Engine Test Code – Spark Ignition and Diesel – SAE J816b

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ENGINE TEST CODE—
SPARK IGNITION AND DIESEL—SAE J816b

SAE Standard

Report of Engine Committee approved April 1962 and last revised July 1971. Editorial change March 1973.

[This new standard test code has been adopted by SAE to supersede the former SAE Engine Test Code—Nonturbocharged Spark Ignition and Diesel. The new standard has evolved from that code and from the following former SAE documents: SAE Gasoline Engine Test Code adopted in 1917, SAE Diesel Engine Test Code adopted in 1931, and the 1963 publication designated as SAE J606 which referenced these two codes as one publication.]

The purpose of this code is to provide a standard procedure covering laboratory dynamometer test methods for determining performance characteristics of diesel and spark ignition engines. It is applicable to four-stroke and two-stroke cycle diesel engines, naturally aspirated, mechanically supercharged or turbocharged, with or without charge air cooling. It is also applicable to all types of spark ignition engines except turbocharged spark ignition engines on which definitive power correction data are lacking. It is not intended as a laboratory manual or a method for establishing rated power or for derating engines for altitude.

This code is composed of the following Sections:

1. Definitions of Terminology
2. Test Equipment Requirements
3. Test Procedures
4. Computations
5. Presentation of Results

1. Definitions of Terminology

1.1 Power Output—Engine power output shall be[1] expressed in units of "horsepower," equivalent to 550 ft-lb/s or "kilowatts" equivalent to 1000 J/s.

1.1.1 OBSERVED POWER is the power actually developed by an engine under the atmospheric conditions existing during the test.

1.1.2 CORRECTED POWER is the observed power adjusted to standard atmospheric conditions, using the correction methods specified in paragraph 4.

1.2 Gross and Net Power

1.2.1 GROSS POWER is the power output of a "basic" engine as defined in paragraph 1.6.

1.2.2 NET POWER is the power output of a "fully equipped" engine as defined in paragraph 1.6.

1.3 Brake Power—Brake power is the power available at the output member(s) for doing useful work.

1.3.1 MAXIMUM BRAKE POWER[2] is the highest power developed at a given speed.

1.3.2 PEAK BRAKE POWER[2] is the highest power developed within the engine speed range.

1.3.3 PEAK POWER ENGINE SPEED is the speed at which peak power occurs. If peak power speed cannot be read easily due to flatness of the power curve, it may be approximated as the average of the two engine speeds at which power is 98% of its highest value.

1.3.4 INTERMITTENT BRAKE POWER is the highest power recommended by the manufacturer for satisfactory operation within the manufacturer's specified conditions of load, speed, and duty cycle.

1.3.5 CONTINUOUS BRAKE POWER is the power recommended by the manufacturer for satisfactory operation under the manufacturer's specified continuous duty conditions.

1.3.6 RATED BRAKE POWER is the power specified by the manufacturer for a given application at a given (rated) speed. (See paragraph 5.)

1.4 Friction Power—Friction power is the power required to drive the engine as equipped during the power test. Friction may be approximated by one of the following methods with sufficient accuracy for the purposes of this code:

(a) Hot motoring method (preferred method, see paragraph 3.6.1.2).

(b) Calculated friction using mechanical efficiency equations or tables. (See paragraphs 4.5.2.2 and 4.5.3.2.)

1.5 Indicated Power—Indicated power is the power developed in the cylinders. For the purpose of this case, it is defined as the sum of the brake power and the friction power.

[1] Any specified condition or action preceded by "shall be" is a requirement of this code; if preceded by "should be," it is recommended but not required.

[2] Maximum and peak brake power are outside the usual operating range of commercial diesel engines.

1.6 Engine

1.6.1 BASIC ENGINE is an engine equipped only with the built-in accessories essential to its operation: fuel pump, oil pump, coolant pump, and built-in emission control equipment. A generator or alternator is to be included only if some accessories (such as a fuel pump) are electrically driven.

1.6.2 FULLY EQUIPPED ENGINE is an engine equipped with all the accessories necessary to perform its intended functions unaided. This includes, but is not restricted to, the basic engine of paragraph 1.6.1 plus intake air system, exhaust system, cooling system, generator or alternator, starter, and emission control equipment.

2. Test Equipment Requirements—The required limits of accuracy concern the instrument precision specified by the manufacturer of the instruments used and do not include human or other probable errors involved in the reading.

2.1 Torque

2.1.1 Dynamometer and scale capacity shall be compatible with engine size. Dynamometer shall be capable of maintaining load and speed conditions as defined in paragraph 3.

2.1.2 Dynamometer coupling drive between engine and dynamometer shall be suitable for operation through the test engine speed range with minimum power loss or out-of-balance.

2.1.3 DYNAMOMETER BALANCE, CALIBRATION, AND SENSITIVITY

2.1.3.1 Scales shall be checked for zero scale reading with the dynamometer frame in the neutral position.

2.1.3.2 Calibration of the dynamometer with the engine running at some fixed beam lead, for example, 100 lb (445 N), may be checked by the addition of a 100 lb (445 N) weight to the opposite side, which should bring the scale back to zero. This shall be done for several different loads within the range of expected operation and shall be repeated under static conditions. The result thus obtained shall be accurate within ±½% of the observed full load reading.

2.1.3.3 Sensitivity of the dynamometer and scales shall be checked by adding small increments of weight until the pointer moves a readable amount. The magnitude of this weight, which is the sensitivity, shall not exceed ¼% of the observed full load reading. Several points shall be checked within the operating range.

2.2 Speed

2.2.1 Revolution counter shall be accurate within ±¼% of the observed reading or ±10 revolutions, whichever is less.

2.2.2 Tachometer shall be accurate within ±½% of the observed value if the reading is used for computations.

2.3 Time—The time measuring instruments shall be accurate within ±¼% of the observed reading.

2.4 Fuel System

2.4.1 The engine fuel system used in the test shall be in accordance with the manufacturer's specifications.

2.4.2 Fuel consumption measurement (mass or volume) instrumentation shall be accurate within ±1% of the observed reading.

2.5 Temperatures

2.5.1 Temperatures shall be measured in degrees Fahrenheit using English units or degrees Celsius using metric units.

2.5.2 Accuracy of instrumentation for measuring temperatures of 400°F (204°C) or less should be ±2°F (±1°C), and at temperatures above 400°F (204°C) should be ±10°F (±5°C).

2.5.3 The necessary temperature measurements and corresponding locations are as follows:

2.5.3.1 Temperature of the inlet air to the engine (ambient air) shall be measured in a manner to get a mass average temperature. The temperature shall be taken in the engine inlet air stream or within 6 in. (152 mm) of the air inlet horn or air cleaner. Care should be taken to shield the thermometer or thermocouple from radiant heat sources, and a sufficient number of locations shall be checked to assure a representative average inlet temperature.

2.5.3.2 *Coolant Temperatures*—Temperatures in liquid-cooled engines shall be measured at the inlet and outlet of the engine. Temperatures in air-cooled engines should be measured at point(s) specified by the manufacturer, such as spark plug(s) and cylinder head fin(s).

2.5.3.3 Oil temperatures shall be measured in the oil gallery.

2.5.3.4 Fuel temperature shall be measured at the outlet of the volumetric fuel measuring device if used. Fuel supply temperature should be measured at the outlet of the primary filter for fuel injected engines and at the carburetor for carbureted engines.

2.6 Pressures

2.6.1 Pressures shall be measured in pounds per square inch, inches of mercury, or inches of water (pascals), either above or below atmospheric pressure.

2.6.2 The necessary pressure measurements, the required instrument accuracies, and corresponding locations are as follows:

2.6.2.1 Air cleaner and piping restriction ±0.1 in. water (±25 Pa).

2.6.2.2 Exhaust pressure measured within 6 in. (152 mm) downstream of the outlet of the engine exhaust system specified for the test ±0.1 in. Hg or ±338 Pa. (See paragraphs 3.6.1.1 and 3.6.2.1.)

2.7 Atmospheric Conditions

2.7.1 All measurements shall be made in a location representative of the engine's test environment.

2.7.2 Barometric pressure: aneroid or mercury barometer corrected for temperature (accuracy ±0.02 in. Hg or ±68 Pa).

2.7.3 Wet and dry bulb temperatures shall be measured with a sling-psychrometer or equivalent. The thermometers used shall be accurate within ±0.5°F or ±0.3°C.

2.8 Exhaust Smoke—Diesel Engines—SAE J255 should be used to guide smoke testing. The U. S. Public Health Service smoke measuring instrumentation and procedures are currently generally accepted and should be followed for engine smoke evaluation, especially when engine transients are to be considered.[3]

Since these procedures will be updated and added to over a period of time, the current SAE Handbook should be consulted for proper diesel engine exhaust smoke testing when tests are to be run.

2.9 Engine Emissions—SAE Recommended Practices and Information Reports on measurement of engine emissions are available to guide these tests. A current list is as follows:

SAE J170, Measurement of Fuel Evaporative Emissions from Gasoline Powered Passenger Cars and Light Trucks.

SAE J171, Measurement of Fuel Evaporative Emissions from Gasoline Powered Passenger Cars and Light Trucks Using the Enclosure Technique.

SAE J177, Measurement of Carbon Dioxide, Carbon Monoxide, and Oxides of Nitrogen in Diesel Exhaust.

SAE J215, Continuous Hydrocarbon Analysis of Diesel Exhaust.

SAE J244, Measurement of Intake or Exhaust Flow in Diesel Engines.

SAE J900, Crankcase Emission Control Test Code.

SAE J989, Carbon Monoxide Concentration Test Procedure.

Since these procedures will be updated and added to over a period of time, the current SAE Handbook should be consulted for proper engine emissions testing when tests are to be run.

3. Test Procedures—This section contains the required test procedures for determining the following engine performance characteristics: gross power, net power, and part throttle fuel consumption.

3.1 Description of Tests

3.1.1 Gross brake power test consists of a run at full throttle to determine power output versus speed of the basic engine as defined in paragraph 1.6.

3.1.2 Net brake power test consists of a run at full throttle to determine power output versus speed of the fully equipped engine as defined in paragraph 1.6.

3.1.3 Part throttle fuel consumption test consists of a series of runs at various speeds to determine the fuel consumption at specified percentages of the observed brake power at full throttle.

3.2 Engine Installation and Adjustments—The test engine shall be a representative unit within the manufacturer's specifications. All auxiliary equipment used on the test engine such as fan, air cleaner, muffler, and pumps shall be listed and described.

Spark ignition carbureted engines should be mounted on the dynamometer stand at the installation angle specified for their application. If engine exhaust is connected to a laboratory exhaust system, that system shall not cause a back pressure exceeding the value specified by the manufacturer or a vacuum of more than 3 in. (76 mm) of water. If the engine air inlet is connected to a laboratory air system, the system should neither supply air to the engine above atmospheric pressure nor at a vacuum exceeding that specified by the manufacturer.

The generator (alternator) shall be disconnected if an external power source is used for ignition and/or starting unless certain accessories such as the fuel pump or coolant fan are electrically driven, in which case the generator or alternator shall operate at a load sufficient to power them. On spark ignition engines, the intake manifold heat control shall be secured in the "off" position for the full throttle tests.

Adjustments shall be made before the test in accordance with the manufacturer's instructions. No changes or adjustments shall be made during the test except as indicated in the test procedure.

3.3 Run-In—The engine shall be run-in according to the manufacturer's recommendations. If no such recommendation is available, the engine shall be run-in until power and fuel consumption are repeatable within 1% over a 4 h period.

3.4 Fuels and Lubricants

3.4.1 Fuel used shall conform to the manufacturer's specifications:

3.4.1.1 *Spark Ignition Engines*

(a) Record Research and Motor octane number and API gravity of liquid fuel.

(b) Record lower heat value (LHV) in Btu/ft^3 (kJ/m^3) at 60°F (16°C) and 29.92 in. Hg (101 kPa), and composition of gaseous fuels.

3.4.1.2 *Diesel Engines*—Record ASTM or other fuel specification and Cetane No., API gravity, kinematic viscosity in centistokes (m^2/s) at 100°F (37.8°C), and distillation in °F (°C) at 10%, 50%, 90%, and end point.[4]

3.4.2 Lubricating oil used shall conform with the manufacturer's recommendations. Record oil performance level and SAE viscosity number of the lubricant.

3.5 Test Conditions—Performance data shall be obtained under stabilized normal operating conditions, with an adequate fresh air supply to the engine. Combustion chambers of spark ignition engines shall be free of deposits. Test conditions, such as inlet air temperature, should be selected as near to standard as possible (paragraph 4.3) in order to minimize the magnitude of the correction factor.

3.5.1 No data shall be taken until torque, speed, and temperatures have been maintained within 1% for at least 2 min.

3.5.2 Engine speed should be held as nearly constant as possible during a run or reading and shall not deviate from the nominal speed by more than ±1% or ±10 rpm, whichever is greater.

3.5.3 Observed brake load and fuel consumption data shall be taken simultaneously and shall be the average of two stabilized sustained values which do not vary more than 1%. A measuring interval of not less than 30 s shall be used when measuring speed and fuel consumption with an automatically synchronized counter timer combination; for hand operation, the time interval shall be not less than 120 s.

3.5.4 Coolant outlet temperature in liquid-cooled engines shall be controlled at 190 ± 10°F (88 ± 5°C) unless otherwise specified by the manufacturer.

3.5.5 Fuel temperature at the inlet of the diesel engine fuel pump shall be controlled to 100 ± 10°F (37.8 ± 5°C).

3.6 Procedures

3.6.1 Gross Power Test

3.6.1.1 *Engine Equipment and Settings*—A basic engine is used for this test (see paragraph 1.6).

Air cleaner—shall be on a used system with equivalent restriction
Air preheat—optional
Radiator—off } Liquid-cooled
Fan—off }
Fan or blower on, with air control mechanism operating normally—Air-cooled
Muffler, exhaust pipe and tail pipe—off
Heat valve—warmed up positions
Timing—normal
Spark advance—normal
Fuel pump setting—normal
Carburetor setting—normal
Emission controls integral with engine—normal

3.6.1.2 *Procedure*—Record data for at least five approximately evenly spaced operating speeds to define completely the power curve between 600 rpm (or the lowest stable speed) and the maximum engine speed recommended by the manufacturer.

On spark ignition engines and on diesel engines where motoring friction is to be used, the measurement shall be taken with coolant inlet and oil gallery temperatures within 5°F (3°C) of those observed during the power test.

3.6.1.3 *Data to be Recorded for Test Documentation*—See paragraph 5.

Speed
Torque or beam load (power, friction if measured)

[3] If the U. S. Public Health Service Smokemeter is used, the Federal Register, Vol. 33, No. 108 dated June 4, 1968, Part II, shall guide its use. Paragraphs 85.124, 85.125, and 85.126 are applicable.

[4] Kinematic viscosity at standard temperatures other than 37.8°C, such as 20 or 50°C, may be used.

Ambient air temperature, pressure, humidity
Fuel consumption
Laboratory exhaust system pressure
Fuel supply temperature
Inlet air pressure (if connected to laboratory system)
Oil and coolant temperature

The following data should also be recorded where applicable and for safety of operation:

Oil pressure
Intake manifold temperature
Exhaust temperature
Exhaust back pressure (see paragraph 2.6.2.2)
Air cleaner and piping restriction
Ignition or injection timing
Fuel supply pressure

3.6.2 Net Power Test

3.6.2.1 *Engine Equipment and Settings*—A fully equipped engine is used for this test (see paragraph 1.6.2).

Air preheat—if applicable—on
Air cleaner—on
Radiator—on[5] } Liquid-cooled
Fan—on where applicable }
Fan or blower on, air control mechanism operating normally—Air-cooled
Muffler, exhaust pipe, and tail pipe—on, or system providing equivalent restriction
Heat valve—normal
Timing—normal
Spark advance—normal
Fuel pump setting—normal
Carburetor—normal
Emission control equipment—normal

3.6.2.2 *Procedure*—Same as Gross Power Test.

3.6.2.3 *Data to be Recorded for Test Documentation*—Same as Gross Power Test, except air cleaner and piping restriction and exhaust back pressure are required data. (See paragraph 5.)

3.6.3 Part Throttle Fuel Consumption Test

3.6.3.1 *Engine Equipment and Settings*—Same as Gross or Net Power Test, whichever is applicable.

3.6.3.2 *Procedure*—Complete data shall be recorded for at least five approximately evenly spaced engine speeds to define the fuel consumption characteristics of the engine over its intended operating range.

Data shall be recorded at load settings in accordance with the manufacturer's recommendation. If no such recommendation is available, the test should be run at no load, 20, 40, 60, 80, and 100% of maximum load at each speed.

3.6.3.3 *Data to be Recorded for Test Documentation*—Same as Gross or Net Power Test. (See Fig. 2.)

[5]When the radiator is not an integral part of the engine assembly, an equivalent heat exchanger may be used.

4. Computations

4.1 Definition of Symbols

Symbol	Definition	Units	
		English	SI
A	Correction for absolute temperature	460°F	273°C
B	Barometric pressure	in Hg	Pa
C	Correction factor		
D	Engine displacement	in^3	cm^3
E	Correction for units of work	396,000	600,000
F	Fuel consumption (liquid)	lb/h	g/h
	Fuel consumption (gaseous)	ft^3/min	m^3/min
G	Power constant	5252	955
K	Dynamometer constant	G/R	G/R
L	Dynamometer scale reading	lb	daN
M	Time of fuel measurement	min	min
N	Engine speed	rpm	rpm
R	Dynamometer torque arm	ft	m
T	Torque	lb-ft	daN·m
V	Volume of fuel measured (liquid)[6]	cm^3	cm^3
	Volume of fuel measured (gaseous)	ft^3	m^3
W	Mass of fuel	lb	g
LHV	Lower heating value of gaseous fuels at 60 F (16 C) and 29.92 in Hg (760 mm Hg)	Btu/ft^3	kJ/m^3
a	Engine revolutions per cycle		
d	Air density	lb/ft^3	kg/m^3
e	Water vapor pressure in atmosphere	in Hg	Pa
n	Mechanical efficiency	%	%
t	Ambient temperature	°F	°C
x	Coefficient in mechanical efficiency equation		
y	Coefficient in mechanical efficiency equation		
z	Coefficient in mechanical efficiency equation		
(sp. gr.)	Specific gravity of fuel at tank or burette temperature		
bp	Brake power	hp	kW
fp	Friction power	hp	kW
ip	Indicated power	hp	kW
fan p	Fan power	hp	kW
bmep	Brake mean effective pressure	lb/in^2	kPa
imep	Indicated mean effective pressure	lb/in^2	kPa
bsfc	Brake specific fuel consumption (liquid)	lb/hp-h	g/kW-h
	Brake specific fuel consumption (gaseous)	Btu/hp-h	kJ/kW-h
isfc	Indicated specific fuel consumption (liquid)	lb/hp-h	g/kW-h
	Indicated specific fuel consumption (gaseous)	Btu/hp-h	kJ/kW-h
Subscripts			
c	Corrected to standard conditions		
D	Diesel engine		
d	Dry air condition		
m	Moist air condition		
r	Manufacturer's rated value		
S	Spark ignition engine		
t	Observed at test conditions		
Superscript *	To denote standard ambient conditions		

4.2 Useful Equivalents

1 kg = 2.2046 lb mass
1 daN = 2.248 lb force
1 kPa = 0.1450 lb/in.^{2}
1 hp = 33,000 ft-lb/min
1 kW = 1000 N · m/s
1 kW = 1.341 hp

4.3 Standard Ambient Conditions

Barometric pressure	B*	29.38 in. Hg (99 kPa)
Temperature	t*	85°F (29.4°C)
Vapor pressure	e*	0.38 in. Hg (1.3 kPa)
Dry barometric pressure	B_d*	29.00 in. Hg (97.9 kPa)
Dry air density	d_d*	0.0705 lb/ft^3 (1.124 kg/m^3)

4.4 Computations from Test Data

4.4.1 Observed Power

$$\text{Brake power, } bp_t = \frac{(N \cdot L)_t}{K}$$

$$\text{Brake torque, } T_t = (L \cdot R)_t$$

$$\text{Brake mean effective pressure, } bmep_t = \frac{E \cdot L_t \cdot R_t \cdot a}{G \cdot D} = \frac{E \cdot a}{D \cdot N_t}\, bp_t$$

$$\text{Friction power, } fp_t = \frac{(N \cdot L)_t}{K}$$

$$fp_t = bp_t\left(\frac{100}{n} - 1\right)$$

$$\text{Indicated power, } ip_t = bp_t + fp_t$$

$$ip_t = bp_t\left(\frac{100}{n}\right)$$

4.4.2 MECHANICAL EFFICIENCY (FRICTION POWER)—Engine friction for purposes of this code may be established by the methods noted in paragraph 1.4, with the hot motoring method preferred. If friction must be approximated by calculation the method for spark ignition engines is covered in paragraph 4.5.2.2 and for diesel engines in paragraph 4.5.3.2.

4.4.3 FUEL CONSUMPTION

4.4.3.1 *Fuel Consumption (Liquid)*

$$\text{Fuel consumption, } F_t = W_t \cdot \frac{60}{M}$$

$$\text{Brake specific fuel consumption, } bsfc_t = \frac{W_t \cdot 60}{bp_t \cdot M} = \frac{F_t}{bp_t}$$

$$\text{Indicated specific fuel consumption, } isfc_t = \frac{F_t}{bp_t + fp_t} = \frac{F_t}{bp_t \cdot \left(\frac{100}{n}\right)}$$

Fuel mass from volumetric method

$$W_t = V \cdot \frac{(\text{sp. gr.})}{453.6} \quad \text{(English units)}^6$$

$$W_t = V \cdot (\text{sp. gr.}) \quad \text{(SI units)}$$

4.4.3.2 *Fuel Consumption (Gaseous)*

$$\text{Fuel consumption, } F_t = \frac{V_t \cdot 60}{M}$$

$$\text{Brake specific fuel consumption, } bsfc_t = \frac{F_t \cdot LHV}{bp_t}$$

$$\text{Indicated specific fuel consumption, } isfc_t = \frac{F_t \cdot LHV}{bp_t + fp_t} = \frac{F_t \cdot LHV}{bp_t \cdot \left(\frac{100}{n}\right)}$$

4.4.4 BAROMETRIC PRESSURE

$$\text{Dry barometric pressure, } B_d = B - e$$

4.5 Corrected Power

4.5.1 CORRECTION FACTOR—The performance of diesel and spark ignition engines is affected by barometric pressure, temperature, and humidity of the ambient atmosphere. Therefore, in order to provide a common basis of comparison, it is necessary to apply a correction factor to convert the observed data to specified standard atmospheric conditions.

The method of correction prescribed is based upon the assumption that at constant air-fuel ratio, indicated thermal efficiency remains unaffected by changes in atmospheric pressure, temperature, and humidity, or that the effect is negligible. This assumption is valid only if the range of ambient conditions to be covered is sufficiently small so that engine combustion characteristics are not affected. This range cannot be accurately defined since it is a function of individual engine design. For this reason, it is recommended that only test data obtained within the range of dry barometric pressure between 28 and 30 in. Hg (95 and 101 kPa) and inlet air temperature between 60 and 110°F (15.5 and 43.3°C) be used for correction by this standard. If test data obtained outside this range are used as a basis for correction, the atmospheric conditions under which the test was performed shall be shown with the corrected results.

4.5.2 SPARK IGNITION ENGINES

4.5.2.1 *Correction Factor*

$$C_S = \frac{B_d^*}{B_{dt}} \cdot \left(\frac{t_t + A}{t^* + A}\right)^{0.5}$$

4.5.2.2 *Friction*—If the preferred hot motored friction is not used, Table 1 generally may be used to approximate spark ignition engine friction for use in this code. If it is not used, the following equations shall be used to calculate mechanical efficiency and friction power.

When $bmep_t$ is in lb/in.^{2}:

$$n = \frac{100}{1 + \frac{x - y \cdot bmep_t}{bmep_t}}$$

When $bmep_t$ is in kPa:

$$n = \frac{100}{1 + \frac{6.89x - y \cdot bmep_t}{bmep_t}}$$

In both equations:

$$x = 16.3761 + 2.28629\left(\frac{N}{1000}\right) + 0.297053\left(\frac{N}{1000}\right)^2$$

$$y = \frac{1}{100}\left[5.44659 - 0.02495\left(\frac{N}{1000}\right) - 0.174376\left(\frac{N}{1000}\right)^2\right]$$

4.5.2.3 *Correction Calculation*—In the case of the spark ignition engines, in which the air-fuel ratio characteristically remains constant, this type of correction is directly applicable under all conditions.

$$bp_c = (ip_t \cdot C_S) - fp_t$$
$$bp_c = (bp_t + fp_t) \cdot C_S - fp_t$$

$$\text{Corrected brake torque, } T_c = \frac{G}{N} \cdot bp_c$$

$$\text{Corrected brake mean effective pressure, } bmep_c = \frac{E \cdot a}{D \cdot N} \cdot bp_c$$

Fuel consumption—Because the exact manner in which atmospheric conditions affect fuel consumption is not known, a correction is not applied, and both fuel consumption and specific fuel consumption are reported as observed.

[6]Use of SI units for V is consistent with general practice.

TABLE 1—MECHANICAL EFFICIENCY OF SPARK IGNITION ENGINES, %

	bmep, kPa																				
	138	152	165	179	193	207	221	234	248	262	276	290	303	317	331	345	358	372	386	400	414
	bmep, lb/in²																				
rpm	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60
800	53.6	56.1	58.4	60.4	62.4	64.1	65.7	67.2	68.6	69.9	71.1	72.2	73.3	74.3	75.2	76.1	76.9	77.7	78.4	79.1	79.8
1000	52.8	55.3	57.6	59.6	61.6	63.3	64.9	66.4	67.8	69.1	70.3	71.5	72.5	73.5	74.5	75.4	76.2	77.0	77.8	78.5	79.1
1200	51.9	54.4	56.7	58.8	60.7	62.5	64.1	65.6	67.1	68.4	69.6	70.7	71.8	72.8	73.8	74.7	75.5	76.3	77.1	77.8	78.5
1400	51.1	53.6	55.9	58.0	59.9	61.7	63.3	64.8	66.3	67.6	68.8	70.0	71.0	72.1	73.0	73.9	74.8	75.6	76.4	77.1	77.8
1600	50.2	52.8	55.0	57.1	59.1	60.8	62.5	64.0	65.4	66.8	68.0	69.2	70.3	71.3	72.3	73.2	74.1	74.9	75.7	76.4	77.1
1800	49.4	51.9	54.2	56.3	58.2	60.0	61.6	63.2	64.6	66.0	67.2	68.4	69.5	70.5	71.5	72.4	73.3	74.1	74.9	75.7	76.4
2000	48.5	51.0	53.3	55.4	57.4	59.1	60.8	62.3	63.8	65.1	66.4	67.6	68.7	69.7	70.7	71.6	72.5	73.4	74.2	74.9	75.6
2200	47.7	50.2	52.5	54.6	56.5	58.3	59.9	61.5	62.9	64.3	65.5	66.7	67.9	68.9	69.9	70.9	71.7	72.6	73.4	74.2	74.9
2400	46.8	49.3	51.6	53.7	55.6	57.4	59.1	60.6	62.1	63.4	64.7	65.9	67.0	68.1	69.1	70.0	70.9	71.8	72.6	73.4	74.1
2600	46.0	48.5	50.7	52.8	54.7	56.5	58.2	59.8	61.2	62.6	63.8	65.1	66.2	67.3	68.3	69.2	70.1	71.0	71.8	72.6	73.3
2800	45.1	47.6	49.9	51.9	53.9	55.7	57.3	58.9	60.3	61.7	63.0	64.2	65.3	66.4	67.4	68.4	69.3	70.2	71.0	71.8	72.6
3000	44.3	46.7	49.0	51.1	53.0	54.8	56.4	58.0	59.5	60.8	62.1	63.3	64.5	65.6	66.6	67.6	68.5	69.4	70.2	71.0	71.7
3200	43.5	45.9	48.1	50.2	52.1	53.9	55.6	57.1	58.6	60.0	61.3	62.5	63.6	64.7	65.7	66.7	67.6	68.5	69.4	70.2	70.9
3400	42.6	45.0	47.3	49.3	51.2	53.0	54.7	56.2	57.7	59.1	60.4	61.6	62.8	63.8	64.9	65.9	66.8	67.7	68.5	69.3	70.1
3600	41.8	44.2	46.4	48.5	50.4	52.1	53.8	55.4	56.8	58.2	59.5	60.7	61.9	63.0	64.0	65.0	66.0	66.8	67.7	68.5	69.3
3800	41.0	43.4	45.6	47.6	49.5	51.3	52.9	54.5	56.0	57.3	58.6	59.9	61.0	62.1	63.2	64.2	65.1	66.0	66.9	67.7	68.5
4000	40.2	42.5	44.7	46.8	48.6	50.4	52.1	53.6	55.1	56.5	57.8	59.0	60.2	61.3	62.3	63.3	64.2	65.1	66.0	66.8	67.6
4200	39.4	41.7	43.9	45.9	47.8	49.6	51.2	52.8	54.2	55.6	56.9	58.1	59.3	60.4	61.4	62.4	63.4	64.3	65.2	66.0	66.8
4400	38.6	40.9	43.1	45.1	47.0	48.7	50.3	51.9	53.3	54.7	56.0	57.2	58.4	59.5	60.6	61.6	62.5	63.4	64.3	65.1	65.9
4600	37.8	40.1	42.3	44.3	46.1	47.9	49.5	51.0	52.5	53.9	55.2	56.4	57.5	58.7	59.7	60.7	61.7	62.6	63.4	64.3	65.1
4800	37.1	39.4	41.5	43.4	45.3	47.0	48.7	50.2	51.6	53.0	54.3	55.5	56.7	57.8	58.8	59.9	60.8	61.7	62.6	63.4	64.2
5000	36.3	38.6	40.7	42.6	44.5	46.2	47.8	49.3	50.8	52.1	53.4	54.7	55.8	56.9	58.0	59.0	60.0	60.9	61.7	62.6	63.4
5200	35.6	37.8	39.9	41.8	43.7	45.4	47.0	48.5	49.9	51.3	52.6	53.8	55.0	56.1	57.1	58.1	59.1	60.0	60.9	61.7	62.5
5400	34.9	37.1	39.1	41.1	42.9	44.6	46.2	47.7	49.1	50.5	51.8	53.0	54.1	55.2	56.3	57.3	58.3	59.2	60.0	60.9	61.7
5600	34.2	36.3	38.4	40.3	42.1	43.8	45.4	46.9	48.3	49.6	50.9	52.1	53.3	54.4	55.4	56.4	57.4	58.3	59.2	60.0	60.9
5800	33.5	35.6	37.6	39.5	41.3	43.0	44.6	46.1	47.5	48.8	50.1	51.3	52.5	53.6	54.6	55.6	56.6	57.5	58.4	59.2	60.0
6000	32.8	34.9	36.9	38.8	40.5	42.2	43.8	45.3	46.7	48.0	49.3	50.5	51.6	52.7	53.8	54.8	55.7	56.7	57.5	58.4	59.2

	bmep, kPa																				
	414	427	441	455	469	483	496	510	524	538	552	565	579	593	607	620	634	648	662	676	689
	bmep, lb/in²																				
rpm	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100
800	79.8	80.4	81.0	81.6	82.1	82.7	83.2	83.7	84.1	84.6	85.0	85.4	85.8	86.2	86.5	86.9	87.2	87.5	87.8	88.1	88.4
1000	79.1	79.8	80.4	81.0	81.5	82.1	82.6	83.1	83.5	84.0	84.4	84.8	85.2	85.6	86.0	86.3	86.7	87.0	87.3	87.6	87.9
1200	78.5	79.1	79.8	80.4	80.9	81.5	82.0	82.5	82.9	83.4	83.8	84.3	84.7	85.1	85.4	85.8	86.1	86.5	86.8	87.1	87.4
1400	77.8	78.5	79.1	79.7	80.3	80.8	81.3	81.9	82.3	82.8	83.2	83.7	84.1	84.5	84.9	85.2	85.6	85.9	86.3	86.6	86.9
1600	77.1	77.8	78.4	79.0	79.6	80.2	80.7	81.2	81.7	82.2	82.6	83.1	83.5	83.9	84.3	84.6	85.0	85.4	85.7	86.0	86.3
1800	76.4	77.1	77.7	78.3	78.9	79.5	80.0	80.5	81.0	81.5	82.0	82.4	82.8	83.3	83.7	84.0	84.4	84.8	85.1	85.4	85.8
2000	75.6	76.3	77.0	77.6	78.2	78.8	79.3	79.9	80.4	80.9	81.3	81.8	82.2	82.6	83.0	83.4	83.8	84.1	84.5	84.8	85.2
2200	74.9	75.6	76.3	76.9	77.5	78.1	78.6	79.2	79.7	80.2	80.6	81.1	81.5	82.0	82.4	82.8	83.1	83.5	83.9	84.2	84.5
2400	74.1	74.8	75.5	76.1	76.8	77.3	77.9	78.4	79.0	79.5	79.9	80.4	80.9	81.3	81.7	82.1	82.5	82.9	83.2	83.6	83.9
2600	73.3	74.1	74.7	75.4	76.0	76.6	77.2	77.7	78.2	78.7	79.2	79.7	80.2	80.6	81.0	81.4	81.8	82.2	82.5	82.9	83.2
2800	72.6	73.3	74.0	74.6	75.2	75.8	76.4	77.0	77.5	78.0	78.5	79.0	79.4	79.9	80.3	80.7	81.1	81.5	81.9	82.2	82.6
3000	71.7	72.5	73.2	73.8	74.5	75.1	75.7	76.2	76.8	77.3	77.8	78.3	78.7	79.2	79.6	80.0	80.4	80.8	81.2	81.5	81.9
3200	70.9	71.7	72.4	73.0	73.7	74.3	74.9	75.4	76.0	76.5	77.0	77.5	78.0	78.4	78.9	79.3	79.7	80.1	80.5	80.8	81.2
3400	70.1	70.8	71.6	72.2	72.9	73.5	74.1	74.7	75.2	75.7	76.3	76.8	77.2	77.7	78.1	78.6	79.0	79.4	79.8	80.1	80.5
3600	69.3	70.0	70.7	71.4	72.1	72.7	73.3	73.9	74.4	75.0	75.5	76.0	76.5	76.9	77.4	77.8	78.2	78.6	79.0	79.4	79.8
3800	68.5	69.2	69.9	70.6	71.3	71.9	72.5	73.1	73.6	74.2	74.7	75.2	75.7	76.2	76.6	77.1	77.5	77.9	78.3	78.7	79.0
4000	67.6	68.4	69.1	69.8	70.4	71.1	71.7	72.3	72.8	73.4	73.9	74.4	74.9	75.4	75.8	76.3	76.7	77.1	77.5	77.9	78.3
4200	66.8	67.5	68.3	68.9	69.6	70.3	70.9	71.5	72.0	72.6	73.1	73.6	74.1	74.6	75.1	75.5	75.9	76.4	76.8	77.2	77.5
4400	65.9	66.7	67.4	68.1	68.8	69.4	70.1	70.7	71.2	71.8	72.3	72.8	73.3	73.8	74.3	74.7	75.2	75.6	76.0	76.4	76.8
4600	65.1	65.8	66.6	67.3	68.0	68.6	69.2	69.8	70.4	71.0	71.5	72.0	72.5	73.0	73.5	74.0	74.4	74.8	75.2	75.6	76.0
4800	64.2	65.0	65.7	66.4	67.1	67.8	68.4	69.0	69.6	70.2	70.7	71.2	71.7	72.2	72.7	73.2	73.6	74.0	74.5	74.9	75.3
5000	63.4	64.2	64.9	65.6	66.3	66.9	67.6	68.2	68.8	69.3	69.9	70.4	70.9	71.4	71.9	72.4	72.8	73.2	73.7	74.1	74.5
5200	62.5	63.3	64.1	64.8	65.5	66.1	66.8	67.4	68.0	68.5	69.1	69.6	70.1	70.6	71.1	71.6	72.0	72.5	72.9	73.3	73.7
5400	61.7	62.5	63.2	63.9	64.6	65.3	65.9	66.5	67.1	67.7	68.3	68.8	69.3	69.8	70.3	70.8	71.2	71.7	72.1	72.5	72.9
5600	60.9	61.6	62.4	63.1	63.8	64.5	65.1	65.7	66.3	66.9	67.4	68.0	68.5	69.0	69.5	70.0	70.4	70.9	71.3	71.7	72.1
5800	60.0	60.8	61.5	62.3	63.0	63.6	64.3	64.9	65.5	66.1	66.6	67.2	67.7	68.2	68.7	69.2	69.6	70.1	70.5	70.9	71.3
6000	59.2	60.0	60.7	61.4	62.1	62.8	63.4	64.1	64.7	65.2	65.8	66.3	66.9	67.4	67.9	68.4	68.8	69.3	69.7	70.1	70.5

(Table continued on next page)

TABLE I—MECHANICAL EFFICIENCY OF SPARK IGNITION ENGINES, % (CONTINUED)

	bmep, kPa																				
	689	703	717	731	745	758	772	786	800	813	827	841	855	869	882	896	910	924	938	951	965
	bmep, lb/in²																				
rpm	100	102	104	106	108	110	112	114	116	118	120	122	124	126	128	130	132	134	136	138	140
800	88.4	88.7	89.0	89.3	89.5	89.8	90.0	90.2	90.5	90.7	90.9	91.1	91.3	91.5	91.7	91.9	92.1	92.2	92.4	92.6	92.7
1000	87.9	88.2	88.5	88.8	89.0	89.3	89.5	89.8	90.0	90.2	90.5	90.7	90.9	91.1	91.3	91.5	91.6	91.8	92.0	92.2	92.3
1200	87.4	87.7	88.0	88.3	88.5	88.8	89.1	89.3	89.5	89.8	90.0	90.2	90.4	90.6	90.8	91.0	91.2	91.4	91.6	91.7	91.9
1400	86.9	87.2	87.5	87.8	88.0	88.3	88.6	88.8	89.0	89.3	89.5	89.7	89.9	90.1	90.4	90.5	90.7	90.9	91.1	91.3	91.5
1600	86.3	86.6	86.9	87.2	87.5	87.8	88.0	88.3	88.5	88.8	89.0	89.2	89.4	89.7	89.9	90.1	90.3	90.5	90.6	90.8	91.0
1800	85.8	86.1	86.4	86.7	86.9	87.2	87.5	87.7	88.0	88.2	88.5	88.7	88.9	89.1	89.3	89.6	89.8	89.9	90.1	90.3	90.5
2000	85.2	85.5	85.8	86.1	86.4	86.6	86.9	87.2	87.4	87.7	87.9	88.1	88.4	88.6	88.8	89.0	89.2	89.4	89.6	89.8	90.0
2200	84.5	84.9	85.2	85.5	85.8	86.0	86.3	86.6	86.8	87.1	87.3	87.6	87.8	88.0	88.3	88.5	88.7	88.9	89.1	89.3	89.5
2400	83.9	84.2	84.5	84.8	85.1	85.4	85.7	86.0	86.3	86.5	86.8	87.0	87.2	87.5	87.7	87.9	88.1	88.3	88.5	88.7	88.9
2600	83.2	83.6	83.9	84.2	84.5	84.8	85.1	85.4	85.6	85.9	86.2	86.4	86.6	86.9	87.1	87.3	87.5	87.8	88.0	88.2	88.4
2800	82.6	82.9	83.2	83.6	83.9	84.2	84.5	84.7	85.0	85.3	85.5	85.8	86.0	86.3	86.5	86.7	86.9	87.2	87.4	87.6	87.8
3000	81.9	82.2	82.6	82.9	83.2	83.5	83.8	84.1	84.4	84.6	84.9	85.2	85.4	85.6	85.9	86.1	86.3	86.6	86.8	87.0	87.2
3200	81.2	81.5	81.9	82.2	82.5	82.8	83.1	83.4	83.7	84.0	84.2	84.5	84.8	85.0	85.2	85.5	85.7	85.9	86.2	86.4	86.6
3400	80.5	80.8	81.2	81.5	81.8	82.1	82.5	82.7	83.0	83.3	83.6	83.8	84.1	84.4	84.6	84.8	85.1	85.3	85.5	85.7	85.9
3600	79.8	80.1	80.5	80.8	81.1	81.5	81.8	82.1	82.3	82.6	82.9	83.2	83.4	83.7	83.9	84.2	84.4	84.6	84.9	85.1	85.3
3800	79.0	79.4	79.8	80.1	80.4	80.7	81.1	81.4	81.7	81.9	82.2	82.5	82.8	83.0	83.3	83.5	83.7	84.0	84.2	84.4	84.7
4000	78.3	78.7	79.0	79.4	79.7	80.0	80.3	80.6	80.9	81.2	81.5	81.8	82.1	82.3	82.6	82.8	83.1	83.3	83.5	83.8	84.0
4200	77.5	77.9	78.3	78.6	79.0	79.3	79.6	79.9	80.2	80.5	80.8	81.1	81.4	81.6	81.9	82.1	82.4	82.6	82.9	83.1	83.3
4400	76.8	77.2	77.5	77.9	78.2	78.6	78.9	79.2	79.5	79.8	80.1	80.4	80.6	80.9	81.2	81.4	81.7	81.9	82.2	82.4	82.6
4600	76.0	76.4	76.8	77.1	77.5	77.8	78.1	78.5	78.8	79.1	79.4	79.6	79.9	80.2	80.5	80.7	81.0	81.2	81.5	81.7	81.9
4800	75.3	75.6	76.0	76.4	76.7	77.1	77.4	77.7	78.0	78.3	78.6	78.9	79.2	79.5	79.7	80.0	80.3	80.5	80.8	81.0	81.2
5000	74.5	74.9	75.2	75.6	76.0	76.3	76.6	77.0	77.3	77.6	77.8	78.2	78.5	78.7	79.0	79.3	79.5	79.8	80.0	80.3	80.5
5200	73.7	74.1	74.5	74.8	75.2	75.5	75.9	76.2	76.5	76.8	77.1	77.4	77.7	78.0	78.3	78.5	78.8	79.1	79.3	79.6	79.8
5400	72.9	73.3	73.7	74.1	74.4	74.8	75.1	75.4	75.8	76.1	76.4	76.7	77.0	77.3	77.5	77.8	78.1	78.3	78.6	78.8	79.1
5600	72.1	72.5	72.9	73.3	73.6	74.0	74.3	74.7	75.0	75.3	75.6	75.9	76.2	76.5	76.8	77.1	77.3	77.6	77.8	78.1	78.3
5800	71.3	71.7	72.1	72.5	72.9	73.2	73.6	73.9	74.2	74.5	74.9	75.2	75.5	75.7	76.0	76.3	76.6	76.8	77.1	77.4	77.6
6000	70.5	70.9	71.3	71.7	72.1	72.4	72.8	73.1	73.5	73.8	74.1	74.4	74.7	75.0	75.3	75.6	75.8	76.1	76.4	76.6	76.9

4.5.3 Diesel Engines

4.5.3.1 *Correction Factor*

$$C_D = \frac{B_d^*}{B_{dt}} \cdot \left(\frac{t_t + A}{t^* + A}\right)^{0.7}$$

4.5.3.2 *Friction*—If the preferred hot motored friction is not used, Table 2 may be used to approximate diesel engine friction for use in this code. If it is not used, the following equations shall be used to calculate mechanical efficiency and friction power:

When $bmep_t$ is in lb/in.²:

$$n = \frac{100}{1 + \frac{z}{bmep_t}}$$

When $bmep_t$ is in kPa:

$$n = \frac{100}{1 + \frac{6.89z}{bmep_t}}$$

In both equations:

$$z = 20.1893 - 3.75948\left(\frac{N}{1000}\right) + 3.33129\left(\frac{N}{1000}\right)^2$$

4.5.3.3 *Correction Calculation*—Since the diesel engine operates at a set fuel rate, the correction factor defined in paragraph 4.5.3.1 shall be applied in conjunction with the following procedure.

At test atmospheric conditions, engine power and fuel rate shall be measured and recorded at three fuel rate settings at the same engine speed. One test point should be at the desired fuel setting. When the test air density is less than standard density, the other two points should be at approximately 5% and 10% lower fuel rates. When the test air density is greater than standard density, the other two points should be at approximately 5% and 10% higher fuel rates for best accuracy. When practical considerations, such as limited pump delivery, prevent use of the higher rates, points at lower fuel rates may be used, but some accuracy will be lost due to extrapolation rather than interpolation of data. Engine friction shall be recorded as friction power at the rated fuel setting for naturally aspirated engines and as mechanical efficiency at each fuel setting for turbocharged engines. Calculate $isfc_t$ at each test point (see paragraph 4.4.3) and plot versus fuel rate as shown in Fig. 1.

Find corrected indicated specific fuel consumption ($isfc_c$) on Fig. 1 at F′:

$$F' = \frac{F_r}{C_D}$$

Calculate corrected bp for naturally aspirated engines by

$$bp_c = \frac{F_r}{isfc_c} - fp_t$$

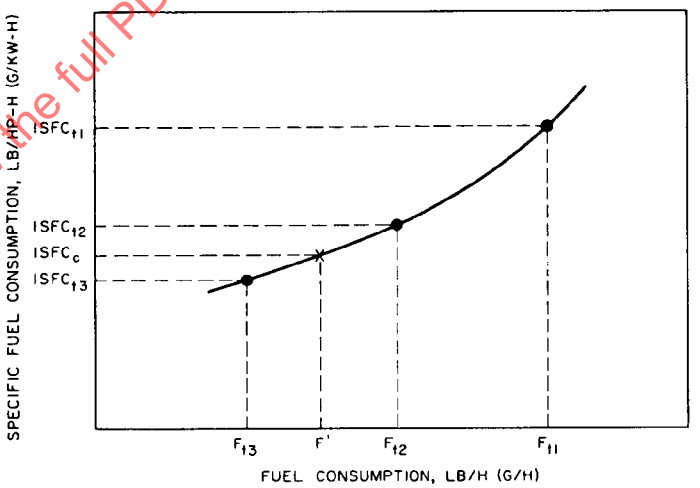

FIG. 1—METHOD OF ESTABLISHING FUEL CONSUMPTION FOR POWER CORRECTION FOR DIESEL ENGINES

or for turbocharged engines by

$$bp_c = \frac{F_r}{isfc_c} \cdot \left(\frac{n}{100}\right)$$

where mechanical efficiency (n) may be obtained from hot motored test data or the formula in paragraph 4.5.3.2.

Abbreviated correction procedures based upon this method will be considered acceptable if they result in corrected values identical to those obtained by this three-point procedure.

$$\text{Corrected brake torque, } T = \frac{G}{N} \cdot bp_c$$

$$\text{Corrected brake mean effective pressure, } bmep_c = \frac{E \cdot a}{D \cdot N} \cdot bp_c$$

Fuel consumption—Fuel consumption at standard conditions is, by definition, the same as at test conditions.

$$F_c = F_t$$

$$\text{Brake specific fuel consumption, } bsfc_c = \frac{F_c}{bp_c}$$

TABLE 2—MECHANICAL EFFICIENCY OF DIESEL ENGINES, %

	bmep, kPa																				
	276	290	303	317	331	345	358	372	386	400	414	427	441	455	469	483	496	510	524	538	552
	bmep, lb/in²																				
rpm	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80
800	67.4	68.5	69.5	70.4	71.3	72.1	72.9	73.7	74.4	75.0	75.6	76.2	76.8	77.4	77.9	78.4	78.8	79.3	79.7	80.2	80.6
900	67.2	68.3	69.3	70.2	71.1	71.9	72.7	73.5	74.2	74.8	75.5	76.1	76.6	77.2	77.7	78.2	78.7	79.1	79.6	80.0	80.4
1000	66.9	68.0	69.0	70.0	70.8	71.7	72.5	73.2	73.9	74.6	75.2	75.8	76.4	77.0	77.5	78.0	78.5	78.9	79.4	79.8	80.2
1100	66.6	67.6	68.7	69.6	70.5	71.3	72.1	72.9	73.6	74.3	74.9	75.5	76.1	76.7	77.2	77.7	78.2	78.7	79.1	79.5	79.9
1200	66.1	67.2	68.2	69.2	70.1	70.9	71.7	72.5	73.2	73.9	74.6	75.2	75.8	76.3	76.9	77.4	77.9	78.3	78.8	79.2	79.6
1300	65.6	66.7	67.8	68.7	69.6	70.5	71.3	72.1	72.8	73.5	74.1	74.8	75.4	75.9	76.5	77.0	77.5	78.0	78.4	78.8	79.3
1400	65.1	66.2	67.2	68.2	69.1	70.0	70.8	71.6	72.3	73.0	73.7	74.3	74.9	75.5	76.0	76.5	77.0	77.5	78.0	78.4	78.9
1500	64.5	65.6	66.6	67.6	68.5	69.4	70.2	71.0	71.8	72.5	73.1	73.8	74.4	75.0	75.5	76.0	76.6	77.0	77.5	78.0	78.4
1600	63.8	64.9	66.0	67.0	67.9	68.8	69.6	70.4	71.2	71.9	72.5	73.2	73.8	74.4	75.0	75.5	76.0	76.5	77.0	77.5	77.9
1700	63.1	64.2	65.3	66.3	67.2	68.1	68.9	69.7	70.5	71.2	71.9	72.6	73.2	73.8	74.4	74.9	75.5	76.0	76.4	76.9	77.4
1800	62.3	63.4	64.5	65.5	66.5	67.4	68.2	69.0	69.8	70.5	71.2	71.9	72.5	73.2	73.7	74.3	74.8	75.3	75.8	76.3	76.8
1900	61.5	62.6	63.7	64.7	65.7	66.6	67.5	68.3	69.1	69.8	70.5	71.2	71.9	72.5	73.1	73.6	74.2	74.7	75.2	75.7	76.1
2000	60.6	61.8	62.9	63.9	64.9	65.8	66.7	67.5	68.3	69.1	69.8	70.5	71.1	71.7	72.3	72.9	73.5	74.0	74.5	75.0	75.5
2100	59.7	60.9	62.0	63.0	64.0	64.9	65.8	66.7	67.5	68.2	69.0	69.7	70.3	71.0	71.6	72.2	72.7	73.3	73.8	74.3	74.8
2200	58.8	60.0	61.1	62.1	63.1	64.1	65.0	65.8	66.6	67.4	68.1	68.9	69.5	70.2	70.8	71.4	72.0	72.5	73.0	73.6	74.0
2300	57.8	59.0	60.1	61.2	62.2	63.2	64.1	64.9	65.8	66.5	67.3	68.0	68.7	69.4	70.0	70.6	71.2	71.7	72.3	72.8	73.3
2400	56.9	58.0	59.2	60.2	61.3	62.2	63.1	64.0	64.8	65.6	66.4	67.1	67.8	68.5	69.1	69.8	70.3	70.9	71.5	72.0	72.5
2500	55.9	57.1	58.2	59.3	60.3	61.3	62.2	63.1	63.9	64.7	65.5	66.2	66.9	67.6	68.3	68.9	69.5	70.1	70.6	71.2	71.7
2600	54.8	56.0	57.2	58.3	59.3	60.3	61.2	62.1	63.0	63.8	64.6	65.3	66.0	66.7	67.4	68.0	68.6	69.2	69.8	70.3	70.8
2700	53.8	55.0	56.2	57.3	58.3	59.3	60.2	61.1	62.0	62.8	63.6	64.4	65.1	65.8	66.5	67.1	67.7	68.3	68.9	69.4	70.0
2800	52.8	54.0	55.2	56.2	57.3	58.3	59.2	60.1	61.0	61.8	62.6	63.4	64.1	64.8	65.5	66.2	66.8	67.4	68.0	68.6	69.1
2900	51.7	53.0	54.1	55.2	56.3	57.3	58.2	59.1	60.0	60.9	61.7	62.4	63.2	63.9	64.6	65.2	65.9	66.5	67.1	67.6	68.2
3000	50.7	51.9	53.1	54.2	55.2	56.2	57.2	58.1	59.0	59.9	60.7	61.5	62.2	62.9	63.6	64.3	64.9	65.5	66.1	66.7	67.3
3100	49.7	50.9	52.0	53.1	54.2	55.2	56.2	57.1	58.0	58.9	59.7	60.5	61.2	61.9	62.6	63.3	64.0	64.6	65.2	65.8	66.4
3200	48.6	49.8	51.0	52.1	53.2	54.2	55.2	56.1	57.0	57.8	58.7	59.5	60.2	61.0	61.7	62.3	63.0	63.6	64.3	64.9	65.4
3300	47.6	48.8	50.0	51.1	52.1	53.2	54.1	55.1	56.0	56.8	57.7	58.5	59.2	60.0	60.7	61.4	62.0	62.7	63.3	63.9	64.5
3400	46.6	47.8	48.9	50.0	51.1	52.1	53.1	54.0	54.9	55.8	56.6	57.5	58.2	59.0	59.7	60.4	61.1	61.7	62.3	62.9	63.5
3500	45.5	46.8	47.9	49.0	50.1	51.1	52.1	53.0	53.9	54.8	55.6	56.4	57.2	58.0	58.7	59.4	60.1	60.7	61.4	62.0	62.6
3600	44.5	45.7	46.9	48.0	49.1	50.1	51.1	52.0	52.9	53.8	54.6	55.4	56.2	57.0	57.7	58.4	59.1	59.8	60.4	61.0	61.6
3700	43.5	44.7	45.9	47.0	48.1	49.1	50.1	51.0	51.9	52.8	53.6	54.4	55.2	56.0	56.7	57.4	58.1	58.8	59.4	60.1	60.7
3800	42.5	43.7	44.9	46.0	47.1	48.1	49.1	50.0	50.9	51.8	52.6	53.4	54.2	55.0	55.7	56.4	57.1	57.8	58.5	59.1	59.7
3900	41.6	42.8	43.9	45.0	46.1	47.1	48.1	49.0	49.9	50.8	51.6	52.5	53.2	54.0	54.8	55.5	56.2	56.8	57.5	58.1	58.7
4000	40.6	41.8	42.9	44.0	45.1	46.1	47.1	48.0	48.9	49.8	50.7	51.5	52.3	53.0	53.8	54.5	55.2	55.9	56.5	57.2	57.8

	bmep, kPa																				
	552	565	579	593	607	620	634	648	662	676	689	703	717	731	745	758	772	786	800	813	827
	bmep, lb/in²																				
rpm	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120
800	80.6	80.9	81.3	81.7	82.0	82.3	82.6	83.0	83.3	83.5	83.8	84.1	84.3	84.6	84.8	85.1	85.3	85.5	85.7	85.9	86.1
900	80.4	80.8	81.2	81.5	81.9	82.2	82.5	82.8	83.1	83.4	83.7	83.9	84.2	84.5	84.7	84.9	85.2	85.4	85.6	85.8	86.0
1000	80.2	80.6	81.0	81.3	81.7	82.0	82.3	82.6	82.9	83.2	83.5	83.8	84.0	84.3	84.5	84.8	85.0	85.2	85.4	85.7	85.9
1100	79.9	80.3	80.7	81.1	81.4	81.8	82.1	82.4	82.7	83.0	82.3	83.5	83.8	84.1	84.3	84.6	84.8	85.0	85.2	85.5	85.7
1200	79.6	80.0	80.4	80.8	81.1	81.5	81.8	82.1	82.4	82.7	83.0	83.3	83.6	83.8	84.1	84.3	84.5	84.8	85.0	85.2	85.4
1300	79.3	79.7	80.1	80.4	80.8	81.1	81.5	81.8	82.1	82.4	82.7	83.0	83.2	83.5	83.8	84.0	84.3	84.5	84.7	84.9	85.1
1400	78.9	79.3	79.7	80.0	80.4	80.7	81.1	81.4	81.7	82.0	82.3	82.6	82.9	83.2	83.4	83.7	83.9	84.2	84.4	84.6	84.8
1500	78.4	78.8	79.2	79.6	80.0	80.3	80.7	81.0	81.3	81.6	81.9	82.2	82.5	82.8	83.0	83.3	83.6	83.8	84.0	84.3	84.5
1600	77.9	78.3	78.7	79.1	79.5	79.9	80.2	80.5	80.9	81.2	81.5	81.8	82.1	82.4	82.6	82.9	83.1	83.4	83.6	83.9	84.1
1700	77.4	77.8	78.2	78.6	79.0	79.3	79.7	80.1	80.4	80.7	81.0	81.3	81.6	81.9	82.2	82.4	82.7	83.0	83.2	83.4	83.7
1800	76.8	77.2	77.6	78.0	78.4	78.8	79.2	79.5	79.9	80.2	80.5	80.8	81.1	81.4	81.7	82.0	82.2	82.5	82.7	83.0	83.2
1900	76.1	76.6	77.0	77.4	77.8	78.2	78.6	78.9	79.3	79.6	80.0	80.3	80.6	80.9	81.2	81.4	81.7	82.0	82.2	82.5	82.7
2000	75.5	75.9	76.4	76.8	77.2	77.6	78.0	78.3	78.7	79.0	79.4	79.7	80.0	80.3	80.6	80.9	81.2	81.4	81.7	81.9	82.2
2100	74.8	75.2	75.7	76.1	76.5	76.9	77.3	77.7	78.1	78.4	78.7	79.1	79.4	79.7	80.0	80.3	80.6	80.9	81.1	81.4	81.6
2200	74.0	74.5	75.0	75.4	75.8	76.2	76.6	77.0	77.4	77.8	78.1	78.4	78.8	79.1	79.4	79.7	80.0	80.3	80.5	80.8	81.1
2300	73.3	73.8	74.2	74.7	75.1	75.5	75.9	76.3	76.7	77.1	77.4	77.8	78.1	78.4	78.7	79.0	79.3	79.6	79.9	80.2	80.4
2400	72.5	73.0	73.5	73.9	74.4	74.8	75.2	75.6	76.0	76.4	76.7	77.1	77.4	77.7	78.1	78.4	78.7	79.0	79.3	79.5	79.8
2500	71.7	72.2	72.7	73.1	73.6	74.0	74.4	74.8	75.2	75.6	76.0	76.3	76.7	77.0	77.4	77.7	78.0	78.3	78.6	78.9	79.1
2600	70.8	71.3	71.8	72.3	72.8	73.2	73.6	74.1	74.5	74.8	75.2	75.6	75.9	76.3	76.6	77.0	77.3	77.6	77.9	78.2	78.5
2700	70.0	70.5	71.0	71.5	71.9	72.4	72.8	73.3	73.7	74.1	74.4	74.8	75.2	75.5	75.9	76.2	76.5	76.9	77.2	77.5	77.8
2800	69.1	69.6	70.1	70.6	71.1	71.6	72.0	72.4	72.8	73.3	73.6	74.0	74.4	74.8	75.1	75.5	75.8	76.1	76.4	76.7	77.0
2900	68.2	68.7	69.2	69.7	70.2	70.7	71.2	71.6	72.0	72.4	72.8	73.2	73.6	74.0	74.3	74.7	75.0	75.3	75.7	76.0	76.3
3000	67.3	67.8	68.4	68.9	69.4	69.8	70.3	70.7	71.2	71.6	72.0	72.4	72.8	73.2	73.5	73.9	74.2	74.6	74.9	75.2	75.5
3100	66.4	66.9	67.4	68.0	68.5	68.9	69.4	69.9	70.3	70.7	71.1	71.6	71.9	72.3	72.7	73.1	73.4	73.8	74.1	74.4	74.7
3200	65.4	66.0	66.5	67.0	67.6	68.0	68.5	69.0	69.4	69.9	70.3	70.7	71.1	71.5	71.9	72.2	72.6	73.0	73.3	73.6	74.0
3300	64.5	65.0	65.6	66.1	66.6	67.1	67.6	68.1	68.5	69.0	69.4	69.8	70.2	70.6	71.0	71.4	71.8	72.1	72.5	72.8	73.1
3400	63.5	64.1	64.7	65.2	65.7	66.2	66.7	67.2	67.6	68.1	68.5	69.0	69.4	69.8	70.2	70.6	70.9	71.3	71.6	72.0	72.3
3500	62.6	63.2	63.7	64.3	64.8	65.3	65.8	66.3	66.7	67.2	67.6	68.1	68.5	68.9	69.3	69.7	70.1	70.4	70.8	71.2	71.5
3600	61.6	62.2	62.8	63.3	63.8	64.4	64.9	65.4	65.8	66.3	66.7	67.2	67.6	68.0	68.4	68.8	69.2	69.6	70.0	70.3	70.7
3700	60.7	61.2	61.8	62.4	62.9	63.4	63.9	64.4	64.9	65.4	65.8	66.3	66.7	67.1	67.5	67.9	68.3	68.7	69.1	69.5	69.8
3800	59.7	60.3	60.9	61.4	62.0	62.5	63.0	63.5	64.0	64.5	64.9	65.4	65.8	66.2	66.7	67.1	67.5	67.9	68.2	68.6	69.0
3900	58.7	59.3	59.9	60.5	61.0	61.6	62.1	62.6	63.1	63.6	64.0	64.5	64.9	65.4	65.8	66.2	66.6	67.0	67.4	67.7	68.1
4000	57.8	58.4	59.0	59.5	60.1	60.6	61.1	61.7	62.2	62.6	63.1	63.6	64.0	64.5	64.9	65.3	65.7	66.1	66.5	66.9	67.2

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