Fuel Economy Measurement—Road Test Procedure—Cold Start and Warm-Up Fuel Economy —SAE J1256 JUN80

SAE Recommended Practice
Approved June 1980

THIS IS A PREPRINT WHICH IS SUBJECT TO REVISIONS AND CORRECTIONS. THE FINAL VERSION WILL APPEAR IN THE 1981 EDITION OF THE SAE HANDBOOK.

Society of Automotive Engineers, Inc.
400 COMMONWEALTH DRIVE, WARRENDALE, PA. 15096

LAND SEA AIR SPACE

PREPRINT

The ϕ symbol is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. If the symbol is next to the report title, it indicates a complete revision of the report.

FUEL ECONOMY MEASUREMENT-ROAD TEST ϕPROCEDURE—COLD START AND WARM-UP FUEL ECONOMY—SAE J1256 JUN80

SAE Recommended Practice

Report of the Passenger Car and Light Duty Truck Fuel Economy Measurement Committee, approved May 1979, completely revised June 1980.

1. Purpose—This recommended practice provides uniform testing procedures for measuring the cold start and warm-up fuel economy of light duty vehicles (motor vehicles designed primarily for transportation of persons and having a capacity of 12 persons or less, or for transportation of property and rated at 6000 lb (2700 kg) or less) on suitable roads.[1]

2. Scope—This procedure incorporates a modified driving cycle replicate of consumer operation as contained and shown in SAE J1082b (January, 1979) and which is run on a suitable road or test track. The procedure yields cold start and warm-up fuel economy values indicative of consumer level at the ambient condition of the test. Within referenced limitations, the procedure can be utilized to determine the fuel economy differential among vehicles or between vehicle changes.

3. Definitions

3.1 **Driving Cycle**—The urban driving pattern is defined by paragraph 8.3.4.2. This driving pattern is a modification for cold starting of the SAE J1082b (January, 1979) urban driving cycle.

3.2 **Test Vehicle**—Passenger car or light truck prepared for test according to Section 7.

3.3 **Test Vehicle Weight**—Unloaded vehicle weight plus 300 lb (136 kg).

3.4 **Observed Cold Fuel Economy**—Observed cold fuel economy will be reported for both 0–2 mi (0–3.2 km) and 0–4 mi (0–6.4 km). The 0–2 mi (0–3.2 km) fuel economy will be determined by dividing the 2.0 mi (3.2 km) of the urban cycle by the fuel consumed during Cycle 1. The 0–4 mi (0–6.4 km) fuel economy will be determined by dividing 4.0 mi (6.4 km) by the fuel consumed during Cycle 1 and Cycle 2. Economy will be expressed in miles per gallon (kilometers per liter).

3.5 **Corrected Cold Fuel Economy**—Corrected economy is the observed economy multiplied by the correction factors listed in Sections 11 and 12. Corrected fuel economy will be expressed as miles per gallon (kilometers per liter).

3.6 **Correction Factors**—Factors used to adjust data to the standard ambient condition of 60° F (15.6°C) and reference fuel properties.

3.7 **Test Repeatability Guidelines**—These guidelines are intended to provide an estimate of repeatability of test data for replicate tests (assumes a standard deviation equal to 1.9% of the mean). Average fuel economy refers to the harmonic average.

3.7.1 Estimate of true average (90% confidence interval) fuel economy for vehicle being tested.

$$\text{True Average} = \text{Observed Average} \pm \frac{0.031}{\sqrt{n}} \cdot (\text{Observed Average})$$

The observed average is the average fuel economy for n tests; where n is the number of replicable tests.

Example 1 (U.S. units)—If a vehicle obtained 14.8 mi/gal and 15.2 mi/gal on two tests on the same cycle, the observed average fuel economy would be 15.0 and the true average (90% confidence) would be:

$$15.0 \pm \left[\frac{0.031}{2} \cdot 15.0\right] = 15.0 \pm 0.3 \text{ mi/gal}$$

Example 2 (SI units)—If a vehicle obtained 6.29 km/L and 6.46 km/L on two tests on the same cycle, the observed average fuel economy would be 6.38 km/L and the true average (90% confidence) would be:

$$6.33 \pm \left[\frac{0.031}{2} \cdot 6.38\right] = 6.38 \pm 0.14 \text{ km/L}$$

3.7.2 Estimate of the 95th Percentile Range for Replicate Tests—The 95th percentile range = R = 0.019Q · (Observed Average); where Q = the critical value obtained from a table for the studentized[2] range and the observed average represents the average for n tests.

Selected values for 0.019Q are:

n	0.019Q
2	0.053
3	0.063
4	0.069
5	0.073
10	0.085

Example 1 (U.S. units)—If a vehicle obtains 14.5 mi/gal and 15.5 mi/gal on two tests on the same cycle, the observed average fuel economy would be 15.0 mi/gal and the 95th percentile range would be:

$$R = 0.053 \cdot 15.0 = 0.8 \text{ mi/gal}$$

The difference between the two tests is 1.0 mi/gal which is greater than the difference that would be expected for 95% of the cases in which two tests were conducted. Consequently, additional tests should be conducted to provide more confidence in the average fuel economy.

Example 2 (SI units)—If a vehicle obtains 6.20 km/L and 6.60 km/L on two tests on the same cycle, the observed average fuel economy would be 6.40 km/L and the 95th percentile range would be:

$$R = 0.053 \cdot 6.40 = 0.34 \text{ km/L}$$

The difference between the two tests is 0.4 km/L which is greater than the difference that would be expected for 95% of the cases in which two tests were conducted. Consequently, additional tests should be conducted to provide more confidence in the average fuel economy.

4. Instrumentation—All instrumentation shall be calibrated.

4.1 **Fuel**—The fuel measurement device must be compatible with the vehicle fuel system and should alter the fuel temperature and pressure as little as practical. The fuel measurement system must be accurate to within 0.5% of the fuel used during a driving cycle.

4.2 **Speed**—The speed indicating device shall indicate vehicle speed in miles per hour (kilometers per hour) and be accurate within 0.5 mi/h (1 km/h).

4.3 **Acceleration**—The acceleration indicating device must be capable of indicating both positive and negative acceleration. It shall indicate acceleration/deceleration in ft/s^2 (m/s^2) and be accurate within 0.5 ft/s^2 (0.2 m/s^2).

4.4 **Time**—The time measuring instrument must be capable of measuring time interval to 0.1 s and be accurate within 0.1 s in 1 min.

4.5 **Temperature**—The temperature indicating devices must be capable of measuring to the nearest 2° F or 1°C. Accuracy must be within ±2° F or ±1°C. The sensing element shall be shielded from radiant heat sources.

4.6 **Atmospheric Pressure**—An aneroid or mercury barometer should be used. This device should be accurate within 0.1 in Hg or 0.3 kPa.

4.7 **Wind**—Wind speed should be measured with a device that provides an indication of wind speed that is accurate within 2 mi/h (3 km/h). Wind direction should also be indicated.

4.8 **Distance**—A distance indicating device is required if the tests are not conducted on a premarked course. This device must be capable of indicating distance to within 15 ft (5 m) and must be capable of accuracy within 30 ft in 1 mi (6 m in 1 km).

4.9 **Vehicle Weight**—Vehicle weight should be measured with a device that is accurate within 0.5% with a resolution of 20 lb (10 kg) or less.

5. Test Material

5.1 **Test Vehicle**—The test vehicle shall be completely defined on the Test Vehicle and Preparation List. (The test vehicle will normally be representative of a production built vehicle—any exceptions must be properly noted.)

5.2 **Test Fuel**—Normally, service station fuel will be satisfactory for test purposes. Distillation, specific gravity, and Reid Vapor Pressure should be recorded.

5.3 **Lubricants**—Lubricants used shall conform to the manufacturer's recommendation for the predominant weather condition in which the vehicle is being tested.

6. Test Conditions

6.1 **Ambient Temperature**—Tests and soaks should be conducted at ambient temperatures between 30 and 90° F (-1 and 32°C). For temperatures below 30° F (-1°C) the temperature correction factors may not be valid.

6.2 **Wind Speed**—Tests must not be conducted when average wind speed exceeds 15 mi/h (24 km/h) or when gusts exceed 20 mi/h (32 km/h). During the soak period, higher wind speed is allowable.

6.3 **Road Conditions**—Roads must be dry, clean, smooth, and not exceed 1.0% grade. If operating on a closed track, the start and stop points should be selected such that the schedule elevation difference is 10 ft (3 m) or less.

[1] This recommended practice does not apply to mandatory fuel economy standards for passenger vehicles first established by the "Energy Policy and Conservation Act", Public Law 94-163, 94th Congress S.622, December 22, 1975. Details of the mandatory dynamometer procedure can be obtained by contacting Environmental Protection Agency, Fourth and M Streets, S.W., Washington, DC 20460.

[2] D. B. Owens, "Handbook of Statistical Tables." Reading, MA: Addison Wesley Publishing Co., Inc. 1962. pp. 144–148.

6.4 It is recommended that roadside markers be used to indicate the points at which speed changes are to be made as indicated in paragraph 8.3.

7. Test Vehicle Preparation

7.1 **Break-In**—The vehicle should have accumulated a minimum of 2000 mi (3200 km) of operation prior to test. At least 1000 mi (1600 km) must have been driven at cycling speeds between 40 mi/h (64 km/h) and maximum legal highway speeds. If a closed track is available for break-in the maximum speed should not exceed 100 mi/h (160 km/h). Chassis dynamometer break-in is acceptable. All of the tires must have operated at least 100 road or track miles (160 km) prior to the test. Tires must have at least 75% of the tread remaining and tread must be in good condition.

7.2 **Inspection**—The vehicle must be inspected and adjusted where necessary to meet manufacturer's specifications. Checks are specified on the Test Vehicle Specifications and Preparation List.

7.3 **Instrumentation**—The fuel measuring device and other instrumentation, as necessary, must be installed in a manner not to hinder the vehicle operation or operating characteristics.

7.4 **Test Weight**—The vehicle weight must be adjusted to provide the test weight indicated in paragraph 3.3 (this test weight includes instrumentation and operator).

7.5 **Tire Pressure**—The cold tire pressure should be the minimum recommended by the manufacturer for the vehicle test weight.

8. Test Procedure

8.1 **Preconditioning**—The vehicle must be driven a minimum of 20 mi at 55 mi/h (90 km/h) for maximum legal highway speed to stabilize engine and driveline operating temperatures immediately prior to the cold soak.

8.1.1 Cold Soak—The vehicle should be parked close enough to the start of the test course to fulfill the requirements of paragraph 8.3.4 and exposed to ambient weather for a period of not less than 12 h nor more than 24 h prior to the beginning of a cold urban test. The temperature of the engine oil, engine block coolant, and/or ambient air is to be recorded just prior to the start of the test. In areas of rapidly changing ambient temperature, all three temperatures should be recorded and should not vary by more than 10° F (6°C) for a valid test.

8.1.2 Start Procedures—Spark Ignition Engines

8.1.2.1 Manufacturer's Recommended Procedure—Where the manufacturer has specified a vehicle starting procedure, that procedure should be followed.

8.1.2.2 Where no recommended starting procedure is specified, the following procedure is recommended. Deviations or other starting procedures should be documented.

8.1.2.2.1 Manual Choke Equipped Vehicles—Vehicles equipped with manual chokes will be started by slowly depressing the accelerator pedal fully to the floor while simultaneously adjusting the choke to the fully closed position. Release the accelerator pedal and start the engine. When the engine is running, release the choke only to the point where the engine continues to run smoothly. The choke should continue to be released during the driving cycle as rapidly as possible while maintaining smooth operation.

8.1.2.2.2 Automatic Choke Equipped Vehicles—Vehicles equipped with automatic chokes will be started by turning the key to the ON position, then fully depressing the accelerator and releasing, and starting the vehicle. After the vehicle has been moved to the starting position, tap the throttle lightly to reduce the idle speed.

8.1.3 Start Procedures—Diesel Engines

8.1.3.1 Manufacturer's Recommended Procedure—Where the manufacturer has specified a vehicle starting procedure, that procedure should be followed.

8.1.3.2 Where no starting procedures are recommended, the starting procedure used should be documented.

8.1.3.2.1 Vehicles Equipped with Glow Plug Lights or Other Preheat Warning Devices—Glow plugs are normally preheated via a separate ignition switch position or a separate actuation switch. Actuate the glow plug. When the glow plug light goes out or otherwise indicates the preheat cycle is completed, depress the accelerator pedal to at least halfway to the floor and hold, and turn the ignition key to the start position. Release the ignition switch and throttle pedal when the engine has reached a smooth running condition.

8.1.3.2.2 Vehicles NOT Equipped with Glow Plug Lights or Other Preheat Warning Devices—Glow plug preheaters are required to start automotive type diesel engines. Sixty second preheats will generally be satisfactory at 30° F (-1°C). Fifteen seconds of preheat will be sufficient at 90° F (32°C) ambient. After the appropriate preheat cycle, the starting procedure will be followed as above.

8.2 **Vehicle Controls**—Air conditioning compressor, headlamps, and other accessories that consume power should be turned off unless required for safe vehicle operation. Air conditioning or heater/defroster operation required to clear windows should be turned off as soon as safe vehicle operation is possible.

8.3 **Driving Schedules**

8.3.1 General Driving Instructions

8.3.1.1 Vehicles incapable of attaining acceleration rates specified by the driving schedules will be driven at maximum acceleration until specified schedule speed is reached.

8.3.1.2 Vehicles with automatic transmissions should be driven with the transmission in drive range. If transmission hunting should be encountered at a specified acceleration, the acceleration should be increased to maintain the transmission in the same gear and this departure from the schedule noted on the data form.

8.3.1.3 Vehicles equipped with manual transmissions will be operated in the following manner: Idles will be made in gear, clutch disengaged. Decelerations will be made in gear, and the clutch will be disengaged at 15 mi/h (24 km/h) on a stop. All cruise operation should be in the highest gear that will prevent engine lugging. Downshifts will be permitted to obtain specified acceleration rate after a deceleration or to obtain a smooth engine operation at a slow speed. The following manual transmission shift speeds may be modified as necessary to avoid engine lugging or overspeed. Departure from specified shift speeds should be noted on the data form.

8.3.1.4 Vehicle with manual 3-speed transmissions will be shifted (1–2) at 15 mi/h (24 km/h) and (2–3) at 25 mi/h (40 km/h) or when a lower specified cruise speed is reached. For example, the 20 mi/h (32 km/h) cruise after accelerating at the 0.5, 0.7, and 0.8 mi (0.80, 1.13, and 1.29 km) markers in the Urban Cycle would be conducted in the highest gear that will prevent engine lugging.

8.3.1.5 Vehicles with manual 4-speed transmissions, except truck-type transmissions will be shifted (1–2) at 15 mi/h (24 km/h), (2–3) at 25 mi/h (40 km/h), and (3–4) when a specified cruise speed is reached.

8.3.1.6 Vehicles with manual truck-type transmissions containing a creeper gear will not use the creeper gear during the driving cycles.

8.3.1.7 Vehicles with manual 5-speed transmissions or manually engaged overdrive will be shifted (1–2) at 15 mi/h (24 km/h), (2–3) at 25 mi/h (40 km/h), and (3–4) at specified cruise speed. Upshift to 5th gear at the manufacturer's recommended speed for smooth operation at cruising speed.

8.3.1.8 Vehicles with overdrive transmissions where the overdrive unit engages automatically are to be driven with the actuator switch in the position which will lock out the overdrive unit. Manually engaged overdrives will not be engaged during this test cycle.

8.3.1.9 On a vehicle with an automatic transmission, brakes should be applied to maintain the schedule speed if the engine idle results in vehicle speed above that specified. For manual transmission vehicles, the transmission should be downshifted.

8.3.2 General Cycle Instructions

8.3.2.1 The cold start cycle follows the same driving cycle as the J1082b (January, 1979) urban cycle with the special instructions for starting and movement prior to the start of the test. It should be noted on the test data sheet if defroster, heater, or air conditioning were required for safety; otherwise they should not be used during this test.

8.3.2.2 The cold start tests may be conducted as a sequence of repeated urban cycle of 2.0 mi (3.2 km) each. The 0–2 mi (0–3.2 km) test is Cycle 1. The 0–4 mi (0–6.4 km) test consists of Cycles 1 and 2. Additional cycles may be run to stabilized fuel economy to meet the urban cycle requirements of J1082b (January, 1979).

Cycle 1 is operation from 0–2.0 mi (0–3.2 km). Cycle 2 is operation from 2.0–4.0 mi (3.2–6.4 km). Cycle 3 is operation from 4.0–6.0 mi (6.4–9.7 km), etc.

8.3.2.3 The urban acceleration and deceleration should be maintained within 1 ft/s^2 (0.3 m/s^2) of that specified. Vehicle speeds should be maintained within 1 mi/h (1.6 km/h).

8.3.2.4 Driving cycle maneuvers are initiated at the points indicated except for the stop at the end of the urban cycle, which is to be completed by the point indicated.

8.3.2.5 Fuel temperature will be recorded on the data form during all idle periods.

8.3.2.6 Record weather data for each test cycle.

8.3.2.7 Ambient conditions should be such that repeatability may be attained in as few cycles as possible.

8.3.2.8 Fuel consumption for a cold start test shall be the average of at least two tests, each preceded by a 12–24 h soak period. Fuel consumption will be the arithmetic average of Cycle 1 fuel over the 0–2 mi (0–3.2 km) tests and Cycles 1 and 2 over the 0–4 mi (0–6.4 km) test. Re-

cord the number of stalls which occur during the test and record the total fuel used, including starts. Time lost due to starting and stalls should be subtracted from total elapsed time when comparing to 463 s for the 1% time repeatability for the 0–2 mi (0–3.2 km) cycle.

8.3.2.9 Fuel consumption for each cold start test shall be the average of two consecutive tests that repeat within 2%. Elapsed time must repeat within 1%.

8.3.3 General Cycle Summary Table—This cycle summary is exclusive of restart time or distance required to move the vehicle from the cold soak area to the driving course.

Cycle	mi/h	(km/h)	Test Time s	Time mi	Time (km)	Idle Time s	Stops
Cold Start Cycle 0–2 mi (0–3.2 km)	15.6	(25.1)	463	2.0	(3.22)	60	8
Cold Start Cycle 0–4 mi (0–6.4 km)	15.6	(25.1)	926	4.0	(6.44)	120	16

8.3.4 Cold Start Driving Cycle

8.3.4.1 Starting Instructions—Fuel line and fuel filter fill will be accomplished immediately prior to starting the vehicle. Care should be taken not to fill the carburetor float bowl. One method of accomplishing this would require the installation of a three-way valve as close to the carburetor as possible. A purge line, with a clear section of hose in it, could then be tapped off and an observer could tell when the fuel line was void of air. The flow through the purge line would then be shut off, but flow to the carburetor still would be stopped by the valve. Fuel consumption for the Cycle 1 test will include all fuel used to start the vehicle and run the cycle including fuel used for the carburetor bowl fill, but excluding fuel line fill. Start the fuel meter and timing device and then immediately start the engine in accordance with paragraph 8.1.2 or 8.1.3. Allow the engine to run with foot removed from the accelerator pedal (on fast-idle cam). Note that this driving cycle commences with a 15 s idle. If it is necessary to move the vehicle from a cold soak parking area to the driving course, it must be accomplished during the initial 15 s idle period and while the engine is operating on fast idle. As an alterantive the test vehicle may be pushed from a cold soak area to the start of the driving course. This movement, however, should not be greater than the distance that the vehicle would travel under its own power as described above.

8.3.4.2 Driving Cycle (0–2 mi (0–3.2 km) cycle)

Distance mi	Distance (km)	Operation
0.0	(0.0)	Start engine, idle 15 s, accelerate to 15 mi/h (24 km/h) at 7 ft/s^2 (2.1 m/s^2). Proceed at 15 mi/h (24 km/h) to the 0.2 mi (0.32 km) marker.
0.2	(0.32)	Stop at 4 ft/s^2 (1.2 m/s^2), accelerate to 15 mi/h (24 km/h) at 7 ft/s^2 (2.1 m/s^2). Proceed at 15 mi/h (24 km/h) to the 0.3 mi (0.48 km) marker.
0.3	(0.48)	Decelerate to 5 mi/h (8 km/h) at 4 ft/s^2 (1.2 m/s^2), accelerate to 15 mi/h (24 km/h) at 7 ft/s^2 (2.1 m/s^2). Proceed at 15 mi/h (24 km/h) to the 0.5 mi (0.80 km) marker.
0.5	(0.80)	Stop at 4 ft/s^2 (1.2 m/s^2), record fuel temperature and idle 15 s, accelerate to 20 mi/h (32 km/h) at 7 ft/s^2 (2.1 m/s^2). Proceed at 20 mi/h (32 km/h) to the 0.7 mi (1.13 km) marker.
0.7	(1.13)	Stop at 4 ft/s^2 (1.2 m/s^2), accelerate to 20 mi/h (32 km/h) at 7 ft/s^2 (2.1 m/s^2). Proceed at 20 mi/h (32 km/h) to the 0.8 mi (1.29 km) marker.
0.8	(1.29)	Decelerate to 10 mi/h (16 km/h) at 4 ft/s^2 (1.2 m/s^2), accelerate to 20 mi/h (32 km/h) at 5 ft/s^2 (1.5 m/s^2). Proceed at 20 mi/h (32 km/h) to the 1.0 mi (1.61 km) marker.
1.0	(1.61)	Stop at 4 ft/s^2 (1.2 m/s^2), record fuel temperature at idle 15 s, accelerate to 15 mi/h (24 km/h) at 7 ft/s^2 (2.1 m/s^2), then to 25 mi/h (40 km/h) at 5 ft/s^2 (1.5 m/s^2). Proceed at 25 mi/h (40 km/h) to the 1.2 mi (1.93 km) marker.
1.2	(1.93)	Stop at 4 ft/s^2 (1.2 m/s^2), accelerate to 15 mi/h (24 km/h) at 7 ft/s^2 (2.1 m/s^2), then to 25 mi/h (40 km/h) at 5 ft/s^2 (1.5 m/s^2). Proceed at 25 mi/h (40 km/h) to the 1.3 mi (2.09 km) marker.
1.3	(2.09)	Decelerate to 15 mi/h (24 km/h) at 4 ft/s^2 (1.2 m/s^2), accelerate to 25 mi/h (40 km/h at 5 ft/s^2 (1.5 m/s^2). Proceed at 25 mi/h (40 km/h) to the 1.5 mi (2.41 km) marker.
1.5	(2.41)	Stop at 4 ft/s^2 (1.2 m/s^2), record fuel temperature at idle 15 s, accelerate to 15 mi/h (24 km/h) at 7 ft/s^2 (2.1 m/s^2), then to 30 mi/h (48 km/h) at 5 ft/s^2 (1.5 m/s^2). Proceed at 30 mi/h (48 km/h) to the 1.7 mi (2.74 km) marker.
1.7	(2.74)	Stop at 4 ft/s^2 (1.2 m/s^2), accelerate to 15 mi/h (24 km/h) at 7 ft/s^2 (2.1 m/s^2) and then to 30 mi/h (48 km/h) at 5 ft/s^2 (1.5 m/s^2). Proceed at 30 mi/h (48 km/h) to the 1.8 mi (2.90 km) marker.
1.8	(2.90)	Decelerate to 20 mi/h (32 km/h) at 4 ft/s^2 (1.2 m/s^2), accelerate to 30 mi/h (48 km/h) at 5 ft/s^2 (1.5 m/s^2). Proceed at 30 mi/h (48 km/h).
2.0	(3.22)	Begin braking at 4 ft/s^2 (1.2 m/s^2) to arrive at stop at 2.0 mi (3.22 km) marker. Stop fuel meter and timing device at stop, record fuel consumed, elapsed time, and fuel temperature.

8.3.4.3 Driving Cycle (0–4 mi (0–6.4 km) cycle)—The 0–4 mi (0–6.4 km) cycle is a repetition of the 0–2 mi (0–3.2 km) cycle with the following exception:

Mile 2.0—Begin braking at 4 ft/s^2 (1.2 m/s^2) to arrive at stop at 2.0 mi (3.2 km) marker. Record fuel temperature and idle 15 s, accelerate to 15 mi/h (24 km/h) at 7 ft/s^2 (2.1 m/s^2). Proceed at 15 mi/h (24 km/h) to the 0.2 mi (0.3 km) marker.

Note—The 2.0–4.0 mi (3.2–6.4 km) driving cycle repeats the test cycle shown in paragraph 8.3.4.2 and will be called Cycle 2. The 0.2 mi (0.3 km) stop begins at 2.2 mi (3.5 km), and 0.3 mi (0.5 km) deceleration begins at 2.3 mi (3.7 km), etc. Repetitions of additional cycles of this test in a fully warmed-up condition can be treated as an urban cycle fuel economy test as noted in J1082b (January, 1979).

9. Data Recording—Data shall be entered as required on test data forms.

9.1 Test Vehicle Specifications and Preparation List.

9.2 Data Form.

9.3 Summary Sheet.

10. Data Correction—General—Fuel economy data is corrected with three factors: C_1, C_2, and C_3. Factors C_2 and C_3 account for differentials in fuel properties and should be applied to all data. C_1 corrects fuel economy on the basis of average vehicle temperature response.

Note—If fuel economy results are to be quoted as results indicative of values at the ambient temperature condition of the test, correction factor C_1 should not be applied. When comparing relative fuel economy, it is rare that tests will be run at the same ambient condition. For this comparison, correction factor C_1 can be applied. Where a vehicle is suspected to respond differently than as indicated by the supplied correction factor or where extreme accuracy is needed, comparative tests should be run over a temperature span and an independent correction factor, C_1, be developed. Where the supplied correction factor C_1 is used, it should be used with caution to correct for small changes in test temperature conditions. Correction factor C_1 represents an accumulation of test results on about 25 1975–1977 model year vehicles with as many as 60 tests on individual cars. This correction factor will not precisely correct any specific vehicle, over-correcting some and under-correcting others, and can induce error with attempts to correct over large temperature spans. The extreme of the data available indicates that one of the 25 test vehicles was over-corrected by 1.8% while another was undercorrected by 5.8% for the 10°F (6°C) change in ambient. It is therefore recommended that data for comparison purposes be run within a temperature span of 10°F (6°C) to minimize the likelihood of induced error.

11. Data Correction (U.S. Units)

11.1 Reference Conditions

Reference Temperature	60°F
Fuel Temperature	60°F
Fuel Gravity (Gasoline)	0.737 Specific Gravity, 60.5° API Gravity
Fuel Gravity (ASTM 1D)	0.820 Specific Gravity, 41.0° API Gravity
Fuel Gravity (ASTM 2D)	0.845 Specific Gravity, 36.0° API Gravity
Fuel Net Heating Value	
(ASTM 1D)	126 700 Btu/gal
(ASTM 2D)	129 900 Btu/gal

11.2 Fuel Economy Correction (Gasoline)

11.2.1 Definitions (Units)

T_A—Average ambient temperature during cold urban test cycle (°F).
T_f—Average fuel temperature at measuring instrument during test cycle (°F).
G_s—Specific gravity of test fuel at 60° F.
G_A—API gravity of test fuel at 60° F.
FE_o—Observed fuel economy (mi/gal).
FE_c—Corrected fuel economy (mi/gal).

11.2.2 Correction Formula

$$FE_c = FE_o \cdot C_1 \cdot C_2 \cdot C_3$$

11.2.3 Correction Factors

$C_1 = 1 + 0.0050\ (60\text{-}T_A)$ 0—2 mi (See note in Section 10)
$= 1 + 0.0044\ (60\text{-}T_A)$ 0—4 mi
$C_2 = 1.0 + 0.8\ (0.737 - G_s)$
or
$C_2 = 1.0 + 0.0032\ (G_A - 60.5)$

C_3 is derived from Table 1 based on gravity of fuel at 60° F and T_f or from the following analytical equation: $C_3 = a + bT_f + cT_f^2$, where a, b, c are:

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Coefficient	2	3	4
a	$9.7108\ (10)^{-1}$	$9.6513\ (10)^{-1}$	$9.5982\ (10)^{-1}$
b	$4.6590\ (10)^{-4}$	$5.5473\ (10)^{-4}$	$6.3156\ (10)^{-4}$
c	$2.6156\ (10)^{-7}$	$4.3541\ (10)^{-7}$	$6.2624\ (10)^{-7}$

11.3 Fuel Economy Correction (Diesel)

Note—The method for correcting observed fuel economy for vehicles with diesel engines has not been investigated to the same degree that it has for gasoline-powered vehicles. The correction factors for gasoline-powered vehicles are recommended for use until additional data becomes available.

11.3.1 Definitions (See paragraph 11.2.1.)

H = Volumetric heating value of diesel test fuel (Btu/gal)

11.3.2 Correction Formula

$$FE_c = FE_o \cdot C_1 \cdot C_2 \cdot C_3$$

11.3.3 Correction Factors

$C_1 = 1 + 0.0050\ (60 - T_A)$ 0—2 mi (See Note in Section 10.)
$= 1 + 0.0044\ (60 - T_A)$ 0—4 mi
$C_2 = K/H$
K = 126 700 (ASTM 1D type fuels)
= 129 900 (ASTM 2D type fuels)

H—shall be obtained from Fig. 1 by using the observed API gravity at 60° F and the 50% distillation point or from calorimeter tests.

C_3 is derived from Table 1 based on gravity of fuel at 60° F and T_f or from the following analytical equation:

$$C_3 = a + bT_f + cT_f^2$$

where the coefficients a, b, c are:

ASTM Fuel Group

Coefficient	1	2
a	$9.7645\ (10)^{-1}$	$9.7108\ (10)^{-1}$
b	$3.8674\ (10)^{-4}$	$4.6590\ (10)^{-4}$
c	$9.3735\ (10)^{-8}$	$2.6156\ (10)^{-7}$

12. Data Correction (SI Units)

12.1 Reference Conditions

Reference Temperature	15.6°C
Fuel Temperature	15.6°C
Fuel Gravity (Gasoline)	0.737 Specific Gravity
Fuel Gravity (ASTM 1D)	0.820 Specific Gravity
(ASTM 2D)	0.845 Specific Gravity
Fuel Net Heating Value	
(ASTM 1D)	35.31 MJ/L
(ASTM 2D)	36.21 MJ/L

12.2 Fuel Economy Correction (Gasoline)

12.2.1 Definitions (Units)

T_A—Average ambient temperature during test cycle (°C).
T_f—Average fuel temperature during test cycle (°C).
G_s—Specific gravity of test fuel at 15.6°C.
G_A—API gravity of test fuel at 15.6°C.
FE_o—Observed fuel economy (km/L).
FE_c—Corrected fuel economy (km/L).

12.2.2 Correction Formula

$$FE_c = FE_o \cdot C_1 \cdot C_2 \cdot C_3$$

12.2.3 Correction Factors

$C_1 = 1 + 0.0090\ (15.6 - T_A)$ 0—2 mi (See Note in Section 10.)
$= 1 + 0.0079\ (15.6 - T_A)$ 0—4 mi
$C_2 = 1.0 + 0.8\ (0.737 - G_s)$ or $C_2 = 1.0 + 0.0032\ (G_A - 60.5)$

C_3 is derived from Table 1A based on gravity of fuel at 15.6°C and T_f or from the following analytical equation:

$$C_3 = a' + b'T_f + c'T_f^2$$

where the coefficients a', b', c' are:

ASTM Fuel Group

Coefficient	1	2	3	4
a'	$9.8892\ (10)^{-1}$	$9.8626\ (10)^{-1}$	$9.8333\ (10)^{-1}$	$9.8067\ (10)^{-1}$
b'	$7.0693\ (10)^{-4}$	$8.6875\ (10)^{-4}$	$1.0487\ (10)^{-3}$	$1.2090\ (10)^{-3}$
c'	$3.0370\ (10)^{-7}$	$8.4745\ (10)^{-7}$	$1.4107\ (10)^{-6}$	$2.0290\ (10)^{-6}$

12.3 Fuel Economy Correction (Diesel)

Note—The method for correcting observed fuel economy for vehicles with diesel engines has not been investigated to the same degree that it has for gasoline powered vehicles.

The correction factors for gasoline powered vehicles are recommended for use until additional data become available.

12.3.1 Definitions (See paragraph 12.2.1.)

H = Volumetric heating value of test fuel (MJ/L)

12.3.2 Correction Formula

$$FE_c = FE_o \cdot C_1 \cdot C_2 \cdot C_3$$

12.3.3 Correction Factors

$C_1 = 1.0 + 0.0090\ (15.6 - T_A)$ 0—2 mi (See Note in Section 10.)
$= 1 + 0.0079\ (15.6 - T_A)$ 0—4 mi
$C_2 = KH$
K = 35.31 MJ/L for ASTM 1D type fuel
= 36.21 MJ/L for ASTM 2D type fuel

H shall be determined from Fig. 1 by using the API gravity at 15.6°C and 50% distillation point or from calorimeter tests.

C_3 is derived from Table 1A based on gravity of fuel at 15.6°C and T_f or from the following analytical equation:

$$C_3 = a' + b'T_f + c'T_f^2$$

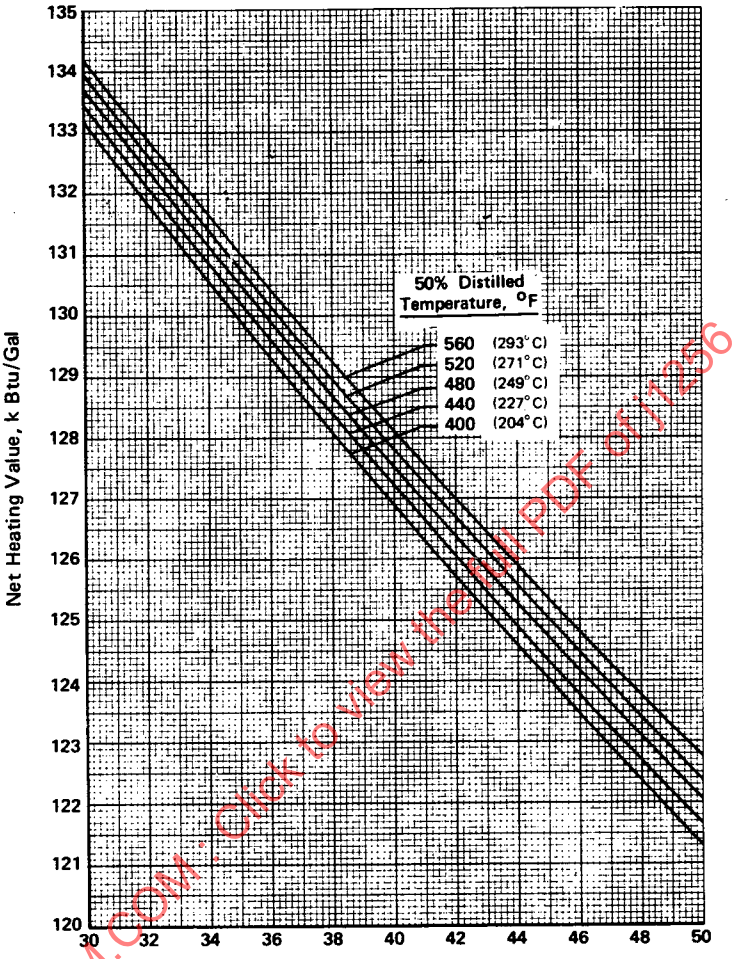
where the coefficients a', b', c' are:

ASTM Fuel Group

Coefficient	1	2
a'	$9.8892\ (10)^{-1}$	$9.8626\ (10)^{-1}$
b'	$7.0693\ (10)^{-4}$	$8.6875\ (10)^{-4}$
c'	$3.0370\ (10)^{-7}$	$8.4745\ (10)^{-7}$

13. Data Presentation

13.1 Test Vehicle Specifications and Preparation List.
13.2 Fuel Economy Test-Data Form.
13.3 Fuel Economy Test Data-Summary Sheet.



Note: 1 Btu/gal = 278.7 J/L
k Btu/gal = 1000 Btu/gal

FIG. 1—VOLUMETRIC NET HEAT CONTENT OF DIESEL FUELS

TABLE 1—C_3—FUEL TEMPERATURE CORRECTION FACTOR[a]

ASTM Group Number	Specific Gravity Range	API Gravity Range, °API
1	0.8499–0.9659	15.0–34.9
2	0.7754–0.8498	35.0–50.9
3	0.7239–0.7753	51.0–63.9
4	0.6723–0.7238	64.0–78.9

Fuel Temp., °F	C_3				Fuel Temp., °F	C_3			
	Group 1	Group 2	Group 3	Group 4		Group 1	Group 2	Group 3	Group 4
0	0.9765	0.9711	0.9651	0.9598	70	1.0040	1.0050	1.0061	1.0072
1	0.9768	0.9715	0.9656	0.9604	71	1.0044	1.0055	1.0067	1.0079
2	0.9772	0.9720	0.9662	0.9611	72	1.0048	1.0060	1.0074	1.0086
3	0.9776	0.9725	0.9667	0.9616	73	1.0052	1.0065	1.0080	1.0093
4	0.9780	0.9730	0.9673	0.9623	74	1.0056	1.0070	1.0086	1.0100
5	0.9784	0.9734	0.9679	0.9629	75	1.0060	1.0076	1.0092	1.0107
6	0.9788	0.9739	0.9684	0.9636	76	1.0064	1.0081	1.0098	1.0114
7	0.9791	0.9743	0.9690	0.9642	77	1.0068	1.0085	1.0104	1.0121
8	0.9795	0.9748	0.9696	0.9649	78	1.0071	1.0090	1.0110	1.0129
9	0.9799	0.9753	0.9701	0.9655	79	1.0076	1.0095	1.0116	1.0136
10	0.9803	0.9758	0.9707	0.9661	80	1.0080	1.0100	1.0122	1.0143
11	0.9807	0.9763	0.9713	0.9668	81	1.0084	1.0105	1.0129	1.0151
12	0.9811	0.9768	0.9718	0.9675	82	1.0088	1.0110	1.0136	1.0158
13	0.9814	0.9772	0.9724	0.9681	83	1.0092	1.0115	1.0142	1.0166
14	0.9818	0.9777	0.9730	0.9688	84	1.0096	1.0120	1.0148	1.0173
15	0.9822	0.9782	0.9735	0.9695	85	1.0100	1.0126	1.0154	1.0180
16	0.9826	0.9787	0.9741	0.9701	86	1.0104	1.0131	1.0160	1.0187
17	0.9830	0.9790	0.9747	0.9708	87	1.0108	1.0136	1.0167	1.0195
18	0.9835	0.9795	0.9753	0.9714	88	1.0112	1.0141	1.0173	1.0202
19	0.9839	0.9800	0.9759	0.9721	89	1.0116	1.0146	1.0179	1.0209
20	0.9843	0.9805	0.9765	0.9728	90	1.0120	1.0151	1.0185	1.0218
21	0.9846	0.9810	0.9770	0.9734	91	1.0124	1.0156	1.0192	1.0225
22	0.9850	0.9814	0.9776	0.9741	92	1.0129	1.0162	1.0198	1.0232
23	0.9854	0.9819	0.9782	0.9748	93	1.0133	1.0167	1.0205	1.0240
24	0.9858	0.9824	0.9788	0.9753	94	1.0137	1.0172	1.0211	1.0247
25	0.9862	0.9829	0.9793	0.9760	95	1.0141	1.0177	1.0218	1.0254
26	0.9866	0.9834	0.9799	0.9767	96	1.0145	1.0182	1.0224	1.0262
27	0.9870	0.9839	0.9805	0.9773	97	1.0148	1.0187	1.0230	1.0269
28	0.9874	0.9843	0.9811	0.9780	98	1.0152	1.0193	1.0236	1.0276
29	0.9878	0.9848	0.9816	0.9787	99	1.0156	1.0198	1.0243	1.0285
30	0.9881	0.9853	0.9822	0.9793	100	1.0160	1.0203	1.0249	1.0292
31	0.9885	0.9858	0.9828	0.9800	101	1.0165	1.0208	1.0255	1.0300
32	0.9889	0.9863	0.9834	0.9807	102	1.0169	1.0213	1.0262	1.0307
33	0.9893	0.9868	0.9840	0.9814	103	1.0173	1.0219	1.0269	1.0314
34	0.9897	0.9873	0.9845	0.9820	104	1.0177	1.0224	1.0275	1.0322
35	0.9901	0.9878	0.9851	0.9827	105	1.0181	1.0229	1.0282	1.0330
36	0.9905	0.9882	0.9857	0.9834	106	1.0185	1.0234	1.0288	1.0338
37	0.9909	0.9887	0.9863	0.9841	107	1.0190	1.0240	1.0294	1.0346
38	0.9913	0.9892	0.9869	0.9847	108	1.0194	1.0245	1.0301	1.0353
39	0.9917	0.9897	0.9875	0.9854	109	1.0198	1.0250	1.0307	1.0360
40	0.9921	0.9902	0.9880	0.9861	110	1.0201	1.0255	1.0314	1.0368
41	0.9925	0.9907	0.9886	0.9868	111	1.0205	1.0261	1.0320	1.0376
42	0.9928	0.9912	0.9892	0.9875	112	1.0209	1.02–6	1.0327	1.0384
43	0.9932	0.9917	0.9898	0.9881	113	1.0213	1.0271	1.0334	1.0392
44	0.9936	0.9922	0.9904	0.9888	114	1.0218	1.0276	1.0340	1.0399
45	0.9940	0.9926	0.9910	0.9895	115	1.0222	1.0282	1.0347	1.0407
46	0.9944	0.9930	0.9916	0.9902	116	1.0226	1.0287	1.0353	1.0414
47	0.9948	0.9935	0.9922	0.9910	117	1.0230	1.0291	1.0359	1.0422
48	0.9952	0.9940	0.9928	0.9917	118	1.0234	1.0296	1.0366	1.0431
49	0.9956	0.9945	0.9933	0.9924	119	1.0238	1.0302	1.0372	1.0438
50	0.9960	0.9950	0.9939	0.9930	120	1.0243	1.0307	1.0380	1.0446
51	0.9964	0.9955	0.9946	0.9937	121	1.0246	1.0312	1.0386	1.0454
52	0.9968	0.9960	0.9952	0.9944	122	1.0250	1.0318	1.0393	1.0461
53	0.9973	0.9965	0.9958	0.9951	123	1.0254	1.0323	1.0399	1.0469
54	0.9977	0.9971	0.9964	0.9958	124	1.0258	1.0328	1.0406	1.0478
55	0.9981	0.9976	0.9971	0.9965	125	1.0263	1.0334	1.0412	1.0485
56	0.9984	0.9980	0.9977	0.9973	126	1.0267	1.0339	1.0419	1.0493
57	0.9988	0.9985	0.9983	0.9980	127	1.0271	1.0344	1.0425	1.0501
58	0.9992	0.9990	0.9988	0.9986	128	1.0275	1.0350	1.0433	1.0509
59	0.9996	0.9995	0.9994	0.9993	129	1.0279	1.0355	1.0440	1.0517
60	1.0000	1.0000	1.0000	1.0000	130	1.0283	1.0360	1.0446	1.0525
61	1.0004	1.0005	1.0006	1.0007	131	1.0287	1.0366	1.0452	1.0533
62	1.0008	1.0010	1.0012	1.0014	132	1.0291	1.0371	1.0459	1.0541
63	1.0012	1.0015	1.0018	1.0021	133	1.0295	1.0377	1.0466	1.0548
64	1.0016	1.0020	1.0024	1.0028	134	1.0300	1.0382	1.0473	1.0557
65	1.0020	1.0025	1.0030	1.0035	135	1.0304	1.0387	1.0480	1.0565
66	1.0024	1.0030	1.0036	1.0042	136	1.0308	1.0393	1.0486	1.0573
67	1.0028	1.0035	1.0042	1.0049	137	1.0312	1.0398	1.0493	1.0581
68	1.0032	1.0040	1.0049	1.0056	138	1.0316	1.0404	1.0500	1.0589
69	1.0036	1.0045	1.0055	1.0064	139	1.0320	1.0409	1.0506	1.0598

continued next page

TABLE 1—C_3—FUEL TEMPERATURE CORRECTION FACTOR[a] (*continued*)

Fuel Temp., °F	C_3				Fuel Temp., °F	C_3			
	Group 1	Group 2	Group 3	Group 4		Group 1	Group 2	Group 3	Group 4
140	1.0324	1.0414	1.0513	1.0606	145	1.0345	1.0442	1.0547	1.0646
141	1.0328	1.0420	1.0520	1.0613	146	1.0350	1.0447	1.0554	1.0654
142	1.0333	1.0425	1.0527	1.0621	147	1.0353	1.0452	1.0561	1.0662
143	1.0337	1.0431	1.0534	1.0630	148	1.0357	1.0458	1.0568	1.0671
144	1.0341	1.0436	1.0541	1.0638	149	1.0362	1.0464	1.0575	1.0679
					150	1.0366	1.0469	1.0582	1.0687

[a]This table is based on Tables 25 and 7 of "Petroleum Measurement Tables" published by the American Society for Testing and Materials, 1916 Race St., Philadelphia, PA, 19103.

Values given are reciprocals of the multiplier values in Tables 25 and 7 as:

$$C_3 = \frac{1}{\text{multiplier for volume reduction to 60°F}}.$$

TABLE 1A—C_3—FUEL TEMPERATURE CORRECTION FACTOR[a] (SI UNITS)

ASTM Group Number	Specific Gravity Range	API Gravity Range, °API
1	0.8499–0.9659	15.0–34.9
2	0.7754–0.8498	35.0–50.9
3	0.7239–0.7753	51.0–63.9
4	0.6723–0.7238	64.0–78.9

Fuel Temp., °C	C_3				Fuel Temp., °C	C_3			
	Group 1	Group 2	Group 3	Group 4		Group 1	Group 2	Group 3	Group 4
−15	0.9784	0.9734	0.9679	0.9629	25	1.0068	1.0085	1.0104	1.0121
−14	0.9791	0.9742	0.9689	0.9641	26	1.0075	1.0095	1.0115	1.0134
−13	0.9798	0.9751	0.9699	0.9653	27	1.0083	1.0104	1.0127	1.0147
−12	0.9805	0.9760	0.9710	0.9664	28	1.0090	1.0113	1.0138	1.0161
−11	0.9812	0.9768	0.9720	0.9676	29	1.0097	1.0122	1.0150	1.0174
−10	0.9818	0.9777	0.9730	0.9688	30	1.0104	1.0131	1.0161	1.0187
−9	0.9826	0.9785	0.9741	0.9700	31	1.0112	1.0141	1.0172	1.0201
−8	0.9833	0.9794	0.9751	0.9712	32	1.0119	1.0150	1.0184	1.0214
−7	0.9840	0.9803	0.9761	0.9724	33	1.0126	1.0159	1.0195	1.0228
−6	0.9847	0.9811	0.9772	0.9736	34	1.0133	1.0168	1.0207	1.0241
−5	0.9854	0.9819	0.9782	0.9748	35	1.0141	1.0177	1.0218	1.0254
−4	0.9861	0.9828	0.9792	0.9760	36	1.0148	1.0187	1.0229	1.0268
−3	0.9868	0.9837	0.9803	0.9771	37	1.0155	1.0196	1.0241	1.0281
−2	0.9875	0.9845	0.9813	0.9783	38	1.0162	1.0205	1.0252	1.0295
−1	0.9882	0.9854	0.9823	0.9795	39	1.0170	1.0214	1.0264	1.0308
0	0.9889	0.9863	0.9834	0.9807	40	1.0177	1.0224	1.0275	1.0322
1	0.9896	0.9871	0.9844	0.9820	41	1.0184	1.0233	1.0287	1.0336
2	0.9903	0.9880	0.9854	0.9832	42	1.0191	1.0243	1.0299	1.0350
3	0.9910	0.9889	0.9865	0.9844	43	1.0199	1.0252	1.0310	1.0364
4	0.9918	0.9898	0.9876	0.9856	44	1.0206	1.0262	1.0322	1.0378
5	0.9925	0.9907	0.9886	0.9868	45	1.0213	1.0271	1.0334	1.0392
6	0.9932	0.9916	0.9897	0.9881	46	1.0221	1.0281	1.0346	1.0406
7	0.9939	0.9924	0.9908	0.9893	47	1.0228	1.0290	1.0358	1.0419
8	0.9946	0.9933	0.9918	0.9906	48	1.0235	1.0300	1.0370	1.0433
9	0.9953	0.9942	0.9929	0.9918	49	1.0243	1.0309	1.0381	1.0447
10	0.9960	0.9950	0.9939	0.9930	50	1.0250	1.0318	1.0393	1.0461
11	0.9968	0.9960	0.9950	0.9943	51	1.0258	1.0328	1.0405	1.0475
12	0.9975	0.9969	0.9961	0.9956	52	1.0265	1.0338	1.0417	1.0490
13	0.9982	0.9978	0.9972	0.9968	53	1.0272	1.0347	1.0429	1.0504
14	0.9989	0.9986	0.9983	0.9981	54	1.0280	1.0357	1.0441	1.0519
15	0.9996	0.9995	0.9994	0.9993	55	1.0287	1.0366	1.0453	1.0533
16	1.0003	1.0004	1.0005	1.0005	56	1.0294	1.0376	1.0465	1.0548
17	1.0010	1.0013	1.0016	1.0018	57	1.0302	1.0385	1.0477	1.0562
18	1.0018	1.0022	1.0027	1.0031	58	1.0309	1.0395	1.0489	1.0577
19	1.0025	1.0031	1.0038	1.0044	59	1.0316	1.0404	1.0501	1.0592
20	1.0032	1.0040	1.0049	1.0056	60	1.0324	1.0414	1.0513	1.0606
21	1.0039	1.0049	1.0060	1.0069	61	1.0332	1.0424	1.0526	1.0621
22	1.0046	1.0058	1.0071	1.0082	62	1.0339	1.0434	1.0538	1.0635
23	1.0054	1.0067	1.0082	1.0095	63	1.0347	1.0444	1.0550	1.0650
24	1.0061	1.0076	1.0093	1.0108	64	1.0354	1.0454	1.0562	1.0664

[a]This table is based on Tables 25 and 7 of "Petroleum Measurement Tables" published by the American Society for Testing and Materials, 1916 Race St., Philadelphia, PA, 19103.

Values given are reciprocals of the multiplier values as:

$$C_3 = \frac{1}{\text{multiplier for volume reduction to 15.6°C}}.$$