes              |

<sup>A</sup> Conventional field service hydrometers calibrated for use with ethylene glycol.

<sup>B</sup> Hydrometer specifically calibrated for use with PG coolants.

<sup>C</sup> Shall be a refractometer with a propylene glycol freeze point scale.

<sup>D</sup> Approximate freeze point determinations can be made for mixtures of EG and PG base coolants by calculating the average of readings on each scale. The freeze point determined by this method will be within  $\pm 4^{\circ}\text{C}$  ( $\pm 7^{\circ}\text{F}$ ), regardless of whether the coolant is all EG, PG, or a mixture of both.

### X3. RECYCLED COOLANT ADVISORY

X3.1 This recycled predilute aqueous engine coolant specification is based on performance experience developed in the industry from the recycling of used engine coolants. Only recycled prediluted aqueous engine coolants originating from light-, medium- and heavy-duty engine coolant products and blends with virgin glycol are covered by this standard. Recycled coolants made with glycols from other sources such as medical waste, distillation bottoms, airplane/airport deicers and polyester production waste have been reported as having

unsatisfactory performance effects on product performance. A specification is currently under development by Committee D15 for redistilled glycols that will address the concerns associated with processing glycols from these other sources.

X3.2 Committee D15 is in the process of developing specifications for redistilled glycols from used engine coolant and non-engine coolant sources to be used in engine coolant formulation and application.

### SUMMARY OF CHANGES

Committee D15 has identified the location of selected changes to this standard since the last issue (D6471-06) that may impact the use of this standard.

(1) Removed D1888 from Section 2 since it has been withdrawn. Also removed D4656, D5216 and D6257 from Section 2 and from X1.1.4 since they have been withdrawn and merged into Specification D3306.

(2) Replaced method for determining total solids in water in Table X1.1 (Federal Method 2540B) and added new method to Section 2.

(3) Changed the freeze point requirements in 6.3 and 6.4, Table 1, Table A1.2, and Table A2.2.

(4) Changed the propylene glycol freeze point requirement in Note A2.1.

(5) Removed SAE HS 40 *Maintenance of Automotive Engine Cooling Systems* from Section 2. Removed X1.1.5 since the MNL-6 and SAE HS 40 are no longer available.

(6) Renumbered footnotes.

*ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.*

*This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.*

*This standard is copyrighted by ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (www.astm.org). Permission rights to photocopy the standard may also be secured from the ASTM website (www.astm.org/COPYRIGHT/).*