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Standard Specification for Lubricants for Two-Stroke-Cycle Spark-Ignition Gasoline Engines (TSC-4)¹

This standard is issued under the fixed designation D 4681; 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.

1. Scope

1.1 This specification sets out the requirements of lubricants intended for use in two-stroke-cycle spark-ignition gasoline engines, typically larger water-cooled outboard motors, which are particularly prone to damage caused by deposit-induced preignition and to problems involving ring sticking, piston scuffing, and corrosion. A method is described by which the conformance of a lubricant to these requirements can be determined.

1.2 *The following safety hazards caveat pertains only to the test methods described in this specification. These test methods may involve the use of hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems 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.*

1.3 The values for temperature, pressure, etc. stated in SI units are the standard; except that as the test engine used is designed to inch-pound standards, the values for dimensions, clearances, etc. stated in inch-pound units are the standard for the purpose of test engine setup and inspection. The conversion value of 25.4 mm = 1 in. is exact.

2. Referenced Documents

2.1 ASTM Standards:

- B 152 Specification for Copper, Sheet, Strip, Plate, and Rolled Bar²
- D 97 Test Methods for Pour Point of Petroleum Oils³
- D 235 Specification for Mineral Spirits (Petroleum Spirits) (Hydrocarbon Dry Cleaning Solvent)³
- D 439 Specification for Automotive Gasoline³
- D 664 Test Method for Acid Number by Potentiometric Titration³
- D 874 Test Method for Sulfated Ash from Lubricating Oils and Additives³
- D 1193 Specification for Reagent Water⁴
- D 2270 Practice for Calculating Viscosity Index from Kinematic Viscosity at 40°C and 100°C⁵
- D 2896 Test Method for Total Base Number of Petroleum Products by Potentiometric Perchloric Acid Titration⁵

¹ This specification is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.B on Automotive Lubricants.

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² Annual Book of ASTM Standards, Vol 02.01.

³ Annual Book of ASTM Standards, Vol 05.01.

⁴ Annual Book of ASTM Standards, Vol 05.05 or 11.01.

⁵ Annual Book of ASTM Standards, Vol 05.02.

D 2983 Test Method for Low-Temperature Viscosity of Automotive Fluid Lubricants Measured by Brookfield Viscometer⁵

D 4682 Specification for Miscibility with Gasoline and the Fluidity of Two-Stroke-Cycle Gasoline Engine Lubricants⁶

E 230 Temperature-Electromotive Force (EMF) Tables for Standardized Thermocouples⁷

G 1 Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens⁸

2.2 ANSI Standard:

MC 96.1 American National Standard for Temperature Measurement Thermocouples⁹

3. Descriptions of Terms Specific to This Standard

3.1 *cowls, cowlings*—the components that enclose the powerhead, whether removable manually or not.

3.2 *engine*—sometimes used as a synonym for motor; both terms can be found in the literature.

3.3 *load wheel, test tank propeller*—a power-absorbing device used instead of a propeller when the outboard motor is operated in a test tank.

3.4 *lower unit*—the portions of the outboard motor other than the powerhead and its cowlings.

3.5 *motor*—the total assembly of cowls, powerhead, and lower unit, excluding the propeller or load wheel and steering, remote control, and electrical cables external to the cowls. This term must not be used as a synonym for powerhead.

3.6 *plug fouling*—deposition of essentially non-conducting material onto the electrodes of a spark plug that can, but will not necessarily, prevent the plug from operating.

3.7 *plug whiskering or plug bridging*—a deposit of conductive material on the spark plug electrodes, that tends to form a bridge between them, thus shorting out the plug.

3.8 *powerhead*—the two-stroke-cycle gasoline engine that provides power to the outboard motor, including carburetors, fuel pumps, flywheel, flywheel alternator, starter, ignition system, and all other directly connected components required for its operation but excluding components attached to the short block by tubes or wires only.

3.9 *scuff, scuffing*—in lubrication, damage caused by instantaneous local welding between the piston and bore surfaces that does not result in immobilization of the parts.

⁶ Annual Book of ASTM Standards, Vol 05.03.

⁷ Annual Book of ASTM Standards, Vol 14.01.

⁸ Annual Book of ASTM Standards, Vol 03.02.

⁹ Order from the American Society of Mechanical Engineers, 345 East 42nd St., New York, NY 10017.

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3.10 *short block*—the cylinder block, crankshaft, connecting rod, and piston assemblies of the powerhead assembled into a complete unit with gaskets, cylinder heads, covers, seals, and all internal parts but excluding the carburetors, fuel pumps, flywheel, alternator and other powerhead components external to and separable from the cylinder block. Hoses attached to the block at both ends, and their associated fittings, are included.

4. Qualification Requirements

4.1 Lubricants subjected to the three test sequences described in Section 10 shall qualify for use in two-stroke-cycle spark-ignition gasoline engines, typically large outboard motors, provided that they meet or exceed the performance criteria of the reference oil as specified in Sections 11 and 12.

5. Test Method

5.1 Summary of Test Method:

5.1.1 Three test sequences are run in the same outboard motor, as specified. In all three sequences the candidate oil(s) shall in principle match or exceed the performance of the reference oil to pass. In order to take account of the differences that can exist between nominally identical motors, a tolerance is allowed in the case of some aspects of performance that will permit a candidate oil whose rating may be slightly below that of the reference oil to pass as far as that performance aspect is concerned. See Section 12. A candidate oil must also equal the performance of the reference oil in a salt water immersion rust test to qualify.

5.2 Engine Test Sequences:

5.2.1 These are run in two or more 1.5 L outboard powerheads specially modified to be more prone to piston scuff and ring sticking than a normal commercial unit. One powerhead is supplied with a reference oil, and the other(s) with the candidate oil(s). All reference and candidate tests are started using a completely new short block with no prior running time whatever. Any number of candidate oils can be run with one reference oil, provided that they are all run in the same building under identical conditions. The test is divided into three phases as described in 5.2.2, 5.2.3, and 5.2.4. All running in Sequences II and III shall be simultaneous; when one unit shall be shut down for any reason during the test all the others shall also be shut down and be restarted together. An internal powerhead inspection is required at the end of each phase.

5.2.2 *Sequence I—Accelerated Lubricity Test*—Using a fuel to oil ratio of 150:1, the motor is run for a total of 60 s at 2000 r/min, then run for 11 min at 5500 r/min wide open throttle (WOT). There must be no piston scuff or other damage.

5.2.3 *Sequence II—General Performance Test*—The motor is run for 21 h at 4500 r/min WOT using a fuel to oil ratio of 50:1. Ring sticking, piston skirt varnish, plug fouling, and exhaust port blockage are evaluated.

5.2.4 *Sequence III—Accelerated Preignition Test*—The motor is run for 98 h at 4500 r/min WOT using a fuel to oil ratio of 24:1. Incidents of preignition are recorded, and ring sticking, piston varnish, plug fouling, and port blockage are again evaluated as for Sequence II.

5.3 *Rust Test*—A steel coupon is dipped in the oil and is then immersed in salt water and the time to reach a specified

level of corrosion is observed. The test is detailed in Annex A1.

6. Significance and Use

6.1 This test procedure is intended for the evaluation of lubricants for use in water-cooled outboard motors, but oils meeting its requirements may be specified by engine manufacturers for use in other types of engines. The test method is designed to reject oils whose performance is below the level given by the reference oil on a go-no-go basis, and does not lend itself readily to the determination of performance differences between candidate oils.

6.2 Significance of the Engine Test Sequences:

6.2.1 *Sequence I—Accelerated Lubricity*—The oil in a two-stroke-cycle gasoline engine is either mixed with the fuel prior to use or is metered into the fuel supply at, or at some point prior to, its passage into the engine crankcase. The possibility of the amount of oil actually present in the engine being less than optimum always exists, due to human error or metering pump malfunction. Also, when oil metering systems are used, short periods of operation with less oil than desirable can be expected when the power is increased suddenly as the response of the metering system is never immediate. It has also been found that the incidence of piston scuff early in the life of the engine can be significantly increased when the oil used is deficient in lubricity as defined by this test procedure.

6.2.2 *Sequence II—General Performance*—This part of the specification evaluates the ability of the oil to prevent deposits and ring sticking when used at a 50:1 volumetric fuel to oil ratio.

6.2.3 *Sequence III—Accelerated Preignition*—Two-stroke-cycle gasoline engines generally are more prone to damage by preignition than are four-stroke-cycle gasoline engines. Outboard motors are quite commonly operated for long periods at high output and are not normally subject to thermal shock in operation. As a result they are particularly liable to suffer from deposit-induced preignition. This part of the procedure is run with twice the normal concentration of oil in the fuel in order to maximize deposit formation.

7. Apparatus

7.1 *Test Motor Configuration*—The test powerhead is a 92.6 in.³ (1.5 L) four-cylinder 90° vee configuration block, P/N 392448, with cast iron cylinder liners 3.375-in. (85.7-mm) bore by 2.588-in. (65.7-mm) stroke, mounted on a model 90TLCOS 90 HP lower unit.¹⁰ The carburetors and fuel pumps used shall be those appropriate to the test powerhead. Other modifications shall be made to allow the test short block to be fitted to the lower unit and to meet the special requirements of this procedure. See Section 9.

7.1.1 *Cooling System*—The cooling water for the powerhead is supplied directly by an electrically driven pump with a capacity of about 75 L/min (20 U.S. gal/min) at about 70 to 80 kPa (10 to 12 lb/in.²) delivery pressure

¹⁰ Orders and enquiries should be made to the Fuels and Lubricants Group, Outboard Engineering Dept., Outboard Marine Corp., 300 Seahorse Drive, Waukegan, IL 60085. In the case of the 90TLCOS motors on which the Test Powerheads are to be mounted, specify that they are to be used for laboratory evaluation of lubricants by the TSC-4 procedure.

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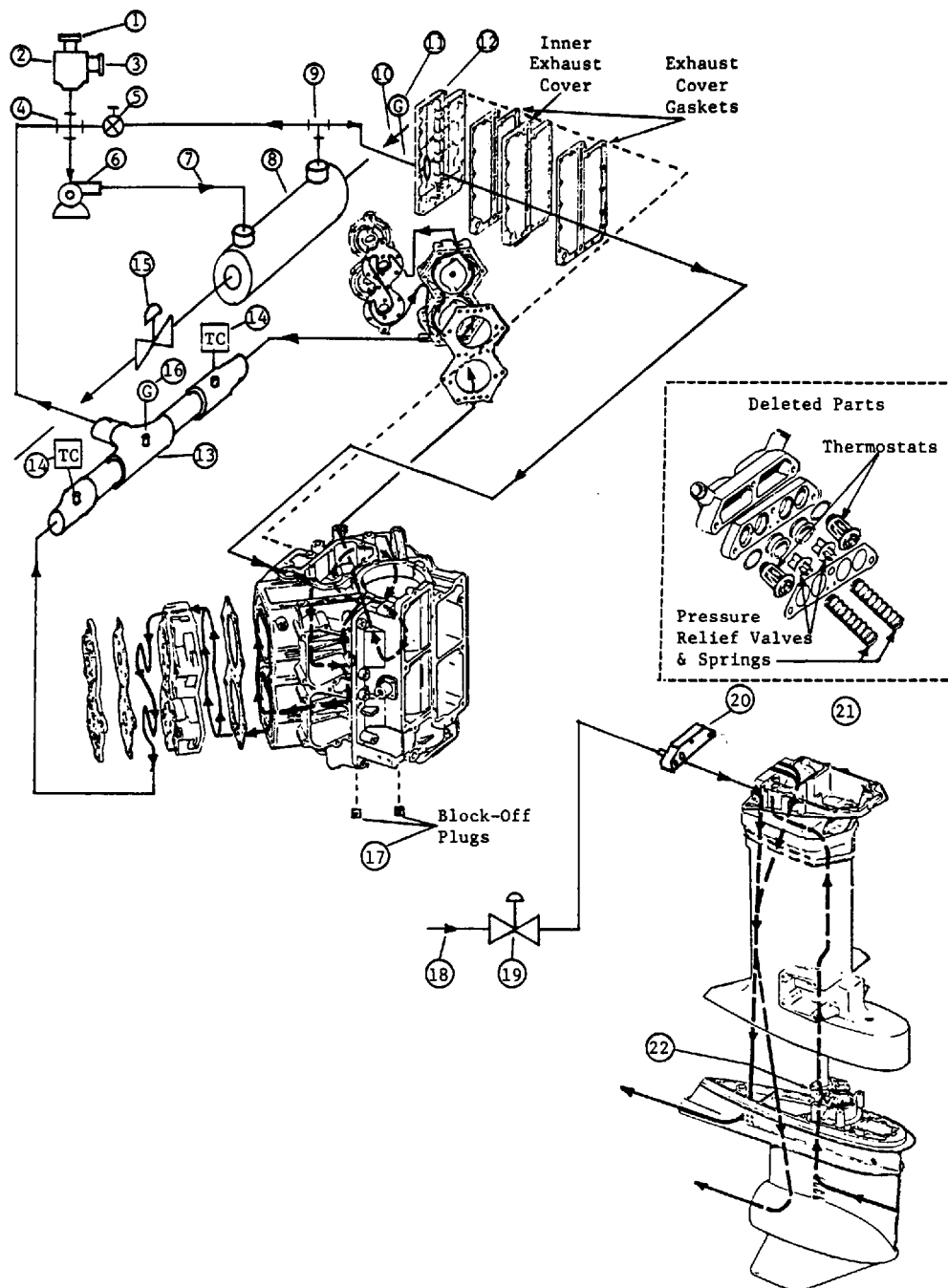


FIG. 1 Typical Engine Cooling System Schematic Phase 2 and 3

through a 15 to 20-mm (0.6 to 0.8-in.) internal-diameter line. This water supply is regulated to give the specified water outlet temperature from the cylinder heads by passage through a heat exchanger with automatic temperature regulation. The system used in Sequences II and III is diagrammed in Fig. 1 and the components are identified in the associated Table 1. The cooling system used in Sequence I is the same except that a water heater of about 4000-W capacity is placed in the circuit in line 7 so that block temperatures can be raised to test specification before the motor is started. Valving to bypass the heater in Sequences II and III can be provided. For Sequence I running, the 200 000 to 250 000 kJ/h (50 000 to 60 000 kcal/h or

200 000 to 250 000 BTU/h) heat exchanger can be replaced by one of about half that capacity. This is not essential, but will facilitate temperature regulation. This can be placed in an alternate loop to the larger exchanger with appropriate valving, or two smaller exchangers can be used in series with a bypass for one of them. Figure 2 shows details of the modifications required to the base of the test short block (see 9.2.1 through 9.2.3) and to the adaptor housing (9.9.2).

7.1.2 Fuel System—Fuel is supplied to the test motor through a fuel connector on the lower cowl and its own fuel pump. Fuel pressure at the connector should not exceed 35 kPa (5 lb/in.²) with the motor stopped.



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TABLE 1 Cooling System Components

Important. Sequence 1 Only—A water heater of about 4000-W capacity is required in line 7 between Items 6 and 8, and Item 8 can be replaced by a heat exchanger of about half its capacity. See 7.1.1.

- (1) Radiator Cap, set to relieve at 28–30 kPa (4 psi).
- (2) Reservoir, approx. 8–10 L (2–2.5 gal) capacity.
- (3) Sight Gage.
- (4) Galvanized Iron Cross, threaded 2–11½ NPTF, connections to Manifold Item 13 and Tee Item 9 reduced to 1–11½ NPTF.
- (5) Gate Valve in recirculation loop for system pressure control, threaded 1–11½ NPTF.
- (6) Water Pump, 75 L/min (20 gal/min) capacity at 200 kPa (30 psi) delivery pressure.
- (7) Engine Coolant water line, shell side of heat exchanger.
- (8) Heat Exchanger, shell and tube type, 200 000–250 000 kJ/h (200 000–250 000 BTU/h) capacity.
- (9) Galvanized Iron Tee, threaded 1–11½ NPTF.
- (10) Process (Raw) Water Line, 1-in. pipe size (21.34-mm outside diameter).
- (11) Water Inlet Pressure Sensor, located 40–65 mm (1.5–2.5 in.) from the inlet to Item 12. Pressure will not normally exceed 100 kPa (15 psi).
- (12) Fabricated Exhaust Cover replacing P/N 317902. See Fig. 7 and 9.2.7.
- (13) Galvanized Iron Engine Coolant Manifold, made from a 1–11½ NPTF tee drilled and tapped to accept a pressure sensor (Item 16) and two 1–11½ to ½–14 NPTF reducing nipples drilled and tapped to receive thermocouples (Item 14).
- (14) Iron-Constantan Grounded and Shielded Thermocouples—These must be located not more than 150 mm (6 in.) from the cylinder head water outlets.
- (15) Temperature-Controlled Pneumatic Flow Control Valve (Honeywell V5011C-1326 is suitable).
- (16) Water Outlet Pressure Sensor.
- (17) Block-Off Plugs.
- (18) Process (Raw) Water for supplementary exhaust cooling.
- (19) Flow Control Valve for supplementary exhaust cooling water.
- (20) Fabricated Cover Plate (See 9.9.1).
- (21) Water Pump Bypass Port (See Fig. 2 and 9.9.2).
- (22) Standard OMC Lower Unit Water Pump.

7.1.3 Load Wheels—Two load wheels (test tank propellers) OMC P/N 315641 are required, one adjusted to give 5400 to 5600 WOT r/min as specified for Sequence I of the test and the other to give 4400 to 4600 WOT r/min as specified for Sequences II and III.

7.1.3.1 Load Wheel Speed Adjustment—The load wheel is essentially an aluminum-spoked wheel and rim, with vanes on the spokes, cast as one piece. Before using the wheel, drill, and tap six 1/8-27 NPSF (National Pipe Thread Straight Dryseal) holes radially through the rim spaced 60° apart around the circumference. If the load wheel gives a lower WOT speed than that specified, remove metal from the rear edges of the vanes as indicated in Fig. 3. Removal of about 1.7 mm (0.07 in.) from the entire radial length of each vane produces a speed increase of about 100 r/min. Due to differences in power output, different motors give slightly different speeds with the same load wheel. If the revolutions per minute must be reduced, insert pairs of 1/8-27 NPTF (National Pipe Thread Taper Dryseal) pipe plugs or nipples into the tapped holes in the rim. The speed reduction depends on the projecting length of the plugs or nipples. These shall be applied or removed as opposite pairs, or serious out-of-balance problems can result.

NOTE 1—Metric and inch system pipe threads are dimensionally identical and are identically designated. Following normal industry practice, Dryseal threads (designation ending with F) have generally been specified, and straight (NPS) rather than taper (NPT) for female pipe threads in aluminum alloy. Non-Dryseal (NPS and NPT) threads can be used with appropriate precautions against leakage, and taper female threads can be used at any time.

7.2 Test Tank:

7.2.1 Use an outboard test tank of 6 m³ (210 ft³) minimum capacity at normal working water level, provided with an exhaust fan of 12 m³/min (420 ft³/min) minimum capacity sucking from a cover that encloses the top of the tank except for the opening necessary to mount the test motor. A design that has been found satisfactory is shown in Fig. 4. The precise dimensions of the tank and capacity of the exhaust fan are not critical provided that the tank water

temperature can be kept essentially constant at a temperature not exceeding 50°C (122°F) and that the exhaust gases do not mix with the intake air.

7.2.2 When a sound-absorbing box is placed over the motor, it must be designed so that it does not interfere with the air flow to the motor. When used, it is important to remove it temporarily every 20 to 30 min while running to check for noises indicative of possible mechanical problems.

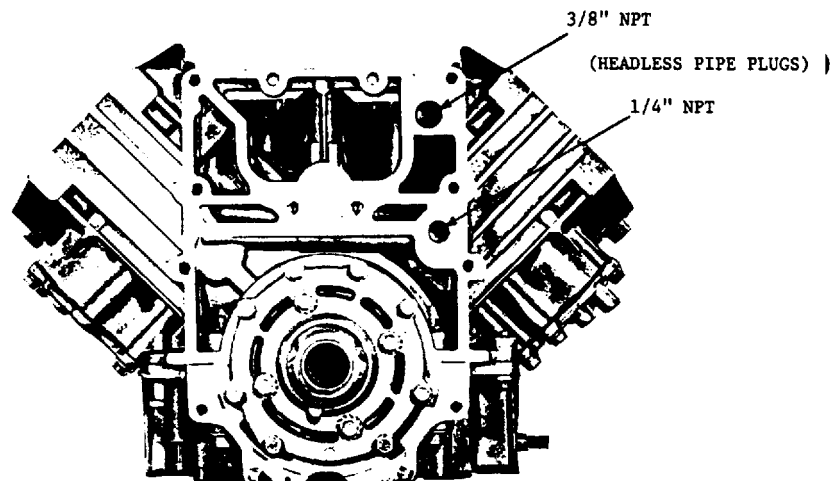
7.3 Instrumentation:

7.3.1 Temperature Measurement—Iron-constantan thermocouples meeting the requirements of Type J of ANSI Specification MC 96.1 (summarized very briefly in Standard E 230) are normally satisfactory for all temperature determinations of this procedure. Constantan is an alloy of approximately 40 % nickel, and 60 % copper by mass.

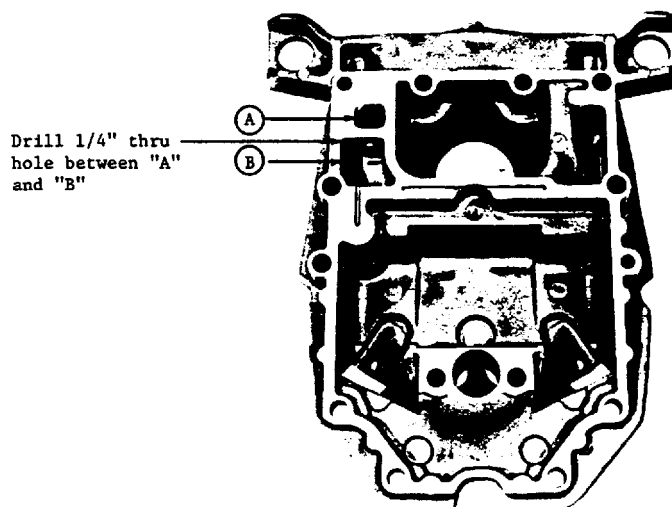
7.3.1.1 Plug Gasket Temperatures—Two thermocouples are required on each spark plug gasket. These can be made by brazing two iron and two constantan glass or silica double insulated wires into holes drilled radially through a solid copper spark plug gasket. A design that has been found satisfactory is given in Appendix X1. The composite gasket normally supplied with the plug is not satisfactory for the attachment of thermocouple wires. A plug gasket temperature increase of 10°C (18°F) or more is an indication of preignition that is potentially damaging to the powerhead. It is therefore highly advisable to arrange that the affected motor be shut off automatically when such a temperature rise occurs. As the test engine shall be stopped or started simultaneously, the automatic shutdown should be arranged to shut down all of them. The engine and cylinder in which the preignition occurred can be identified by examination of the spark plug gasket temperature recordings. At the least an alarm shall be arranged, set at a temperature 2 to 3°C (4 to 6°F) lower, to alert the operator of the potential problem so that he can shut down manually. This alarm or automatic shut-down is normally activated by the second thermocouple provided on each plug gasket.

7.3.1.2 Cooling Water Outlet Temperatures—Two thermocouples shall be provided, one in each cylinder head

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ITEM 17



ITEM 21

FIG. 2 Detail of Cooling System Components

water outlet within 150 mm (6 in.) of the head. These are preferably of the enclosed (shielded) type and are most conveniently mounted by drilling and tapping 1/8-27 NPSF or NPTF through the coolant manifold. See Fig. 1.

7.3.1.3 A similar thermocouple is also recommended in the water inlet to the block to monitor water flow.

7.3.2 Ambient Conditions:

7.3.2.1 *Temperature*—A thermocouple or thermometer shall be provided to read the air temperature in the vicinity of the engine.

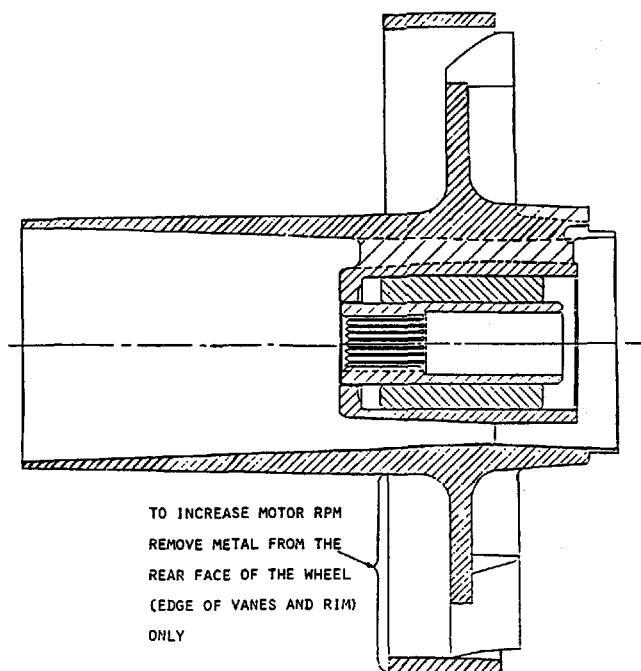
7.3.2.2 *Barometric Pressure*—A barometer recording the pressure in the test room is required.

7.3.2.3 *Humidity*—A hygrometer or a wet and dry bulb thermometer is also required.

7.3.3 *Temperature Recorder*—The four thermocouples used to measure plug gasket temperatures and the two used to measure coolant temperature at the outlets from the cylinder heads must be recorded continuously. Maximum acceptable intervals between successive records of the same temperature are 2 s for the plug gasket temperatures and 2 min for the water outlet temperatures. In order to be able to record the output from these thermocouples, the recorder shall have a minimum temperature range from 40 to 250°C (100 to 480°F). It is preferred, but not required, that the other temperatures to be measured also be recorded continuously.

7.4 *Tachometer*—An electronic or vibration tachometer accurate to ± 25 r/min. An instrument incorporating an

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NOTE—To increase motor revolutions per minute remove metal from the rear face of the wheel (edge of vanes and rim) only.

FIG. 3. Load Wheel

automatic shut-down should the crankshaft speed vary from the desired value by more than ± 200 r/min is desirable but not required.

7.5 Timing Light—Any timing light suitable for use with a high-energy ignition system is satisfactory.

7.6 Fuel Flowmeter—Any type accurate to ± 0.25 kg/h (± 0.5 lb/h) at about 25 kg/h (55 lb/h) can be used, but those measuring mass (weight) directly rather than volume are preferred. When a volume-measuring device is used, the relationship of density to temperature over the range of fuel temperature experienced shall be determined for the actual test fuel mixture used, and the appropriate value used for volume to mass conversion.

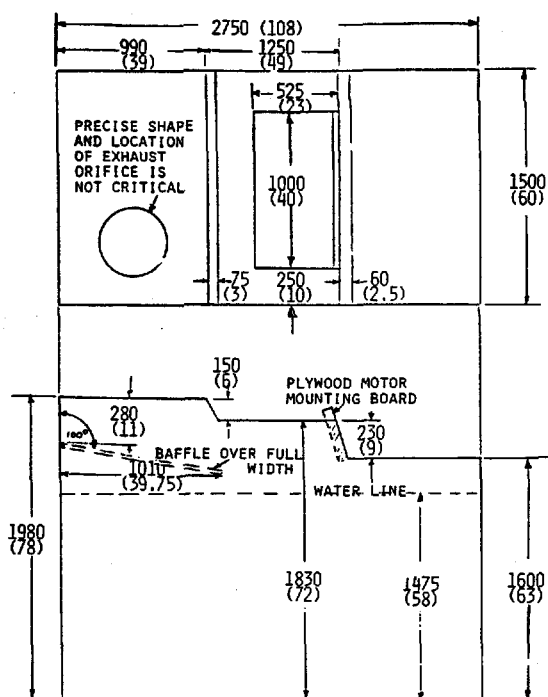
8. Reagents and Materials

8.1 Reference Oil—The reference oil has been assigned the ASTM designation VI-D. It is commercially available under the designation Citgo No. 93734.¹¹ See Annex A1 for information on its properties. The amount of oil required for a test is approximately 200 L (50 U.S. gal).

8.2 Candidate Oil—The amount of candidate oil required is also approximately 200 L (50 U.S. gal).

8.3 Test Gasoline:

8.3.1 This must consist essentially of hydrocarbons, except for conventional anticorrosion, anti-icing, etc. additives in normal concentration. It must not contain oxygenated blending components such as alcohols or ethers. It shall contain 0.8 to 0.9 g/L (3.0 to 3.5 g/gal) of lead as lead alkylates with a standard Motor Mix scavenger package and shall have a minimum Motor octane number of 86 and a



NOTE—Dimensions in millimetres (inches). Material 7–10 (0.25–0.38) thick steel plate except for the 50 by 300 by 1000 (2 by 12 by 40) plywood motor mount. Water inlet and overflow connections not shown.

FIG. 4. Test Tanks

sensitivity (Research octane number minus Motor octane number) of 12 maximum as determined by any test method permitted by Specification D 439. It shall otherwise meet the requirements of D 439, volatility grade A or B.

8.3.2 The amount of gasoline needed to run one candidate oil and one reference oil for all three test phases is approximately 8500 L (2250 U.S. gal), plus 4250 L (1125 U.S. gal) for each additional candidate oil run at the same time.

8.4 Cleaning Solvent—Stoddard solvent meeting the requirements of Specification D 235, Type I.

8.5 Assembly Grease—When assembling the crankpin and crankshaft center main bearings it is necessary to coat the components heavily with grease so that they will remain in place during the operation. Use only OMC Needle Bearing Grease P/N 378642¹² for this purpose. Use of conventional antifriction bearing grease can cause bearing failure during break-in.

8.6 Cooling Water—This should have a maximum hardness (as CaCO_3) of 50 mg/L (50 ppm), but any water known not to cause problems in cooling systems operating at up to about 85°C (185°F) can be used.

8.7 Crankcase Joint Sealant—Use a nonhardening compound such as Gel-Seal II¹² to facilitate dismantling for inspection.

8.8 Plug Thread Lubricant—Use Antiseize Compound No. 133K.¹¹

¹¹ Order from Citgo Petroleum Corp., 555 East Butterfield Rd., Lombard, IL 60148.

¹² Order from Parts and Accessories Dept., Outboard Marine Corp., PO Box 88, 3225 Prairie Ave., Beloit, WI 53511.