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An American National Standard
Method 6012.6—Federal Test
Method Standard No. 791b

Designation: 119/96

Standard Test Method for Knock Characteristics of Aviation Gasolines by the Supercharge MethodSupercharge Rating of Spark-Ignition Aviation Gasoline[1]

This standard is issued under the fixed designation D 909; 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 (ε) indicates an editorial change since the last revision or reapproval.

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

ε[1]NOTE—Adjunct references were corrected editorially in April 2006.

1. Scope

1.1This test method covers the determination of the knock-limited power, under supercharge rich-mixture conditions, of fuels for use in spark-ignition reciprocating aircraft engines, in terms of ASTM supercharge octane or performance number. By operational considerations, this test method is restricted to testing fuels of 85 ASTM supercharge octane number and over.

1.2The values stated in inch-pound units are to be regarded as the standard. The values in parentheses are for information only.

1.3

1.1 This laboratory test method covers the quantitative determination of supercharge ratings of spark-ignition aviation gasoline. The sample fuel is tested using a standardized single cylinder, four-stroke cycle, indirect injected, liquid cooled, CFR engine run in accordance with a defined set of operating conditions.

1.2 The supercharge rating is calculated by linear interpolation of the knock limited power of the sample compared to the knock limited power of bracketing reference fuel blends.

1.3 The rating scale covers the range from 85 octane number to *Iso*octane + 6.0 mL TEL/U.S. gal.

1.4 The values of operating conditions are stated in SI units and are considered standard. The values in parentheses are the historical inch-pound units. The standardized CFR engine measurements and reference fuel concentrations continue to be in historical units.

1.5 *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.* Specific precautionary statements are given in Annex A7A1.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

D1368Test Method for Trace Concentrations of Lead in Primary Reference Fuels

D2268Test Method for Analysis of High-Purity *1193 Specification for Reagent Water*

D 2268 Test Method for Analysis of High-Purity *n*-Heptane and *Iso*octane by Capillary Gas Chromatography

D2599Methods of Test for Lead in Gasoline by X-Ray Spectrometry[3]

D2699Test Method for Research Octane Number of Spark-Ignition Engine Fuel

D2700Test Method for Motor Octane Number of Spark-Ignition Engine Fuel

D 3237 Test Method for Lead in Gasoline by Atomic Absorption Spectroscopy

D 3341 Test Method for Lead in GasolineIodine Monochloride Method

D 4057 Practice for Manual Sampling of Petroleum and Petroleum Products

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

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[1] This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.01 on Combustion Characteristics.

Current edition approved Dec. 10, 2001. Published February 2002. Originally published as D909–58. Last previous edition D909–00

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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.

D 5059 Test Methods for Lead in Gasoline by X-Ray Spectroscopy
E~~1Specification for ASTM Liquid-in-Glass Thermometers~~ 344 Terminology Relating to Thermometry and Hydrometry
E 456 Terminology Relating to Quality and Statistics

2.2 *CFR Engine Manuals:*[3]

CFR F-4 Form 846 Supercharge Method Aviation Gasoline Rating Unit Installation Manual
CFR F-4 Form 893 Supercharge Method Aviation Gasoline Rating Unit Operation & Maintenance

2.3 *Energy Institute Standard:*[4]

IP 224/02 Determination of Low Lead Content of Light Petroleum Distillates by Dithizone Extraction and Colorimetric Method

2.4 *ASTM Adjuncts:*

~~Data Sheet for Supercharge Method (Pads of 50 8 ½ by 11 in. sheets)~~
~~Reference Fuel Framework for Supercharge Method (Pads of 50 8½ by 11 in. data sheets)~~
Rating Data Sheet[5]
~~Petroleum Measurement Tables~~
Reference Fuel Framework Graphs[6]

3. Terminology

3.1 *Definitions:*

3.1.1 ~~*ASTM supercharge octane number of a fuel below 100*—the whole number nearest the percentage by volume of *iso*octane (equals 100) in a blend with *n*-heptane (equals 0) that matches the knock characteristics of the fuel when compared by this test method.~~ 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, or *(2)* an assigned or certified value, based on experimental work of some national or international organization, or *(3)* a consensus or certified value, based on collaborative experimental work under the auspices of a scientific or engineering group. **E 456**

3.1.1.1 *Discussion*—In the context of this test method, accepted reference value is understood to apply to the Supercharge and octane number ratings of specific reference materials determined empirically under reproducibility conditions by the National Exchange Group or another recognized exchange testing organization.

3.1.2 ~~*ASTM supercharge rating of a fuel above 100*—the amount of tetraethyllead (TEL) in *iso*octane, expressed in millilitres per U.S. gallon.~~

~~3.2ASTM supercharge ratings are normally expressed as octane numbers below 100 and as performance numbers above 100. At 100, a rating may be expressed either as 100 octane number or as 100 performance number. Sometimes it is desirable to convert the ASTM supercharge octane number to performance number. This can be done by using Table 1. Table 2 lists the corresponding performance numbers for various concentrations of tetraethyllead in *iso*octane.~~ check fuel, *n—for quality control testing*, a spark-ignition aviation gasoline having supercharge rating ARV determined by the National Exchange Group.

3.1.3 *firing*, *n—for the CFR engine*, operation of the CFR engine with fuel and ignition.

3.1.4 *fuel-air ratio*, *n*—mass ratio of fuel to air in the mixture delivered to the combustion chamber.

3.1.5 *intake manifold pressure*, *n—for supercharged engines*, the positive pressure in the intake manifold.

3.1.6 *octane number*, *n*—for spark-ignition engine fuel, any one of several numerical indicators of resistance to knock obtained by comparison with reference fuels in standardized engine or vehicle tests. **D 4175**

3.1.7 *supercharge rating*, *n*—the numerical rating of the knock resistance of a fuel obtained by comparison of its knock-limited power with that of primary reference fuel blends when both are tested in a standard CFR engine operating under the conditions specified in this test method.

3.1.8 *supercharge performance number*, *n*— a numerical value arbitrarily assigned to the supercharge ratings above 100 ON.

3.1.9 *primary reference fuels*, *n—for knock testing*, volumetrically proportioned mixtures of *iso*octane with *n*-heptane, or blends of tetraethyllead in *iso*octane which define the supercharge rating scale.

3.1.10 *standard knock intensity*, *n—for supercharge method knock testing*, trace or light knock as determined by ear.

3.1.10.1 *Discussion*—Light knock intensity is a level definitely above the commonly defined least audible "trace knock"; it is the softest knock that the operator can definitely and repeatedly recognize by ear although it may not be audible on every combustion cycle (intermittent knock). The variations in knock intensity can occasionally include loud knocks and very light knocks. These variations can also change with mixture ratio; the steadiest knock typically occurring in the vicinity of 0.09 fuel-air ratio.

3.1.11 *power curve*, *n—for supercharge method knock rating*, the characteristic power output, expressed as indicated mean effective pressure, over a range of fuel-air ratios from approximately 0.08 to approximately 0.12, when a supercharge test engine

~~[3] Withdrawn.~~
[3] Available from Waukesha Engine, Dresser Inc., 1101 West St. Paul Ave., Waukesha, WI 53188.
~~[4] Available from ASTM International Headquarters. Order Adjunct No. ADJD090901. Original adjunct produced in 1953.~~
[4] Available from Energy Institute, 61 New Cavendish St., London, WIG 7AR, U.K.
[5] Available from ASTM International Headquarters. Order Adjunct No. ADJD0909~~2~~1. Original adjunct produced in 1953.
[6] Available from ASTM International Headquarters. Order Adjunct No. ~~ADJD1250AM.~~ADJD090902. Original adjunct produced in ~~1952.~~1953.

TABLE 1 ASTM Conversion of Octane Numbers to Performance Numbers

Octane Number	0.0	0.1	0.2
		Performance Number70 Cylinder	
71	49.1	49.2	49.349.
Standard Bore, in.	49.1	49.2	49.3.4
72	50.0	50.1	50.2
Stroke, in.	50.0	50.1	50.2
73	50.9	51.0	51.1
Displacement, cu in.	50.9	51.0	51.1
74	51.9	51.9	52.0
Valve gear	51.9	51.9	52.0
Rocker arm bushing	needle		
75	52.8	52.9	53.0
Intake valve	52.8	52.9	53.0
76	53.8	53.9	54.1
Exhaust valve	53.8	53.9	54.1
77	54.9	55.0	55.1
Valve felts	54.9	55.0	55.1
78	56.0	56.1	56.2
Piston	56.0	56.1	56.2
79	57.1	57.3	57.4
Compression rings:	57.1	57.3	57.4
—			
Type	keystone		
80 —	58.358.5	58.6	58.7
Number required	358.5	58.6	58.7
81	59.6	59.7	59.8
Oil control rings:	59.6	59.7	59.8
82 —	60.9	61.0	61.1
Type	60.9	61.0	61.1
83 —	62.2	62.4	62.5
Number required	2.2	62.4	62.5
84	63.6	63.8	63.9
Crankcase	63.6	63.8	63.9
Rotating balance weights	CFR48, non-leaded version		
85	65.1	65.365.4	65.6
Camshaft, deg overlap	65.1	65.365.4	65.6
86	66.7	66.8	67.0
Ignition	66.7	66.8	67.0
87	68.3	68.5	68.6
Spark plug	68.3	68.5	68.6
88 —	70.0	70.2	70.4
Type	70.0	70.2	70.4
89 —	71.8	72.0	72.2
Gasket	71.8	72.0	72.2
Humidity control	compressed air		
90	73.7	73.9	74.1
Fuel system	73.7	73.9	74.1
91	7 5.7	—75.9	76.1
Pump timing	inlet port closes at 5.7	70 ±5.9	76.1
92	77.8	78.0	78.2
Injection pump:	77.8	78.0	78.2
93 —	80.0	80.2	80.5
Plunger diameter, mm	80.0	80.2	80.5
94 —	82.4	82.6	82.8
Lift at port closure, in.	0.4	82.6	82.8
Injector	Pintle type		
95	84.8	85.1	85.4
Injector line	84.8	85.1	85.4
96 —	87.5	87.8	88.188.
Bore, in.	87.5	87.8	88.1/88
97 —	90.3	90.6	90.9
Length, in.	90.3	90.6	90.9
98	—93.3	93.6	94.0
98	93.3	93.6	94.0
99	—96.6	96.9	97.2
100 —	100.0	—...	—...

TABLE 2 ASTM Conversion of Tetraethyllead in Isooctane to Performance Numbers

Tetraethyl-lead in *Iso*octane, mL per U. S. gal	0.00ASTM *Iso*octane	0.01ASTM *n*-Heptane	0.02	0.03	0.04	0.05	0.0
				Performance Number Performance Numberd			
0.0	100.0	1 00.4	100.8	101.2101.6	102.0	102.4	102.8
*Iso*octane, %	not less than 99.75	not greater than 0.10	100.8	101.ASTMD 2101.6	102.0	102.4	102.8
0.1	1 04.0	104.3	104.7	105.0	105.4	105.7	106.1
n-Heptane, %	not greater than 0.10	not less than 99.75	104.7	105.0	105.4	105.7	10ASTMD 22
0.2	1 07.4	1 07.8	108.1	108.4	108.7	109.0	109.3
Lead Content, g/gal	not greater than 0.002	not greater than 0.002	108.1	108.4	108.7	109.0	109.3
0.4	113.3	113.6	113.8	114.1	114.3	114.6	114.8
0.5	115.8	116.1	116.3	116.5	116.8	117.0	117.211
0.6	118.1	118.3	118.6	118.8	119.0	119.2	119.4
0.7	120.2	120.4	120.6	120.8	121.0	121.2	121.4
0.8	122.2	122.4	122.6	122.8	122.9	123.1	123.3
0.9	124.0	124.2	124.4	124.5	124.7	124.9	125.1
1.0	125.7	125.9	126.1	126.2	126.4	126.5	126.7
1.1	127.3	127.5	127.6	127.8	127.9	128.1	128.2
1.2	128.8	129.0	129.1	129.3	129.4	129.6	129.7
1.3	130.2	130.4	130.5	130.7	130.8	130.9	131.1
1.4	131.6	131.7	131.8	132.0	132.1	132.2	132.4
1.5	132.9	133.0	133.1	133.2	133.3	133.5	133.6
1.6	134.1	134.2	134.3	134.4	134.5	134.6	134.8
1.7	135.2	135.3	135.4	135.6	135.7	135.8	135.9
1.8	136.3	136.4	136.5	136.6	136.7	136.8	137.0
1.9	137.4	137.5	137.6	137.7	137.8	137.9	138.0
2.0	138.4	138.5	138.6	138.7	138.8	138.9	139.0
2.1	139.3	139.4	139.5	139.6	139.7	139.8	139.9
2.2	140.3	140.4	140.4	140.5	140.6	140.7	140.8
2.3	141.1	141.2	141.3	141.4	141.5	141.6	141.7
2.4	142.0	142.1	142.2	142.3	142.3	142.4	142.5
2.5	142.8	142.9	143.0	143.1	143.2	143.2	143.3
2.6	143.6	143.7	143.8	143.9	143.9	144.0	144.1
2.7	144.4	144.5	144.6	144.6	144.7	144.8	144.8
2.8	145.1	145.2	145.3	145.4	145.4	145.5	145.6
2.9	145.9	145.9	146.0	146.1	146.1	146.2	146.3
3.0	146.6	146.6	146.7	146.8	146.8	146.9	147.0
3.1	147.2	147.3	147.4	147.4	147.5	147.6	147.6
3.2	147.9	148.0	148.0	148.1	148.2	148.2	148.3
3.3	148.5	148.6	148.7	148.7	148.8	148.8	148.9
3.4	149.2	149.2	149.3	149.3	149.4	149.5	149.5
3.5	149.8	149.8	149.9	149.9	150.0	150.1	150.1
3.6	150.3	150.4	150.5	150.5	150.6	150.6	150.7
3.7	150.9	151.0	151.0	151.1	151.1	151.2	151.2
3.8	151.5	151.5	151.6	151.6	151.7	151.7	151.8
3.9	152.0	152.1	152.1	152.2	152.2	152.3	152.3
4.0	152.5	152.6	152.6	152.7	152.7	152.8	152.8
4.1	153.1	153.1	153.2	153.2	153.3	153.3	153.4
4.2	153.6	153.6	153.7	153.7	153.8	153.8	153.9
4.3	154.1	154.1	154.1	154.2	154.2	154.3	154.3
4.4	154.5	154.6	154.6	154.7	154.7	154.8	154.8
4.5	155.0	155.1	155.1	155.1	155.2	155.2	155.3
4.6	155.5	155.5	155.6	155.6	155.6	155.7	155.7
4.7	155.9	156.0	156.0	156.0	156.1	156.1	156.2
4.8	156.4	156.4	156.4	156.5	156.5	156.6	156.6
4.9	156.8	156.8	156.9	156.9	157.0	157.0	157.0
5.0	157.2	157.2	157.3	157.3	157.4	157.4	157.5
5.1	157.6	157.7	157.7	157.7	157.8	157.8	157.9
5.2	158.0	158.1	158.1	158.1	158.2	158.2	158.3
5.3	158.4	158.5	158.5	158.5	158.6	158.6	158.7
5.4	158.8	158.9	158.9	158.9	159.0	159.0	159.0
5.5	159.2	159.2	159.3	159.3	159.3	159.4	159.4
5.6	159.6	159.6	159.6	159.7	159.7	159.8	159.8
5.7	159.9	160.0	160.0	160.1	160.1	160.1	160.2
5.8	160.3	160.3	160.4	160.4	160.4	160.5	160.5
5.9	160.7	160.7	160.7	160.8	160.8	160.8	160.9
6.0	161.0	...	...	...	...	...	...

is operated on *iso*octane plus 6 ml of tetraethyllead per U.S. gallon under standard conditions at a constant intake manifold pressure of 40 in. of Hg (134.3 kPa) absolute.

3.1.12 *knock-limited power curve*, *n—for supercharge method knock rating*, the non-linear standard knock intensity characteristic of a primary reference fuel blend or a sample fuel, expressed as indicated mean effective pressures, over the range of fuel-air ratios from approximately 0.08 to approximately 0.12.

3.1.13 *reference fuel framework*, *n—for supercharge method knock rating*, the graphic representation of the knock-limited power curves for the specified primary reference fuel blends of *iso*octane + *n*-heptane and *iso*octane + TEL (mL/U.S. gal) that defines the expected indicated mean effective pressure versus fuel-air ratio characteristics for supercharge test engines operating properly under standardized conditions.

3.1.14 *mean effective pressure*, *n*—for internal-combustion engines, the steady state pressure which, if applied to the piston during the expansion stroke is a function of the measured power.[7]

3.1.15 *indicated mean effective pressure*, *n— for spark-ignition engines*, the measure of engine power developed in the engine cylinder or combustion chamber.

3.1.16 *brake mean effective pressure*, *n— for spark-ignition engines*, the measure of engine power at the output shaft as typically measured by an absorption dynamometer or brake.

3.1.17 *friction mean effective pressure*, *n— for spark-ignition engines*, the measure of the difference between IMEP and BMEP or power absorbed in mechanical friction and any auxiliaries.

3.1.18 *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**

3.1.18.1 *Discussion*—In the context of this method, a short time interval is understood to be the time for two back-to-back ratings because of the length of time required for each rating.

3.1.19 *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**

3.2 *Abbreviations:*

3.2.1 *ARV*—accepted reference value
3.2.2 *ABDC*—after bottom dead center
3.2.3 *ATDC*—after top dead center
3.2.4 *BBDC*—before bottom dead center
3.2.5 *BMEP*—break mean effective pressure
3.2.6 *BTDC*—before top dead center
3.2.7 *C.R.*—compression ratio
3.2.8 *FMEP*—friction mean effective pressure
3.2.9 *IAT*—intake air temperature
3.2.10 *IMEP*—indicated mean effective pressure
3.2.11 *NEG*—National Exchange Group
3.2.12 *O.N.*—octane number
3.2.13 *PN*—performance number
3.2.14 *PRF*—primary reference fuel
3.2.15 *RTD*—resistance thermometer device (Terminology E 344) platinum type
3.2.16 *TDC*—top dead center
3.2.17 *TEL*—tetraethyllead
3.2.18 *UV*—ultra violet

4. Summary of Test Method

4.1ASTM supercharge octane or performance number of a fuel is determined by comparing its knock-limited power with those for bracketing blends of reference fuels under standard operating conditions. This is done at constant compression ratio by varying the manifold pressure and fuel flow rate, the independent variables of the test, and measuring indicated mean effective pressure (imep) at enough points to define the mixture response curves for the sample and the reference fuels. When the knock-limited power for the sample is bracketed between those for two adjacent reference fuels suitably chosen from the prescribed list (see 12.1.2), the rating of the sample is calculated by interpolation at the fuel-air ratio for maximum power for the lower bracketing reference fuel.

4.1 The supercharge method rating of a fuel is determined by comparing the knock-limited power of the sample to those for bracketing blends of reference fuels under standard operating conditions. Testing is performed at fixed compression ratio by varying the intake manifold pressure and fuel flow rate, and measuring IMEP at a minimum of six points to define the mixture response curves, IMEP versus fuel-air ratio, for the sample and reference fuels. The knock-limited power for the sample is

[7] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02–1467.

[7] See *The Internal-Combustion Engine* by Taylor and Taylor, International Textbook Company, Scranton, PA.

bracketed between those for two adjacent reference fuels, and the rating for the sample is calculated by interpolation of the IMEP at the fuel-air ratio which produces maximum power (IMEP) for the lower bracketing reference fuel.

5. Significance and Use

~~5.1The supercharge test method provides a means of determining the rich-mixture antiknock performance of aviation gasoline. The test method utilizes a single-cylinder engine and requires critical adjustment of the fuel/air ratio and inlet-manifold pressure to establish the knock-limited power characteristic of the gasoline. The knock-limited power rating of the gasoline sample is determined by comparing its knock-limited power level with that of the knock-limited power level of primary reference fuels whose volumetric composition establishes the rating scale. The rating is expressed as an octane number at and below 100 and as a performance number above 100.~~

~~5.2It is customary to express grades of aviation fuel in terms of double numbers. The first number expresses the antiknock quality by its lean-mixture or aviation rating, and the second by its rich-mixture or supercharge rating. See Test Method D2700.~~

~~5.3This test is used by engine manufacturers, by petroleum refiners and marketers, and in commerce as a primary specification measurement to ensure proper matching of fuel antiknock quality and engine requirement.~~

5.1 Supercharge method ratings can provide an indication of the rich-mixture antiknock performance of aviation gasoline in aviation piston engines.

5.2 Supercharge method ratings are used by petroleum refiners and marketers and in commerce as a primary specification measurement to insure proper matching of fuel antiknock quality and engine requirement.

5.3 Supercharge method ratings may be used by aviation engine and aircraft manufacturers as a specification measurement related to matching of fuels and engines.

6. Interferences

6.1 *Precaution*—Avoid exposure of sample fuels to sunlight or fluorescent lamp UV emissions to minimize induced chemical reactions that can affect octane number ratings.[8]

6.1.1 Exposure of these fuels to UV wavelengths shorter than 550 nm for a short period of time can significantly affect octane number ratings.

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 supercharge rating obtained for sample fuels.

7. Apparatus

~~6.1The knock testing unit illustrated in~~

7.1 *Engine Equipment*[9,10]—This test method uses a single cylinder, CFR engine that consists of standard components as follows: crankcase, a cylinder/clamping sleeve, a thermal siphon recirculating jacket coolant system, an intake air system with controlled temperature and pressure equipment, electrical controls, and a suitable exhaust pipe. The engine flywheel is connected to a special electric dynamometer utilized to both start the engine and as a means to absorb power at constant speed when combustion is occurring (engine firing). See Fig. 1 ~~consists of a single-cylinder engine with accessories mounted on a stationary base. It is equipped with controls for varying manifold pressure and fuel flow. The engine and equipment specified in Annex A1 on Apparatus shall be used without modification, and installed as directed in Annex A5 on Installation and Assembly. It is necessary to keep the apparatus in good mechanical condition as described in Annex A4 on Maintenance.~~

~~7.Reference Materials~~

~~7.1*ASTM Knock Test Reference Fuels* , conforming to the specifications in A2.9.1 of Annex A2 on Reference Materials and Blending Accessories, are the following:~~

~~7.1.1ASTM *iso*octane (2,2,4-trimethylpentane),~~

~~7.1.2ASTM *n*-heptane,~~

~~7.1.3ASTM 80 octane number blend of 7.1.1 and 7.1.2~~and Table 1.

7.1.1 The single cylinder test engine for the determination of Supercharge rating is manufactured as a complete unit by Waukesha Engine, Dresser, Inc. The Waukesha Engine designation for the apparatus required for this test method is Model CFR F-4 Supercharge Method Octane Rating Unit. All the required unit information can be found in the Supercharge Method Aviation

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~~[8] These safety precautions have been approved by the Safety and Medical Departments of both Ethyl Corporation and E. I. du Pont de Nemours and Co., Inc.~~

[8] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: D02–1502.

~~[9] Available from B. G. Corp., 136 W. 52nd St., New York, NY 10019.~~

[9] The sole source of supply of the engine equipment and instrumentation known to the committee at this time is Waukesha Engine, Dresser Inc., 1101 West St. Paul Ave., Waukesha, WI 53188.

~~[10] Plastigage, available from the Perfect Circle Co., Hagerstown, IN, is suitable for this purpose. If it is used, the flattened strip is placed on the calibration chart supplied with it and the clearance is read therefrom.~~

[10] 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.

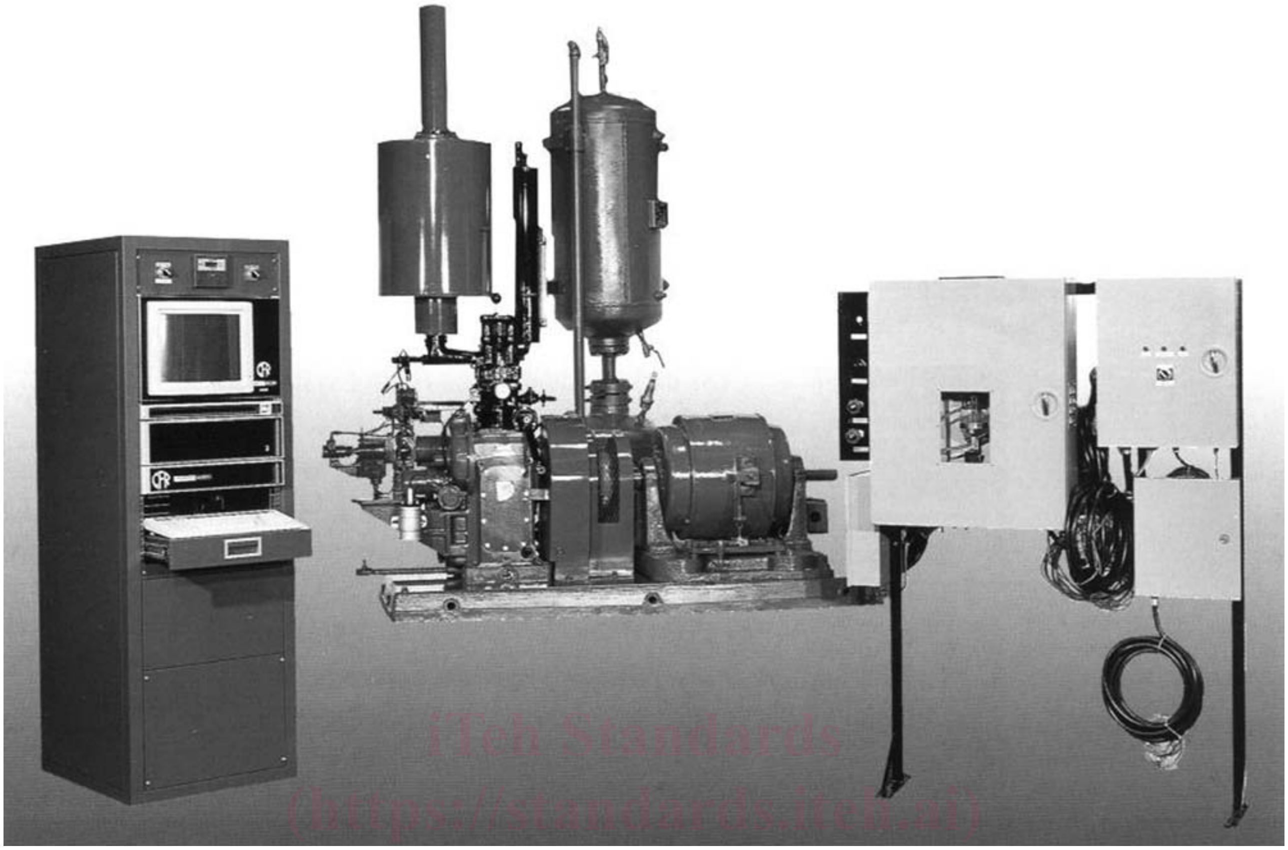

FIG. 1 Supercharge Unit

Gasoline Rating Unit Installation Manual, CFR F-4 Form 846 and the Supercharge Method Aviation Gasoline Rating Unit Operation & Maintenance CFR F-4 Form 893.

7.2 ~~*Tetraethyllead*, conforming to the specifications and requirements in A2.9.4 of Annex A2 on Reference Materials and Blending Accessories, blended with ASTM *iso*octane is required for making ratings above 100 octane number.~~ Auxiliary Equipment—A number of components and devices have been developed to integrate the basic engine equipment into complete laboratory measurement system.

8. ~~Sampling~~

~~8.1Sampling shall be done in accordance with the applicable procedure described in Practice D4057~~Reference Materials

8.1 *Cylinder Jacket Coolant*—Ethylene Glycol shall be used in the cylinder jacket with the required amount of water to obtain a boiling temperature of 191 ± 3°C (375 ± 5°F). (**Warning—**Ethylene glycol based antifreeze is poisonous and may be harmful or fatal if inhaled or swallowed. See Annex A1.)

8.1.1 Water shall be understood to mean reagent water conforming to Type IV of Specification D 1193.

~~9.Operating Conditions~~

~~9.1The following standard operating conditions (see Annex A3 on Operation for further details) are mandatory:~~

~~9.1.1~~

8.2 *Engine Crankcase Lubricating Oil*— An SAE 50 viscosity grade oil meeting the current API service classification for spark-ignition engines shall be used. It shall contain a detergent additive and have a kinematic viscosity of 16.77–25.0 mm^2 per s (cSt) at 100°C (212°F) and a viscosity index of not less than 85. Oils containing viscosity index improvers shall not be used. Multigraded oils shall not be used. (**Warning—**Lubricating oil is combustible and its vapor is harmful. See Annex A1.)

8.3 *PRF,*[10] ,[11] *iso*octane (2,2,4-trimethylpentane) and *n*-heptane meeting the specifications in Table 2. (**Warning—**Primary reference fuel is flammable and its vapors are harmful. Vapors may cause flash fire. See Annex A1.)

~~[11] These Bacharach and Bosch testers have been found satisfactory for the Supercharge method and are available respectively from Bacharach Instrument Co., AMBAC Industries Inc., 625 Alpha Drive, RIDC Industrial Park, Pittsburgh, PA 15238, and from Robert Bosch Corp., 2800 South 25th Ave., Broadview, IL 60153.~~

[11] Primary Reference Fuels are currently available from Chevron Phillips Chemical Company LP., 1301 McKinney, Suite 2130, Houston, TX 77010–3030 or Haltermann Gmbh, Schopenstehl 15, 20095, Hamburg, Germany.

8.4 *Tetraethyllead* concentrated antiknock mixture (aviation mix) containing not less than 61.0 weight % of tetraethyllead and sufficient ethylene dibromide to provide two bromine atoms per atom of lead. The balance of the antiknock mixture shall be a suitable oxidation inhibitor, an oil-soluble dye to provide a distinctive color for identification and kerosene.

8.4.1 *Temperature Corrections*—If the temperature of the fuel is below that of the TEL, the quantity of the TEL is increased and vice versa as calculated by the coefficient of expansion, obtained from the supplier, of concentrated TEL.

8.4.2 *Analysis for TEL*—It is recommended that each blend of fuel, particularly drum blends, be analyzed for lead content in accordance with standard test methods (see Test Methods D 3237, D 3341, and D 5059.)

8.5 *Aviation Check Fuel*—A typical aviation gasoline for which the Supercharge Rating ARV has been determined by the NEG that is used for checking engine performance. This fuel (Aviation Grade 100LL) and supporting statistical data from the ARV determination program are available from the supplier.[10,12] (**Warning—**Check Fuel is flammable and its vapors are harmful. Vapors may cause flash fire. See Annex A1.)

9. Sampling

9.1 Collect samples in accordance with Practices D 4057.

9.2 *Protection from Light*—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 Instrumentation Settings and Standard Operating Conditions

10.1 *Installation of Engine Equipment and Instrumentation* —Installation of the engine and instrumentation requires placement of the engine on a suitable foundation and hook-up of all utilities. Engineering and technical support for this function is required, and the user shall be responsible to comply with all local and national codes and installation requirements.

10.1.1 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. Some of these settings are established by component specifications, others are established at the time of engine assembly or after overhaul, and still others are engine running conditions that must be observed or determined by the operator during the testing process.

10.2 *Conditions Based on Component Specifications*:

10.2.1 *Engine Speed*, 1800 ± 45 rpm, including friction measurement. The maximum variation throughout a test shall not exceed 45 rpm, exclusive of friction measurement.

9.1.2*Compression Ratio*, 7.0 to 1, fixed by adjustment of the clearance volume to 108 ± 0.5 mL on cylinders of standard bore by the bench tilt procedure, Section A3.2 of Annex A3. Clearance volumes for oversize cylinders are shown in this section. If the Type D-1 detonation meter pickup is used, the clearance volumes are 2 mL less than for the Waukesha plug.

9.1.3*, 1800 ± 45 rpm, under both firing and non-firing conditions. The maximum variation throughout a test shall not exceed 45 rpm, exclusive of friction measurement.*

10.2.2 *Compression Ratio*, 7.0 to 1, fixed by adjustment of the clearance volume to 108 ± 0.5 mL on cylinders of standard bore by the bench tilt procedure.

10.2.3 *Indexing Flywheel to TDC*—With the piston at the highest point of travel in the cylinder, set the flywheel pointer mark in alignment with the 0° mark on the flywheel in accordance with the instructions of the manufacturer.

10.2.4 *Valve Timing*—The engine uses a four-stroke cycle with two crankshaft revolutions for each complete combustion cycle. The two critical valve events are those that occur near TDC; intake valve opening and exhaust valve closing.

10.2.4.1 Intake valve opening shall occur at 15.0 ± 2.5° BTDC with closing at 50° ABDC on one revolution of the crankshaft and flywheel.

10.2.4.2 Exhaust valve opening shall occur 50° BBDC on the second revolution of the crankshaft and flywheel, with closing at 15.0 ± 2.5° ATDC on the next revolution of the crankshaft and flywheel.

10.2.5 *Valve Lift*—Intake and exhaust cam lobe contours, while different in shape, shall have a contour rise of 8.00 to 8.25 mm (0.315 to 0.325 in) from the base circle to the top of the lobe.

10.3 *Assembly Settings and Operating Conditions*:

10.3.1 *Spark Advance*, constant, 45°.

9.1.4

10.3.2 *Spark-Plug Gap*, 0.020 ± 0.003 in. (0.51 ± 0.13 mm).

9.1.5*, 0.51 ± 0.13 mm (0.020 ± 0.003 in.).*

10.3.3 *Ignition Settings*:

9.1.5.1*Breaker-Point Gap*, 0.020 in. (0.51 mm).

9.1.5.2Breakerless ignition system basic setting for transducer to rotor (vane) gap is 0.003 to 0.005 in. (0.08 to 0.13 mm).

9.1.6

[12] To obtain calibration points on units equipped with the older type of Toledo Scales, refer to the 1952 ASTM manual of Engine Test Methods for Rating Fuels, pp. 268 to 272.

[12] The sole source of supply of the apparatus known to the committee at this time is Chevron Phillips Chemical Company LP., 1301 McKinney, Suite 2130, Houston, TX 77010–3030.

10.3.3.1 Breakerless ignition system basic setting for transducer to rotor (vane) gap is 0.08 to 0.13 mm (0.003 to 0.005 in.).

10.3.4 *Valve Clearances*~~, 0.008 ± 0.001 in. for the intake, 0.010 ± 0.001 in. for the exhaust, measured with the engine hot and running at equilibrium under standard operating conditions on a reference fuel of 100 octane number at the fuel-air ratio for maximum power and an absolute manifold pressure of 30 in. Hg (101.6 kPa).~~

~~9.1.7*Crankcase Lubricating Oil*, SAE 50, having a kinematic viscosity of 16.77 to 24.96 cSt (mm ^{2}/s) at 210°F (99°C) and a viscosity index of not less than 85. Oils containing viscosity index improvers or multi-graded oils shall not be used.~~

~~9.1.8~~*, 0.20 ± 0.03 mm (0.008 ± 0.001 in.) for the intake, 0.25 ± 0.03 mm (0.010 ± 0.001 in.) for the exhaust, measured with the engine hot and running at equilibrium under standard operating conditions on a reference fuel of 100 octane number at the fuel-air ratio for maximum power and an absolute manifold pressure of 101.6 kPa (30 in. Hg).*

10.3.5 *Oil Pressure*~~, 60 ± 5 psi (0.41 ± 0.03 MPa) gage in the oil gallery leading to the crankshaft bearings.~~

~~9.1.9~~*, 0.41 ± 0.03 MPa (60 ± 5 psi) gage in the oil gallery leading to the crankshaft bearings.*

10.3.6 *Oil Temperature*~~, 165 ± 5°F (74 ± 3°C) at the entrance to the oil gallery.~~

~~9.1.10~~*, 74 ± 3°C (165 ± 5°F) at the entrance to the oil gallery.*

10.3.6.1 *Engine Crankcase Lubricating Oil Level*:

(1) Engine Stopped and Cold—Oil added to the crankcase so that the level is near the top of the sight glass will typically provide the controlling engine running and hot operating level.

(2) Engine Running and Hot—Oil level shall be approximately mid-position in the crankcase oil sight glass.

10.3.7 *Coolant Temperature*~~, 375 ± 5°F (191 ± 3°C) in the top of the coolant return line from the condenser to the cylinder.~~

~~9.1.11*Fuel-Pump Pressure*, 15 ± 2 psi (0.10 ± 0.01 MPa) in the gallery.~~

~~9.1.12*Fuel-Injector Opening Pressure* , 1200 ± 100 psi (8.2 ± 0.69 MPa) for Bosch nozzle; 1450 ± 50 psi (9.9 ± 0.34 MPa) for Ex-Cell-O nozzle.~~

~~9.1.13~~*, 191 ± 3°C (375 ± 5°F) in the top of the coolant return line from the condenser to the cylinder.*

10.3.8 *Fuel Pump Pressure*, 0.10 ± 0.01 MPa (15 ± 2 psi) in the gallery.

10.3.9 *Fuel Injector Opening Pressure* , 8.2 ± 0.69 MPa (1200 ± 100 psi) for Bosch nozzle; 9.9 ± 0.34 MPa (1450 ± 50 psi) for Ex-Cell-O nozzle.

10.3.10 *Fuel Injector Timing*~~—The pump plunger must close the fuel-inlet port at 50 ± 5° after top dead center (atdc) on the intake stroke.~~

~~9.1.14*Air pressure*, 54.4 ± 0.5 psi (0.37 ± 0.003 MPa) absolute at the upstream flange tap of the air-flow meter.~~

~~9.1.15~~*—The pump plunger must close the fuel-inlet port at 50 ± 5° ATDC on the intake stroke.*

10.3.11 *Air Pressure*, 0.37 ± 0.003 MPa (54.4 ± 0.5 psi) absolute at the upstream flange tap of the air flow meter.

10.3.12 *Air Temperatures*~~, 125 ± 5°F (52 ± 3°C) in the downstream leg of the air-flow meter and 225 ± 5°F (107 ± 3°C) in the intake-manifold surge tank.~~

~~9.1.16~~*, 52 ± 3°C (125 ± 5°F) in the downstream leg of the air-flow meter and 107 ± 3°C (225 ± 5°F) in the intake manifold surge tank.*

10.3.13 *Intake Air Humidity*~~, 70 (max) grains of water/lb (0.00997 kg of water/kg) of dry air.~~

~~9.1.17~~*, 0.00997 kg of water/kg (max) (70 grains of water/lb) of dry air.*

10.3.14 *Standard Knock Intensity*, light knock as determined by ear. In determining the light knock point, it is advisable to adjust first to a fairly heavy knock by varying either the manifold pressure or the fuel flow, return to knock-free operation, and finally adjust to the light-knock conditions. Light- knock intensity is a level definitely above the commonly defined least audible "trace knock;" it is the least knock that the operator can definitely and repeatedly recognize by ear. ~~Knock-intensity indicators (see A1.15 of Annex A1) may be used as an aid to the ear in obtaining standard knock intensity.~~

~~9.1.18~~10.3.15 *Satisfactory Engine Condition*~~—The engine should cease firing instantly when the ignition is turned off. If it does not, operating conditions are unsatisfactory. Examine the engine for defects, particularly for combustion chamber and spark plug deposits, and remedy such conditions before rating fuels.[5]~~

~~**10.Starting and Stopping the Engine**~~

~~NOTE1—For protection of both the operator and the equipment, careful study of Annex A3 on Operation should be made.~~

~~10.1*Starting the Engine*—Turn on the cooling water. While the engine is being motored by the dynamometer, turn on the ignition, and then start fuel injection and adjust the fuel-air ratio for maximum power by means of the fuel control knob.~~

~~10.2*Stopping the Engine*—Avoid valve warpage and unnecessary heat stress by operating the engine on unleaded fuel for several minutes at atmospheric manifold pressure or below. Prevent excessive washing of the cylinder walls by stopping the fuel injection before turning off the ignition. To avoid possible corrosion and warping, close both valves by turning the flywheel to top dead center on the compression stroke. Turn off the cooling water.~~— The engine should cease firing instantly when the ignition is turned off. If it does not, operating conditions are unsatisfactory. Examine the engine for defects, particularly for combustion chamber and spark plug deposits, and remedy such conditions before rating fuels.

10.3.16 *Crankcase Internal Pressure*—As measured by a gage or manometer connected to an opening to the inside of the crankcase through a snubber orifice to minimize pulsations, the pressure shall be less than zero (a vacuum) and is typically from 25 to 150 mm (1 to 6 in.) of water less than atmospheric pressure. Vacuum shall not exceed 255 mm (10 in.) of water.

10.3.17 *Exhaust Back Pressure*—As measured by a gage or manometer connected to an opening in the exhaust surge tank or main exhaust stack through a snubber orifice to minimize pulsations, the static pressure should be as low as possible, but shall not create a vacuum nor exceed 255 mm (10 in.) of water differential in excess of atmospheric pressure.

10.3.18 *Exhaust and Crankcase Breather System Resonance* —The exhaust and crankcase breather piping systems shall have sufficient internal volume and length dimensions such that gas resonance does not result.

10.3.19 *Valve Stem Lubrication*—Positive pressure lubrication to the rocker arms is provided. Felt washers are used on the valve stems. A valve and rocker arm cover ensures an oil mist around the valves.

10.3.20 *Cylinder Jacket Coolant Level* :

10.3.20.1 *Engine Stopped and Cold*—Treated water/coolant added to the cooling condenser-cylinder jacket to a level just observable in the bottom of the condenser sight glass will typically provide the controlling engine running and hot operating level.

10.3.20.2 *Engine Running and Hot*—Coolant level in the condenser sight glass shall be within ±1 cm (±0.4 in.) of the LEVEL HOT mark on the coolant condenser.

10.3.21 *Basic Rocker Arm Carrier Adjustment* :

10.3.21.1 *Basic Rocker Arm Carrier Support Setting*—Each rocker arm carrier support shall be threaded into the cylinder so that the distance between the machined surface of the valve tray and the underside of the fork is 19 mm (¾ in.).

10.3.21.2 *Basic Rocker Arm Carrier Setting*— With the cylinder positioned so that the distance between the underside of the cylinder and the top of the clamping sleeve is approximately 16 mm (⅝ in.), the rocker arm carrier shall be set horizontal before tightening the bolts that fasten the long carrier support to the clamping sleeve.

10.3.21.3 *Basic Rocker Arm Setting*—With the engine on TDC on the compression stroke, and the rocker arm carrier set at the basic setting, set the valve adjusting screw to approximately the mid-position in each rocker arm. Then adjust the length of the push rods so that the rocker arms shall be in the horizontal position.

11. ~~Standard Engine Performance~~

~~11.1With the operating conditions of Section 9 established, it is necessary that the engine performance fall within the limits prescribed in 11.1.1 and 11.1.2. Unless the power curve and the mixture response curves for the reference fuels conform to these limits, the test unit is unsatisfactory for rating fuels and corrective steps are necessary.~~

~~11.1.1*Power Curve*, for *iso*octane plus 6 mL of tetraethyllead per U.S. gallon must show a peak of 164.5 ± 3 imep by varying the fuel flow and using standard operating conditions at a constant manifold pressure of 40 in. Hg (135.4 kPa) absolute (see Fig. 2 and Fig. 3~~Engine Fit-for-Use Qualification

11.1 Before conducting either of the fit-for-use tests, operate the engine on an aviation gasoline or reference fuel blend in compliance with the basic engine and instrumentation settings and standard operating conditions for approximately one hour to bring the unit to temperature equilibrium.

11.2 *Fit-for-Use Qualification after Maintenance*—After each top overhaul and whenever any maintenance has been performed other than coolant or lubricant fluid level adjustment or spark plug replacement, the engine shall be qualified as fit-for-use by establishing its power curve.

11.2.1 Test the reference fuel blend of *iso*octane + 6.0 mL of TEL per U.S. gallon under standard operating conditions at a constant manifold pressure of 135.4 kPa (40 in. Hg) while varying the fuel flow from lean to rich to cover the fuel-air ratio range from approximately 0.07 to approximately 0.10.

11.2.2 Obtain at least five IMEP v fuel-air ratio data pairs. Plot the data and fit a smooth curve to determine the maximum IMEP.

11.2.3 The engine is fit-for-use if the maximum IMEP of the power curve is 164 ± 5 IMEP. (See Fig. A2.1 and Fig. A2.5 for expected power curve) and the observed FMEP is no more than 3.0 psi from the expected value for the manifold pressure (see Fig. A2.3).

~~11.1.2*Knock-Limited Power Curves*—At all fuel-air ratios between 0.08 and 0.12, the knock-limited power curves for the reference fuel blends shall conform within ±5% imep to those shown in the reference fuel framework (see Fig. 4). This framework has been established for ASTM supercharge knock test units operating under properly standardized conditions. The imep spread between any two adjacent reference fuel curves as determined with the engine shall agree with the spread of the corresponding framework curves within ±30% of the latter value.~~

11.3 *Fit-for-Use Test for Each Sample*— The fit-for-use condition of the engine shall be verified with every sample rating by conformance with the following limits:

11.3.1 For every sample rating, the IMEP values determined for the reference fuels at any fuel-air ratio from approximately 0.09 to approximately 0.12 shall be within ±5 % of the value shown in the reference fuel framework at that fuel-air ratio.

11.3.2 For every sample rating, at any fuel-air ratio from approximately 0.09 to approximately 0.12, the spread (difference) between the knock-limited power curves for the bracketing reference fuels shall be within ±30 % of the spread shown in the reference fuel framework at that fuel-air ratio.

12. ~~Determination of Knock-Limited IMEP~~

~~12.1Obtain the knock-limited imep of a fuel at any test point by operating the engine at the fuel-air ratio and manifold pressure required for standard knock intensity.~~

~~12.1.1*Stabilization of Conditions*—After standard knock intensity has been obtained, it is necessary to stabilize engine~~

temperatures. During this period minor adjustments of the manifold pressure and fuel flow may be required to maintain standard intensity.

12.1.2*Observations*—When the conditions have been stabilized, record observations for determination of test results and control of engine operation. Brake and friction torques, and fuel- and air-flow rates are required for fuel ratings; coolant, oil, and intake-air temperatures, and oil and absolute manifold pressures are desirable as indications of operating conditions. To ensure that the test points are adequately defining the knock-limited power curve, plot the curve as the points are determined.

12.1.3*Power Determination*—Engine power output is expressed as imep, which is defined as the sum of the brake and friction measurements. Determine brake torque at the stabilized knock condition from the scale reading of the power absorbing unit, and express it as brake mean effective pressure (bmep). Determine the torque required to motor the engine from the scale reading of the power absorbing unit after each brake torque determination by quickly stopping the fuel injection and motoring the engine. Read the friction torque and express it as friction mean effective pressure (fmep).

12.1.4*Fuel-Air Ratio*—The ratio of the weights of fuel and air supplied to the engine during equal operating intervals is the fuel-air ratio. With the engine operating under the stabilized knock conditions, determine the fuel- and air-flow rates by observing the respective measuring devices. In practice, the air- and fuel-flow rates are recorded as minutes per 0.25 lb (0.11 kg) of air and minutes per 0.25 lb (0.11 kg) of fuel, thus allowing the calculation of fuel-air ratio directly from the data.

13.Rating a Sample

13.1Obtain knock-limited power curves for the sample and two bracketing reference fuels as follows:

13.1.1*Knock-Limited Power Curve for Sample*—Determine the knock-limited power curve for the sample from a series of knock-limited imep points established by the procedure and accompanied by the control observations outlined in 12.1.2. This curve corresponds to that of Fig. 5, determined by points 1 to 6. The knock-limited imep points should be distributed throughout a fuel-air ratio range from approximately 0.08 to 0.12 to define the knock-limited power curve. The following plan of testing, with the points determined in the order mentioned, has been found most satisfactory:

13.1.1.1*Determine the First Point*on the knock-limited power curve at approximately 0.08 fuel-air ratio by adjusting the mixture control of the fuel pump at an arbitrarily selected manifold pressure until maximum brake torque is obtained. If knock occurs, reduce the manifold pressure and continue the adjustment of the fuel pump until a maximum brake torque is obtained without knock. Maintaining this setting, increase the manifold pressure until standard knock is obtained, checking as required in 9.1.17. When equilibrium has been reached, record the observations.

13.1.1.2*To Determine Additional Points* , adjust the mixture control of the fuel pump to enrich the mixture and increase the manifold pressure by arbitrary increments (see Fig. 5, Points 2, 3). Following each change, slowly adjust the mixture until standard knock intensity is obtained, checking as required in 9.1.17. When equilibrium has been reached, record the observations. Near the peak of the knock-limited power curve (see Fig. 5, Points 4, 5, 6), it is more convenient to change the mixture control of the fuel pump by arbitrary increments and adjust the manifold pressure for standard knock intensity. When equilibrium has been reached, record the observations. At very rich mixtures make certain that the engine is firing regularly. At least six points are required to define the knock-limited power curve. Four should be on the rising portion of the curve and two at richer mixtures to determine accurately the maximum imep and the fuel-air ratio at which it occurs.

13.1.2*Knock-Limited Power Curves for Reference Fuels* —Immediately bracket the knock-limited power curve of the test sample by determining those for two *adjacent* blends of reference fuels selected from the following list:

ASTM *Iso*octane , vol%	ASTM *n*-Heptane , vol%	Tetraethyllead in *Iso*octane , mL/U.S. gal
85	15	...
90	10	...
95	5	...
100	...	...
100	...	0.5
100	...	1.25
100	...	2.0
100	...	3.0
100	...	4.0
100	...	6.0

Only these blends, prepared from the ASTM knock test reference fuels (see Section 8) may be used. The TEL content shall be determined by Test Method D2599, D3237, or D3341.

14.Calculation and Report

14.1Plot the knock-limited power curves for the sample and the bracketing reference fuels as a graph with fuel-air ratio as the abscissa and knock-limited imep as ordinate (see Fig. 4). The rating of the sample at any fuel-air ratio is that of the ASTM reference fuel which would result in the same imep when the engine is operated at standard knock intensity at the same fuel-air ratio as the sample. Determine the ASTM supercharge rating of the sample by linear interpolation between the knock-limited imep values for the sample and the bracketing reference fuels at the fuel-air ratio for maximum knock-limited imep of the lower-bracketing reference fuel. When the curve for the sample is above that for the upper-bracketing reference fuel at the fuel-air ratio for the peak of the lower-bracketing reference fuel, make the interpolation by using the imep at the intersection of the curve for the sample and a straight line connecting the peaks of the bracketing reference fuel curves.

14.2Report ratings below 100 octane number to the nearest integer. When the interpolated figure ends with 0.50, round to the nearest even number; report for example, 91.50 as 92, not 91.

14.3Report ratings above 100 octane number in concentrations of TEL per U.S. gallon rounded to the nearest 0.01 mL TEL/gal. Convert these ratings to performance numbers using Table 2.

15.Precision and Bias

15.1*Precision*:

15.1.1*Repeatability*—In the range from 1.25 to 2.00 mL TEL/U.S. gal (129.6 to 138.4 performance number), the difference between two test results obtained by the same operator with the same engine under constant operating conditions on identical test specimens within the same day would, in the long run, in the normal and correct operation of the test method, exceed 0.145 mL TEL/U.S. gal in only one case in twenty. Since the relationship between mL TEL/U.S. gal and performance number is not linear, representative repeatability statistics in units of performance number are tabulated in Rating Procedure

12.1 The Supercharge rating of the sample fuel is determined by comparison of its knock-limited power curve to the knock-limited power curves of two bracketing reference fuels.

12.1.1 The compositions of the reference fuel blends that are employed for this method are shown in Table 3.

15.1.2*Reproducibility*— In the range from 1.25 to 2.00 mL TEL/U.S. gal (129.6 to 138.4 performance number), the difference between two single and independent test results obtained by different operators in different laboratories on identical test specimens would, in the long run, in the normal and correct operation of the test method, exceed the value of *R* in only one case in twenty, where *R* is defined by the equation

$$R = 0.116x^3 \quad (1)$$

where
x = the average of the two test results in mL TEL/U.S. gal.

15.1.2.1The reproducibility values in Table 3 exemplify the values of *R* over the applicable range. Since reproducibility varies with level and the relationship between mL TEL and performance number is not linear, reproducibility limits in units of performance number are also tabulated in Table 3

12.2 The knock-limited power curve of either a sample or reference fuel is determined by measuring the power output (IMEP) of the engine as a function of fuel-air ratio.

12.2.1 The accepted knock-limited power curves for the set of reference fuels specified for this test method are plotted in Fig. A2.2.

15.1.3*Interlaboratory Test Program* —The above precision statements are based on test results obtained by the ASTM Aviation National Exchange Group from 1988 to 1998. During this period, four aviation gasoline samples having supercharge ratings in the range from 1.25 to 2.00 mL TEL/U.S. gal were tested each year by 15–23 participating laboratories. A report of the data and analysis used to establish the precision statements is available as a research report.

15.1.4*Precision Below 1.25 mL TEL/U.S. Gal and Above 2.00 mL TEL/U.S. Gal*—There is not sufficient data to establish the precision of this test method for samples having supercharge ratings below 1.25 mL TEL/U.S. gal or above 2.00 mL TEL/U.S. gal.

TABLE 3 Repeatability and Reproducibility Values

Supercharge Rating ML TEL/US gal.	PN				
ASTM *Iso*octane, vol %	ASTM *n*-Heptane, vol %	Tetraethyllead in *Iso*octane, mL/U.S. gal			
ML TEL/US gal.	PN	ML TEL/US gal.PN			
85	15	...			
1.25	129.6	0.14	2.0	0.23	3.2
90	10	.14	2.0	0.23	3.2
1.30	130.2	0.14	1.9	0.26	3.6
95	5	.14	1.9	0.26	3.6
1.40	131.6	0.14	1.8	0.32	4.2
100	...	.14	1.8	0.32	4.2
1.50	132.9	0.14	1.7	0.39	5.0
100	...	0.14	1.7	50 ±0.39	5.05
1.60	134.1	0.14	1.7	0.48	5.6
100	...	14	1.7	25 ±0.48	05
1.70	135.2	0.14	1.6	0.57	6.6
100	...	2.14	1.6	00 ±0.057	6.6
1.80	136.3	0.14	1.5	0.68	7.3
100	...	3.14	1.5	00 ±0.68	7.305
1.90	137.4	0.141.5	0.808.2		
100	...	4.5	00 ±0.05		
2.00	138.4	0.14	1.3	0.93	9.2
100	...	6.14	1.3	00 ±0.93	9.205

15.2*Bias*:

15.2.1This test method has no bias because the supercharge rating of aviation gasoline is defined only in terms of this test method.

ANNEXES

(Mandatory Information)

A1.APPARATUS

A1.1APPARATUS

A1.1.1The apparatus described in this annex is to be used without modification. It consists of a single cylinder engine and accessories mounted on a stationary base. It is equipped with controls for varying manifold pressure, fuel flow, and loading. Suitable instruments are provided for the measurement of these variables. The complete unit is known as the "ASTM-CFR Engine" and is marked by a plate or other approved means with a combination of the respective emblems of the American Society for Testing and Material and the Coordinating Fuel Research Committee, thus:

A1.1.2At present the sole authorized manufacturer of the ASTM-CFR engine is the Waukesha Engine, Dresser Inc., 1000 West Street, Paul Ave., Waukesha, WI 53188. Other manufacturers may be approved in the future, but testing laboratories should not purchase testing units, except from the Waukesha Engine, Dresser Inc., without ascertaining whether such units have been approved. Inquiries in this connection should be directed to Secretary, Committee D-2 on Petroleum Products and Lubricants, 2101 L Street, N.W., Washington, DC 20037.

A1.1.3All necessary instruments and accessories are furnished with the unit. A parts list for ASTM-CFR engines can be obtained from the Waukesha Engine Div.

A1.1.4Subsequent sections of this annex describe the specific units of the apparatus that are to be used. A summary of equipment for this test method appears in Table A1.1.

A1.2Cylinder Cooling System

A1.2.1The evaporative cooling system is equipped with a flexible coolant return pipe and a water-cooled reflux condenser above the coolant level to provide sufficient cooling capacity. Ethylene glycol is used as the coolant. A diagram of the cooling system is shown in Fig. A1.1.

A1.3Crankcase Ventilation

A1.3.1The CFR-48 crankcase is equipped with lip-type oil seals and a breather valve.

A1.3.2Crankcase ventilation is furnished by a breather valve at A, Fig. A1.2, on the left crankcase door. The breather valve assembly uses a hollow cup made of plastic which is installed open end downwards so that its lift is limited by the screw on the cap. The outlet is fitted for a ¾-in. pipe to conduct the crankcase vapors out of the laboratory and must not be connected to the engine exhaust. A condensation trap should be provided to prevent moisture from running back into the crankcase.

A1.4Engine Specifications

A1.4.1A single cylinder engine of continuously variable compression ratio is specified. Descriptive dimensions are listed in Table A1.2.

A1.5Cylinder

A1.5.1The cylinder is made in one piece integral with the cast-iron head, bored and honed, and has a Brinell hardness of 196 to 269. Cylinders of standard bore are preferred equipment, but rebored cylinders up to a maximum of 0.030 in. oversize may be used. *A micrometer* , suitably mounted, is used to measure the height of the cylinder with respect to the piston.

A1.6Piston and Rings

A1.6.1*Piston*—The five-ring, aluminum-alloy piston has a full floating hollow piston pin held in position by piston-pin retainers. Piston clearances are:

Top land	0.022 ± 0.002 in.
Intermediate lands	0.017 ± 0.002 in.
Skirt	0.011 ± 0.0005 in.

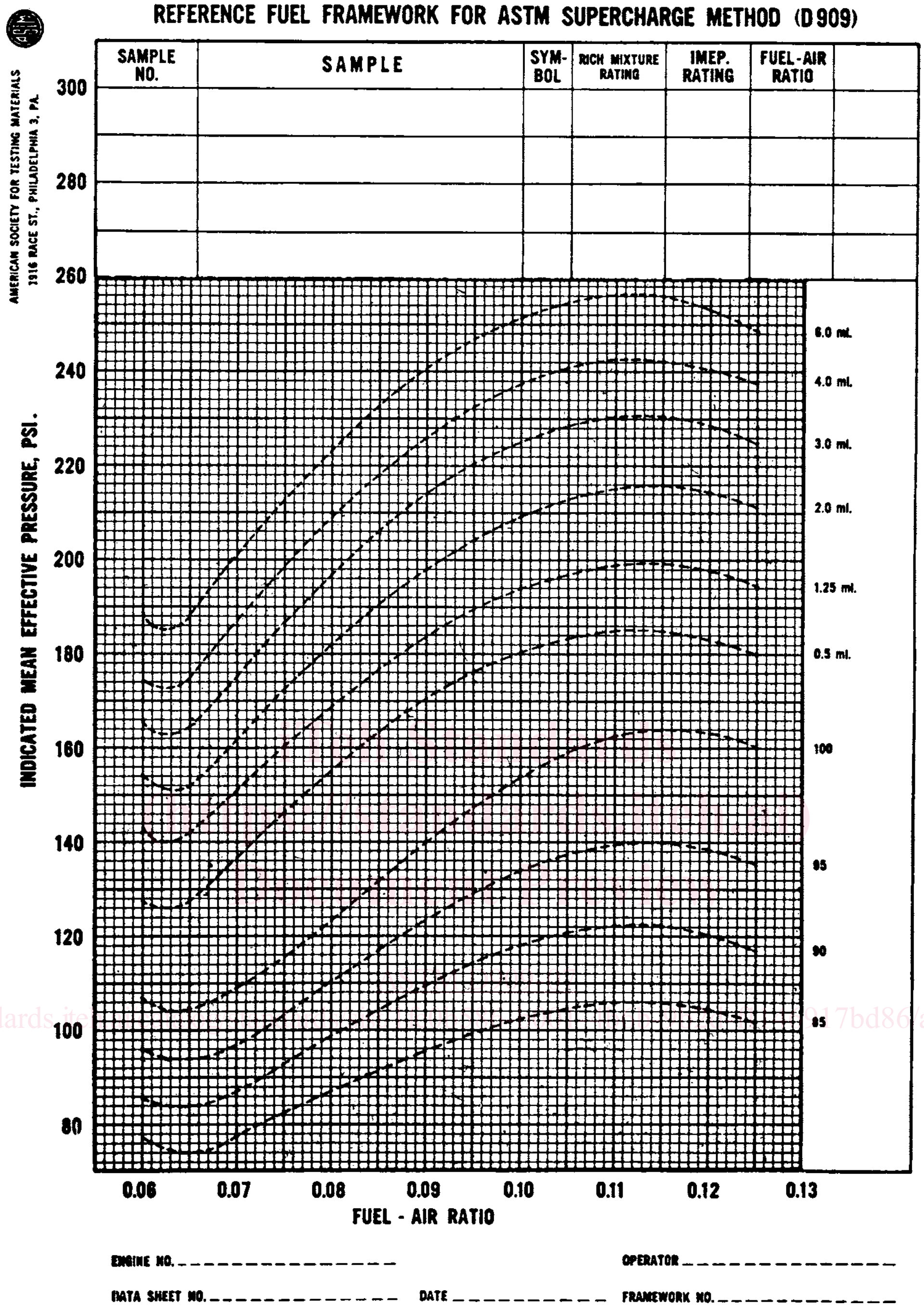

FIG. A2.2 Reference Fuel Framework

~~A1.6.2*Rings*—Three wedge type compression rings and two wedge type oil control rings are required. The set consists of a chromium-plated top compression ring, two plain compression rings, and two narrow-faced oil control rings. When new, ring-gap clearances are 0.015 to 0.020 in. for the compression rings, and 0.010 to 0.018 in. for the oil rings.~~

~~A1.7Valves and Valve Seats~~

~~A1.7.1The intake valve (3⁄8-in. stem) is Stellite faced. The sodium-cooled exhaust valve (7⁄16-in. stem) is Eatonite faced. Both valve-seat inserts are made of solid Stellite.~~

~~A1.7.2The standard face angle for values and inserts is 45°.~~

~~A1.8Valve Guides, Springs, and Push Rods~~

~~A1.8.1*Valve Guides*— The cast-iron alloy valve guides are heat treated and hardened. They are pressed into the cylinder with the shoulder on the guide not quite touching the cylinder to prevent distortion.~~