



Standard Test Method for Determination of Octane Number of Spark-Ignition Engine Fuels by On-Line Direct Comparison Technique¹

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This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers the quantitative ~~on-line~~online determination by direct comparison of the difference in knock rating or delta octane number of a stream sample of spark-ignition engine fuel from that of a comparison reference fuel.

1.2 This test method covers the methodology for obtaining an octane number using the measured delta octane number and the octane number of the comparison reference fuel.

1.3 The comparison reference fuel is required to be of essentially the same composition as the stream sample to be analyzed and can be a secondary fuel termed standard fuel or a tertiary fuel termed prototype fuel.

1.4 The test method utilizes a knock testing unit/automated analyzer system that incorporates computer control of a standardized single-cylinder, four-stroke cycle, variable compression ratio, carbureted, CFR engine with appropriate auxiliary equipment using either Test Method D 2699 Research method or Test Method D 2700 Motor method operating conditions.

1.4.1 Knock measurements are based on operation of both fuels at the specific fuel-air ratio that produces maximum knock intensity for that fuel.

1.4.2 Measured differences in knock intensity are scaled to provide a positive or negative delta octane number of the stream sample from the comparison reference fuel when the fuels are compared at the same compression ratio.

1.4.3 Measured differences in compression ratio are scaled to provide a positive or negative delta octane number of the stream sample from the comparison reference fuel when the fuels are compared at the same knock intensity.

1.5 This test method is limited to testing 78 to 102 octane number spark-ignition engine fuels using either research or motor method conditions.

1.6 The octane number difference between the stream sample and the applicable comparison reference fuel is self-limiting by specifications imposed upon the standard and prototype fuels.

1.7 Specifications for selection, preparation, storage, and dispensing of standard and prototype fuels are provided. Detailed procedures for determination of an appropriate assigned octane number for both standard and prototype fuels are also incorporated.

1.8 The values of operating conditions are stated in SI units and are considered standard. The values in parentheses are historical inch-pound units. The standardized CFR engine measurements continue to be expressed in inch-pound units only because of the extensive and expensive tooling that has been created for this equipment.

1.9 *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.* For more specific hazard warning statements, see Section 8 and Annex A1.

2. Referenced Documents

2.1 ASTM Standards:²

D 1193 Specification for Reagent Water

D 2699 Test Method for Research Octane Number of Spark-Ignition Fuels ~~Engine Fuel~~

D 2700 Test Method for Motor Octane Number of Spark-Ignition Engine Fuel

D 4057 Practice for Manual Sampling of Petroleum and Petroleum Products

D 4175 Terminology Relating to Petroleum, Petroleum Products, and Lubricants

D 4177 Practice for Automatic Sampling of Petroleum and Petroleum Products

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at 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.

D 4814 Specification for Automotive Spark-Ignition Engine Fuel

D 6299 Practice for Applying Statistical Quality Assurance and Control Charting Techniques to Evaluate Analytical Measurement System Performance

D 6624 Practice for Determining a Flow-Proportioned Average Property Value (FPAPV) for a Collected Batch of Process Stream Material Using Stream Analyzer Data

~~E 1 Specification for ASTM Thermometers~~

~~E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods⁷~~

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E 456 Terminology Relating to Quality and Statistics

2.2 *Waukesha CFR Engine Manuals:*

CFR F-1 & F-2 Octane Rating Units Operation & Maintenance FORM 847³

3. Terminology

3.1 Definitions:

3.1.1 *accepted reference value, n*—a value that serves as an agreed-upon reference for comparison, and which is derived as: (1) a theoretical or established value, based on scientific principles, (2) an assigned value, based on experimental work of some national or international organization, or (3) a consensus value, based on collaborative experimental work under the auspices of a scientific or engineering group. — ~~E 456/E 177~~ — E 456/E 177

3.1.1.1 *Discussion*—In the context of this test method, accepted reference value is understood to apply to standard fuel or check fuel average research or motor octane numbers determined under reproducibility conditions by a recognized exchange testing organization having a minimum of 16 participants.

3.1.2 *analytical measurement system, n*— a collection of one or more components or subsystems, such as a sampler, test equipment, instrumentation, display devices, data handler, and printout or output transmitters that is used to determine a quantitative value of a specific property for an unknown sample. **D 6299**

3.1.2.1 *Discussion*—In the context of this test method, the analytical measurement system is comprised of the knock testing unit, automated analyzer system, and any auxiliary equipment required for the safe operation of the engine.

3.1.3 *cylinder height, n*— *for the CFR engine*, the relative vertical position of the engine cylinder with respect to the piston at top dead center (TDC) or the top machine surface of the crankcase. — ~~D 2699/D 2700~~ — D 2699/D 2700

3.1.4 *digital counter reading, n*— *for the CFR engine*, a numerical indication of cylinder height, indexed to a basic setting at a prescribed compression pressure when the engine is motored. — ~~D 2699/D 2700~~ — D 2699/D 2700

3.1.5 *detonation meter, n*— *for knock testing*, the signal conditioning instrument that accepts the electrical signal from the detonation pickup and provides an output signal for display. — ~~D 2699/D 2700~~ — D 2699/D 2700

3.1.6 *detonation pickup, n*— *for knock testing*, magnetostrictive type transducer that threads into the engine cylinder and is exposed to combustion chamber pressure to provide an electrical signal that is proportional to the rate-of-change of cylinder pressure. — ~~D 2699/D 2700~~ — D 2699/D 2700

3.1.7 *fuel-air ratio for maximum knock intensity, n*—*for knock testing*, that proportion of fuel to air which produces the highest knock intensity for each fuel in the knock testing unit, provided this occurs within the specified carburetor fuel level limits. — ~~D 2699/D 2700~~ — D 2699/D 2700

3.1.7.1 *Discussion*—In the context of this test method, the fuel-air ratio for maximum knock intensity can be determined manually or by the automated analyzer system.

3.1.7.2 *dynamic fuel-air ratio for maximum knock, n*—*for knock testing*, the changing of the mixture of fuel and air for engine combustion determined by continually varying fuel level in the carburetor delivery components, through the maximum knock intensity so that the observed peak knock intensity value can be selected as maximum knock intensity reading.

3.1.7.3 *equilibrium fuel-air ratio for maximum knock, n*—*for knock testing*, the changing of the mixture of fuel and air for engine combustion determined by making incremental step changes in fuel-air ratio, observing the equilibrium knock intensity for each step and selecting the fuel-air ratio which produces the highest knock meter reading.

3.1.8 *guide tables, n*— *for knock testing*, the specific relationship between cylinder height (compression ratio) and octane number at standard knock intensity. — ~~D 2699/D 2700~~ — D 2699/D 2700

3.1.9 *knock, n*—*in a spark-ignition engine*, abnormal combustion, often producing audible sound, caused by auto-ignition of the air/fuel mixture. **D 4175**

3.1.10 *knock intensity, n*— *for knock testing*, a measure of the level of knock. — ~~D 2699/D 2700~~ — D 2699/D 2700

3.1.11 *knockmeter, n*—*for knock testing*, the 0 to 100 division indicating meter that displays the knock intensity signal from the detonation meter. — ~~D 2699/D 2700~~ — D 2699/D 2700

⁷ Annual Book of ASTM Standards, Vol 05.05.

³ The sole source of supply of the apparatus known to the committee at this time is Waukesha Engine Division, Dresser Equipment Group, Inc., 1000 W. St. Paul Avenue, Waukesha, WI 53188. Waukesha Engine Division also has CFR engine authorized sales and service organizations in selected geographical areas. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

3.1.11.1 *Discussion*—In the context of this test method, the knock intensity signal may also be displayed using digital or recording instrumentation.

3.1.12 *motor octane number, n*—for spark-ignition engine fuel, the numerical rating of knock resistance obtained by comparison of the fuel's knock intensity with that of primary reference fuel blends when both are tested in a standardized CFR engine operating under the conditions specified in Test Method D 2700.

3.1.13 *repeatability conditions, n*—conditions where independent test results are obtained with the same method on identical test items in the same laboratory by the same operator using the same equipment within short intervals of time. **E 456**

3.1.13.1 *Discussion*—In the context of this test method, application of repeatability conditions is primarily applied to the determination of variability of delta octane numbers generated by repeating the comparison measurements within a short time, by the same operator, using the same comparator, on the same fuel pair.

3.1.14 *reproducibility conditions, n*—conditions where test results are obtained with the same method on identical test items in different laboratories with different operators using different equipment. **E 456**

3.1.15 *research octane number, n*—for spark-ignition engine fuel, the numerical rating of knock resistance obtained by comparison of the fuel's knock intensity with that of primary reference fuel blends when both are tested in a standardized CFR engine operating under the conditions specified in Test Method D 2699.

3.1.16 *spread, n*—in knock measurement, the sensitivity of the detonation meter expressed in knockmeter divisions per octane number. ~~D2699/D2700~~ **D 2699/D 2700**

3.1.17 *site assigned value, n*—a value that serves as an agreed-upon reference for comparison, determined from multiple test results obtained under site precision conditions.

3.1.17.1 *Discussion*—In the context of this test method, site assigned value is understood to apply to prototype fuel average research or motor octane number determined under site precision conditions using direct comparison delta octane number cycles comparing the prototype fuel to a standard fuel having an accepted reference value octane number.

3.1.18 *site precision conditions, n*—conditions under which test results are obtained by one or more operators in a single location practicing the same test method on a single measurement system using test specimens taken at random from the same sample of material over an extended period of time spanning at least a 15 day interval. **D 6299**

3.1.18.1 *Discussion*—In the context of this test method, application of site precision conditions is primarily applied to the determination of the variability of delta octane average results, obtained by different operators, over different days, for the same fuel pair, using the same comparator. Each delta octane average result is obtained from repetitive comparisons of the same fuel pair under repeatability conditions.

3.1.19 *stream sample, n*—the material to be evaluated by an analytical measurement system, typically drawn from a flowing stream of either blended spark-ignition engine fuel or process unit material.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *comparison reference fuel, n*—for direct comparison knock testing, a spark-ignition engine fuel having an assigned octane number that is the reference for the determination of the delta octane number of stream samples.

3.2.1.1 *standard fuel, n*—for direct comparison knock testing, a spark-ignition engine fuel having an octane number accepted reference value (RON_{ARV} or MON_{ARV}) which is used as a secondary comparison reference fuel for (1) determination of the octane number site assigned value (RON_{SAV} or MON_{SAV}) of prototype fuels, (2) determination of the $\Delta O.N.$ of a stream sample, or (3) pairing with another standard fuel for analytical measurement system qualification checkout.

3.2.1.2 *prototype fuel, n*—for direct comparison knock testing, a spark-ignition engine fuel or process unit material having an octane number site assigned value (RON_{SAV} or MON_{SAV}) referenced to an appropriate standard fuel, which is used as a tertiary comparison reference fuel for determination of the $\Delta O.N.$ of a stream sample.

3.2.2 *delta octane number, n*—for direct comparison knock testing, the algebraic difference in octane number between two fuels under research or motor engine conditions, when determined by the direct comparison technique.

3.2.3 *paired check fuels (A and B), n*—for on-line knock testing system qualification checkout, two standard fuels used for system qualification checkout of an analytical measurement system.

3.2.3.1 *expected difference O.N., n*—for on-line knock testing system qualification checkout, the absolute octane number difference between paired check fuels (A–B) based on the $O.N._{ARV}$ for both fuels.

3.2.4 *paired quality control fuels, n*—for on-line system quality control, a pair of fuels, one of which is a comparison reference fuel, to be used in the repetitive testing for $\Delta O.N.$ as a quality control check of the analytical measurement system.

3.2.5 *span, n*—for direct comparison knock testing, a measure of the overall sensitivity of the analyzer. The ratio of the change in delta octane reported produced by a given change in either compression ratio or knock intensity.

3.3 *Acronyms:*

3.3.1 *AMS*—analytical measurement system

3.3.2 *ARV*—accepted reference value

3.3.3 *RON_{ARV}*—research octane number accepted reference value

3.3.4 *MON_{ARV}*—motor octane number accepted reference value

3.3.5 *SAV*—site assigned value

3.3.6 *RON_{SAV}*—research octane number site assigned value

3.3.7 MON_{SAV} —motor octane number site assigned value

3.3.8 *C.R.*—compression ratio

3.3.9 *K.I.*—knock intensity

3.3.10 *O.N.*—octane number

3.3.11 $\Delta O.N.$ —delta octane number

3.3.12 *PRF*—primary reference fuel

3.3.13 *CRF*—comparison reference fuel

3.4 *Symbols:*

3.4.1 *Q*—accuracy qualification value

3.4.2 *K*—accuracy qualification acceptance limit

4. Summary of Test Method

4.1 The delta research (ΔRON) or delta motor (ΔMON) octane number of a stream sample is determined using a standard CFR engine operating under the appropriate test conditions, using an automated repetitive cycle that compares its knock characteristics with those of a comparison reference fuel (CRF) having an assigned octane number. The difference in knock characteristics may be measured as (1) the difference in knock intensity at constant compression ratio, or (2) the difference in compression ratio at constant knock intensity. The system draws the stream sample from a flowing stream and conditions it for delivery to the CFR engine carburetor. Comparison reference fuel is stored in a suitable container and is also appropriately conditioned for delivery to the CFR engine carburetor. System controls sequence the switching of the two fuels as well as monitoring all critical testing variables. The fuel-air ratio of each fuel is adjusted to produce the maximum knock intensity for that fuel.

5. Significance and Use

5.1 The delta octane number ($\Delta O.N.$) measure can quantify the difference of in-line blended spark-ignition engine fuel or process stream material octane number to a desired octane number to aid in optimizing control of blender facilities or refinery process units.

5.2 The $\Delta O.N.$ measure, summed with a statistically sound comparison reference fuels $O.N.$ provides either research or motor octane number value of the current in-line blended spark-ignition engine fuel or process stream material.

5.3 Through the use of cumulative flow-weighted averaging of the repetitive $\Delta O.N.$ results, a statistically significant octane number can be assigned to a tender or batch of in-line blended spark-ignition engine fuel.

6. Interferences

6.1 Certain gases and fumes, which can be present in the area where the knock testing unit is located, may have a measurable effect on the $\Delta O.N.$ result.

6.1.1 Halogenated refrigerant used in air conditioning and refrigeration equipment can promote knock. Halogenated solvents can have the same effect. If vapors from these materials enter the combustion chamber of the CFR engine, the octane number of spark-ignition engine fuel can be depreciated.

6.2 Electrical power subject to transient voltage or frequency surges or distortion can alter CFR engine operating conditions or knock measuring instrumentation performance and thus affect the $\Delta O.N.$ obtained for spark-ignition engine fuels.

6.2.1 Electrical noise can affect the ability of the knock testing unit/automated analytical measurement system to accurately determine the $\Delta O.N.$ of the sample stream fuel.

6.3 *Precaution*—Avoid exposure of sample fuels to sunlight or fluorescent lamp UV emissions to minimize induced chemical reactions that can affect octane number ratings.⁴

6.3.1 Exposure of these fuels to UV wavelengths shorter than 550 nanometers for a short period of time may significantly affect octane number ratings.⁴

7. Apparatus

7.1 This test method utilizes a multi-component analytical measurement system (AMS). It incorporates a knock testing engine with instrumentation to measure and produce an output signal representative of the difference in knock rating or $\Delta O.N.$ An associated automated control system includes a fuel delivery system to introduce a stream sample or CRF to the engine critical carburetor components. The automated system shall also include equipment and controls for switching between the CRF and the stream sample, controls for operating the test engine and monitoring the critical operating conditions, and instrumentation to convert the compression ratio (*C.R.*) or knock intensity (*K.I.*) to a $\Delta O.N.$

7.1.1 An appropriate CFR engine knock testing unit specified for the determination of research octane number or motor octane number and meeting the recommendations of the manufacturer of the AMS. Specific knock testing unit equipment can include the following:

⁴Annual Book of ASTM Standards, Vol 05.02.

⁴Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: D02-1502.

7.1.1.1 For research octane number measurement, a Model CFR F-1, single cylinder engine knock testing unit assembly comprised of the appropriate critical or equivalent equipment components selected by the system manufacturer, and for which specifications are provided in Test Method D 2699, Annex A2.³

7.1.1.2 For motor octane number measurement, a Model CFR F-2, single cylinder engine knock testing unit assembly comprised of the appropriate critical or equivalent equipment components selected by the system manufacturer, and for which specifications are provided in Test Method D 2700, Annex A2.³

7.1.1.3 Instrumentation for the measurement of knock, temperatures or other knock testing unit variables as selected by the system manufacturer, and for which specifications are provided in Annex ~~A3~~, A2, of either Test Method D 2699 or Test Method D 2700, whichever is appropriate.

7.1.1.4 The AMS system installation requires a number of components and devices to integrate the critical or equivalent equipment items into a complete working unit. Specific items to satisfy important criteria for proper operation of the respective CFR engine unit are to comply with the appropriate non-critical equipment specifications in Annex ~~A2 and Annex A3~~, A2, of either Test Method D 2699 or Test Method D 2700, whichever is appropriate.

7.1.1.5 Equipment for adjustment of engine compression ratio and a mechanism for relative measurement of this variable when the Δ O.N. value is based on differences in engine compression ratio.

7.1.2 Automated control equipment for adjustment and monitoring of the critical operating variables of the knock testing unit is required and selected in accordance with the recommendations and instructions of the system manufacturer. Specific variables and conditions to be handled by the automated control equipment can include the following:

7.1.2.1 A mechanism to vary fuel-air ratio and determine the condition that produces a maximum K.I. signal. Determination of the fuel-air ratio for maximum knock intensity can be performed using either the equilibrium or a dynamic search technique.

7.1.2.2 An adjustable octane number scaling function to convert the measured signal variable to an output signal Δ O.N. value, recognizing any non-linear relationship that can exist.

7.1.2.3 Timing controls for fuel switching and measurement functions to meet the specified operating principles of this test method.

7.1.2.4 Suitable sensors for monitoring operating conditions and system safety related functions that are incorporated in the system design.

7.1.3 A sample system to provide a continuously representative stream and deal with the unconsumed stream sample.

7.1.3.1 Equipment to treat the incoming stream sample fuel to remove particulate matter and entrained water to meet the requirements specified by the system manufacturer.

7.1.4 Storage vessels and associated equipment for storing and supplying one or more CRF materials.

8. Reagents and Reference Materials

8.1 *Cylinder Jacket Coolant*—Use water in the cylinder jacket for engine locations where the resultant boiling temperature will be $100 \pm 1.5^\circ\text{C}$ ($212 \pm 3^\circ\text{F}$). Use water with commercial glycol based antifreeze added in sufficient quantity to meet the boiling temperature requirements where altitude dictates. A commercial multifunction water treatment material can be used in the coolant to minimize corrosion and mineral scale that can alter heat transfer and rating results.

8.1.1 Water is understood to mean reagent water conforming to type IV, Specification D 1193. (**Warning** —Ethylene glycol based antifreeze is poisonous and may be harmful or fatal if inhaled or swallowed. See Annex A1.)

8.2 *Engine Crankcase Lubricating Oil*—SAE 30 viscosity grade oil meeting the current API service classification for spark-ignition engines containing a detergent additive and having a kinematic viscosity of 9.3 to 12.5 mm² per s (cst) at 100°C (212°F) and a viscosity index of not less than 85. Do not use oils containing viscosity index improvers or multigrade oils. (**Warning** —Lubricating oil is combustible and its vapor is harmful. See Annex A1.)

8.3 *Standard Fuel*— (**Warning**—Standard fuel is flammable and its vapors are harmful. Vapors may cause flash fire. See Annex A1.) A secondary comparison reference fuel that conforms to the following:

8.3.1 *Octane Number*— Selected to have a RON_{ARV} or MON_{ARV} with respect to the O.N. of the prototype fuel or the stream samples to be analyzed.

8.3.1.1 The difference between standard fuel and related prototype fuel shall not exceed ± 0.5 O.N.

8.3.1.2 The difference between standard fuel and the stream samples to be analyzed shall not exceed ± 1.0 O.N.

(1) *Discussion*— The difference between the standard fuel and the stream sample refers to when the standard fuel is used in direct comparison to the stream sample.

8.3.1.3 Determine the appropriate O.N._{ARV} of standard fuel under reproducibility conditions using a minimum of 16 different exchange participants (see Annex A3).

8.3.2 *Volatility*—Or use with blended stream samples, the standard fuel can be slightly less volatile than the stream samples to be analyzed in the interest of minimizing weathering.

8.3.2.1 A vapor pressure, as defined in Test Method D 4814, of less than 68.9 kPa (10 psi) is preferred but, in any case, it shall not exceed 82.7 kPa (12 psi).

8.3.3 *Hydrocarbon Composition*—Similar to that of a related prototype fuel or the stream samples to be analyzed. Users are cautioned to investigate the O.N. effect of any significant differences in composition matrix between these related fuels.

8.3.4 *Antiknock Compound*—The same organometallic lead or manganese additive compound, in a similar concentration, shall

be present in the standard fuel if it is present in the prototype fuel or stream sample to be analyzed.

8.3.5 *Octane Enhancers*—Compounds such as oxygenates shall be present in the standard fuel, in similar concentration, to that present in the prototype fuel or stream sample to be analyzed.

8.3.6 *Antioxidant*—Add at the treat-rate recommended by the additive supplier to ensure maximum storage stability.

8.3.6.1 Add antioxidant prior to distribution of standard fuel for the determination of the O.N._{ARV}.

8.3.7 *Metal Deactivator*—Add in accordance with supplier recommendations if it is deemed necessary.

8.3.8 *Storage and Handling*—Controlled conditions to minimize the possibility of octane number change or contamination. Systems and procedures shall conform to the requirements set forth in Annex A2 of this test method.

8.4 *Prototype Fuel*—(**Warning**—Prototype fuel is flammable and its vapors are harmful. Vapors may cause flash fire. See Annex A1.) A tertiary comparison reference fuel that conforms to the following:

8.4.1 *Octane Number*—The difference between prototype fuel and the stream samples to be analyzed shall not exceed ± 1.0 O.N.

8.4.1.1 Determine the appropriate O.N._{SAV} of prototype fuel based on the average value of a minimum of 10 direct match knock characteristic comparisons, obtained either manually or automatically, under site precision conditions (see Annex A4).

8.4.2 *Volatility*—For use with blended stream samples, the prototype fuel can be slightly less volatile than the stream samples to be analyzed in the interest of minimizing weathering.

8.4.2.1 A vapor pressure, as defined in Test Method D 4814, of less than 68.9 kPa (10 psi) is preferred but, in any case, it shall not exceed 82.7 kPa (12 psi).

8.4.3 *Hydrocarbon Composition*—Similar to that of the stream samples to be analyzed. Users are cautioned to investigate the O.N. effect of any significant differences in composition matrix between these related fuels.

8.4.4 *Antiknock Compound*—The same organometallic lead or manganese additive compound, in a similar concentration, shall be present in the prototype fuel if it is present in the stream sample to be analyzed.

8.4.5 *Octane Enhancers*—Compounds such as oxygenates shall be present in the prototype fuel, in similar concentration, to that present in the stream sample to be analyzed.

8.4.6 *Antioxidant*—Add at the treat-rate recommended by the additive supplier to ensure maximum storage stability.

8.4.7 *Metal Deactivator*—Add in accordance with supplier recommendations if it is deemed necessary.

8.4.8 *Storage and Handling*—Control conditions to minimize the possibility of octane number change or contamination. Systems and procedures shall conform to the recommendations set forth in Annex A2.

8.5 *Paired Check Fuels*—The paired check fuels will have an expected difference O.N. ranging from 0.2 to 1.0 and be coded so the difference in the accepted reference values (Fuel A–Fuel B) is a positive value.

8.5.1 The fuel characteristics, including those for antiknock compound, octane enhancers, and antioxidant protection are to be similar for the two check fuels of a pair.

8.6 *Paired Quality Control Fuels*—The two quality control fuels, one of which is a comparison reference fuel, shall have Δ O.N. ranging from 0.2 to 1.0.

8.7 *Primary Reference Fuels*—Reference fuel grade *isooctane*, heptane, the 80 O.N. blend of the two meeting the specifications given in Test Method D 2699 or Test Method D 2700, or both. (**Warning**—Primary reference fuels are flammable and the vapors are harmful. Vapors may cause flash fire. See Annex A1.)

9. Sampling

9.1 Collect stream samples for on-line analysis in accordance with Practice D 4177.

9.1.1 Collect, treat, and deliver stream samples to the CFR engine carburetor in a way that minimizes exposure to light of any form.

9.2 Collect stream sample material for preparation, storage and laboratory testing as comparison reference fuels in accordance with Practices D 4057, D 4177, and D 5842.

9.2.1 Collect and store sample fuels in an opaque container, such as a dark brown glass bottle, metal can, or a minimally reactive plastic container to minimize exposure to UV emissions from sources such as sunlight or fluorescent lamps.

10. Basic Engine and Instrument Settings and Operating Conditions

10.1 *Standard Operating Conditions* :

10.1.1 *Installation of CFR Engine Equipment and Instrumentation*—Place the CFR engine on a suitable foundation and hook up all utilities in accordance with the specifications of the engine manufacturer. Assemble the supplemental automated analyzer system and fuel delivery system components in accordance with the instructions of the system manufacturer. All installation aspects are to comply with local and national codes and installation requirements.

10.1.2 Proper operation of the CFR engine requires assembly of a number of engine components and adjustment of a series of engine variables to prescribed specifications. These settings and adjustments are specified in the CFR F-1 & F-2 Octane Rating Unit Operation & Maintenance Manual and in the Basic Engine and Instrument Settings And Standard Operating Conditions sections of Test Method D 2699 or Test Method D 2700, or both, and are of the following types:

10.1.2.1 Conditions based on component specifications (Annex A2 and A3 of Test Method D 2699 or Test Method D 2700, or both).