TECHNICAL REPORT

ISO/TR 15409

First edition
2002-04-01

Road vehicles — Heat rating of spark plugs

Véhicules routiers — Évaluation du degré thermique des bougies d'allumage

Reference number
ISO/TR 15409:2002(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

Attention is drawn to the possibility that some of the elements of this Technical Report may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TR 15409 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 1, *Ignition equipment*.

Introduction

ISO/TC22/SC1, *Ignition equipment*, has studied different methods of spark-plug heat rating. It noted that there exist different measuring methods, each of them requiring costly equipment and a lot of experience, but each of these methods seems to produce sufficient results, one as satisfactory as the others.

The discussions showed no substantial support of any of these methods.

The Subcommittee 1 decided therefore to propose the publication of this information as a Technical Report.

Road vehicles — Heat rating of spark plugs

1 Scope

This Technical Report describes the heat-rating methods of spark plugs used with spark-ignition engines.

2 Reference

ISO 2542:1980, *Internal combustion engines — Spark plug ignition — Terminology*

3 Terms and definitions

For the purposes of this Technical Report, the following terms and definitions apply.

3.1
heat rating
measurement of the thermal characteristics of a spark-plug under operating conditions

3.2
heat-rating value
the outcome of heat rating

NOTE This will be expressed in units corresponding to the heat transfer from a spark plug's firing end or insulator tip.

3.3
heat-rating identifier
numbers, letters or a combination of these, relative to the heat-rating value depending on the spark-plug manufacturer's classification system

3.4
heat range
ability of a spark plug to avoid depositions of soot and carbon as well as to avoid auto-ignition in the vehicle engine application

NOTE 1 That is, a given spark-plug type should operate at as hot a temperature as possible at slow engine speeds and light load conditions, and as cool as possible at wide-open throttle.

NOTE 2 The heat range of a spark plug depends on the design of the electrodes, the insulator nose, the shell and the materials of construction, and the engine used.

4 Heat-rating methods

4.1 For heat rating using the SAE 17,6 in^3 spark-plug heat-rating engine, see annexes A and B.

4.2 For heat rating using vehicle engines, see the methods below.

a) For heat rating by measuring pre- and/or post-ignition and temperature, see annex C.

b) For heat rating by measuring pre- and/or post-ignition and comparison with master spark–plugs, see annex D.

4.3 For heat rating by measuring pre- and/or post-ignition and comparison with master spark–plugs measured in the SAE 17,6 in^3 engine, see annex E.

Annex A
(informative)

The SAE heat-rating method

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400 Commonwealth Drive, Warrendale, PA 15096-0001

SURFACE VEHICLE RECOMMENDED PRACTICE

Submitted for recognition as an American National Standard

SAE J549 | REV. MAR95

Issued 1947-12
Revised 1995-03

Superseding J549 JUN90

PREIGNITION RATING OF SPARK PLUGS

Foreword—This Document has not changed other than to put it into the new SAE Technical Standards Board Format.

1. ***Scope***—This SAE Recommended Practice describes the equipment and procedures used in obtaining preignition ratings of spark plugs.

1.1 The spark plug preignition ratings obtained with the equipment and procedure specified herein are useful for comparative purposes and are not to be considered as absolute values since different numerical values may be obtained in different laboratories.

2. *References*

2.1 **Applicable Publications**—The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J2203—SAE 17.6 Cubic Inch Spark Plug Rating Engine

2.1.2 U.S. GOVERNMENT PUBLICATION—Available from DODSSP, Subscripton Services Desk, Building 4D, 700 Robins Avenue, Philadelphia, PA 19111-5094.

MIL-L-6082D

3. ***Equipment***—SAE 17.6 engine (see SAE J2203) with the cylinder barrel having knurled and chemically treated surface and compression piston rings chromium plated.

4. ***Speed***—The nominal speed is to be 2700 rpm, but is not to be over 2765 rpm when firing, nor below 2670 rpm when motoring.

5. ***Compression Ratio***—5.6:1.

6. ***Spark Advance***—30 degrees Before Top Dead Center (BTDC) for nonaviation plugs, 40 degrees BTDC for aviation plugs or nonaviation plugs that cannot be rated at 30 degrees BTDC.

7. ***Ignition Source***—Magneto or approved alternate.

SAE J549 Revised MAR95

8. ***Spark Plug Installation—***The thread in the spark plug hole opening should conform in size and length to the standards established by SAE for the rating engine.

8.1 SAE recommended torque values should be used when installing plugs in the engine.

8.1.1 Reducer bushings or adaptors should not be used.

9. Fuel—98%—one degree Benzene, 2%—Specification MIL-L-6082D Grade 1100 SAE 60 Nonadditive aviation oil, with 0.8 mL/L (3 cc/gal) T.E.L. added.

10. Fuel Injection Timing—The fuel injection pump port shall begin to close 60 degrees ± 5 degrees of crankshaft angle After Top Dead Center (ATDC) on the intake stroke.

11. Fuel Circulation Rate—2 L/min ± 1 L/min (1/2 gal/min ± 1/4 gal/min).

12. Fuel Injection Pump—The gallery pressure of the fuel injection pump is to be 100 kPa ± 10 kPa (15 psi ± 2 psi).

13. Fuel Pressures-Injection—5170 kPa (750 psi) minimum.

14. Mixture Strength—The mixture strength is that which gives maximum thermal plug temperature.

15. Inlet Air Temperature—107 °C ± 3 °C (225 °F ± 5 °F).

16. Inlet Air Humidity—0.453 kg (75 g ± 25 g of moisture/lb) of dry air.

17. Coolant—The coolant should be water plus 3 L (1 g/gal) of an inhibitor. The total dissolved and suspended solids should not exceed 120 ppm.

18. Jacket Inlet Temperature

a. With pressure cooling control—107 °C ± 3 °C (225 °F ±5 °F)
b. With insert head engine—88 °C ± 1 °C (190 °F ± 2 °F)

19. Coolant Flow—20 L/min ± 2 L/min (5 gal/min ± 1/2 gal/min).

20. Crankcase Oil—Oil is to be nonadditive SAE 120 aviation oil.

21. Oil Pressure

a. In main bearings, 650 kPa ± 40 kPa (95 psi ± 5 psi)
b. In valve gear, 100 kPa (15 psi) minimum at operating temperature

22. Oil Temperature—88 °C ± 5 °C (190 °F ± 10 °F).

23. Oil Quantity—Oil level is maintained at the center of the oil level sight glass.

24. Operating Conditions—The plug rating is that Indicated Mean Effective Pressure (IMEP) value obtained on the engine at a point when the supercharge pressure is 3.37 kPa (1 in Hg) below the preignition point.

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24.1 Preignition Point—The following steps are recommended to attain the preignition point.

24.1.1 The supercharge pressure is increased in 13.5 kPa (4 in Hg) increments until preignition occurs as indicated by a rapid rise in thermal plug temperature. At each setting, the mixture strength is adjusted such that a maximum thermal plug temperature is obtained and held for 3 min.

24.1.2 When preignition occurs, the fuel supply is instantly cut off and the supercharge pressure is decreased 6.7 kPa (2 in Hg) at which point the fuel is turned on and again adjusted for maximum thermal plug temperature. This condition should be held for 3 min or until preignition again occurs.

24.1.3 If preignition occurs after Step 24.1.2, the supercharge pressure should be reduced by 3.37 kPa (1 in Hg) again adjusting for optimum thermal temperature until stable engine operation for 3 min is obtained or preignition occurs. If preignition occurs, refer to Step 24.1.5.

24.1.4 If, after Step 24.1.2 stable engine operation is obtained, the supercharge pressure should be increased by 3.37 kPa (1 in Hg), again adjusting for optimum thermal plug temperature until stable engine operation for 3 min is obtained or preignition occurs. If preignition occurs, refer to Step 24.1.5.

24.1.5 Friction torque should be measured at supercharge pressure 3.37 kPa (1 in Hg) below the preignition point (or previous stabilized setting prior to preignition), and within 30 s after the engine ceases to fire.

24.1.6 Rating data may be verified using a plug that has a rating point at least 50 IMEP above the plugs that have been rated.

25. Calculation of IMEP

$$\text{Indicated HP} = \text{Friction HP} + \text{Brake HP} \qquad \text{(Eq. 1)}$$

$$IHP = \frac{2700}{5252}T_F + \frac{2700}{5252}T_B$$

$$IHP = 0.51(T_F + T_B) = \frac{PIan}{33000}$$

$$0.51(T_F + T_B) - (0.04)(0.01)P = IMEP$$

$$IMEP = 8.65(T_F + T_B)$$

T_F -Friction Torque

T_B - Brake Torque

IMEP - Indicated Mean Effective Pressure

26. Notes

26.1 Marginal Indicia. The change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. An (R) symbol to the left of the document title indicates a complete revision of the report.

PREPARED BY THE SAE IGNITION STANDARDS COMMITTEE

SAE J549 Revised MAR95

Rationale—Not applicable.

Relationship of SAE Standard to ISO Standard—Not applicable.

Application—This SAE Recommended Practice describes the equipment and procedures used in obtaining preignition ratings of spark plugs.

Reference Section

SAE J2203—SAE 17.6 Cubic Inch Spark Plug Rating Engine

MIL-L-6082D

Developed by the SAE Ignition Standards Committee

Annex B
(informative)

Description of the SAE heat-rating engine

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SURFACE VEHICLE STANDARD

SAE J2203 | REAF. NOV1999

Issued 1991-06
Reaffirmed 1999-11

Superseding J2203 MAY1995

Submitted for recognition as an American National Standard

SAE 17.6 Cubic Inch Spark Plug Rating Engine

Foreword—This Document has also changed to comply with the new SAE Technical Standards Board Format. Abbreviations have changed to Section 3. All other section numbers have changed accordingly.

This manual was originally prepared under the auspices of the SAE Ignition Research Committee by the Spark Plug Rating Engine Standardization Panel of the Aircraft Piston Engine Ignition Subcommittee. In 1974, the Spark Plug Rating Engine Standardization Panel was placed under the jurisdiction of the SAE Electrical Equipment Committee.

This manual defines the standard engine to be used in determining spark plug preignition ratings. The engine is known as the SAE 17.6 Cubic Inch[1] Spark Plug Rating Engine. The background of its design, development, and applications is contained in SAE publication SP-243.

In addition to describing the engine, this manual deals with maintenance and overhaul instructions for the engine. Appendices providing engine manufacturing tolerances, replacement limits, and engine bill of materials are included. The manual also includes the procedure for rating spark plugs.

The 17.6 engine has been used for many years in the spark plug industry to classify spark plugs by their preignition rating. Correlation of these ratings among the various test agencies has been accomplished with limited success primarily due to engine variations. This correlation difficulty prompted the Aircraft Piston Engine Ignition Subcommittee of the SAE Ignition Research Committee to investigate methods of standardizing and improving this engine. The Ethyl Corporation (which originated the 17.6 engine) consented to the incorporation of improvements in the engine by SAE.

The Spark Plug Rating Engine Standardization Panel, which was established to standardize and improve this engine, consists of persons who are closely associated with the use or manufacture of the engine. The sum of their individual experiences and the many special projects conducted by the panel have been gathered into this manual.

Conformance with the engine description and rating procedure included in this manual and the diligent following of the Maintenance, Overhaul, and Operation instructions will result in more uniform spark plug rating data from each engine and a closer rating correlation between engines.

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1. With the advent of the metric system, the metric notation should be 288.6 cc for the ending displacement. However, since the term “17.6” is quite familiar in the industry, it will be retained in that form.

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This manual will be revised periodically to reflect engine improvements that have been developed and thoroughly evaluated. Comments, advice, or recommendations concerning the manual or the engine that it defines will be welcomed by this panel and should be sent to SAE Headquarters for consideration.

An engine of this type may be obtained from the Laboratory Equipment Corp. (Labeco), Mooresville, Indiana, and all part numbers herein mentioned are those of Labeco, unless otherwise specifically stated.

This Edition of the manual includes only the 16047 series engine since it is the only type that has been manufactured in the last few years. The older type 5000 series was covered thoroughly in a previous edition of the manual (publication date, July 1964). The 16047 series engine (Figures 1a and 1b) differs from the 5000 series in that it incorporates a Lanchester-type of balancing system consisting of two counter-rotating, chain-driven, counterbalancing shafts, rotating at crankshaft speed, to dampen the unbalanced portion of the connecting rod and piston assembly.

NOTE—Shown for illustrative purposes only. Detailed drawings may be obtained from Laboratory Equipment Corp., Mooresville, Indiana.

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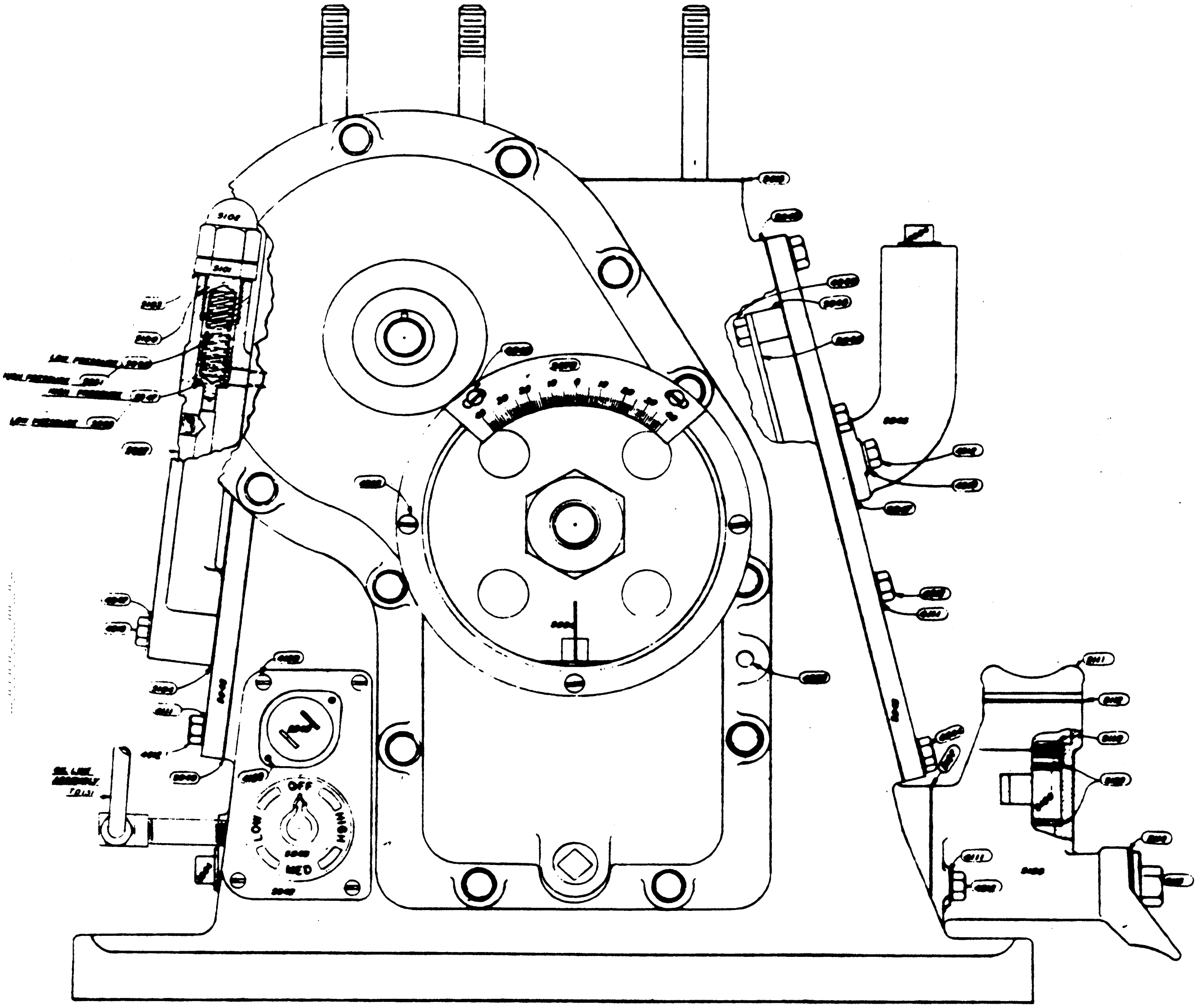

FIGURE 1A—THE 5000 ENGINE

NOTE—Shown for illustrative purposes only. Detailed drawings may be obtained from Laboratory Equipment Corp., Mooresville, Indiana.

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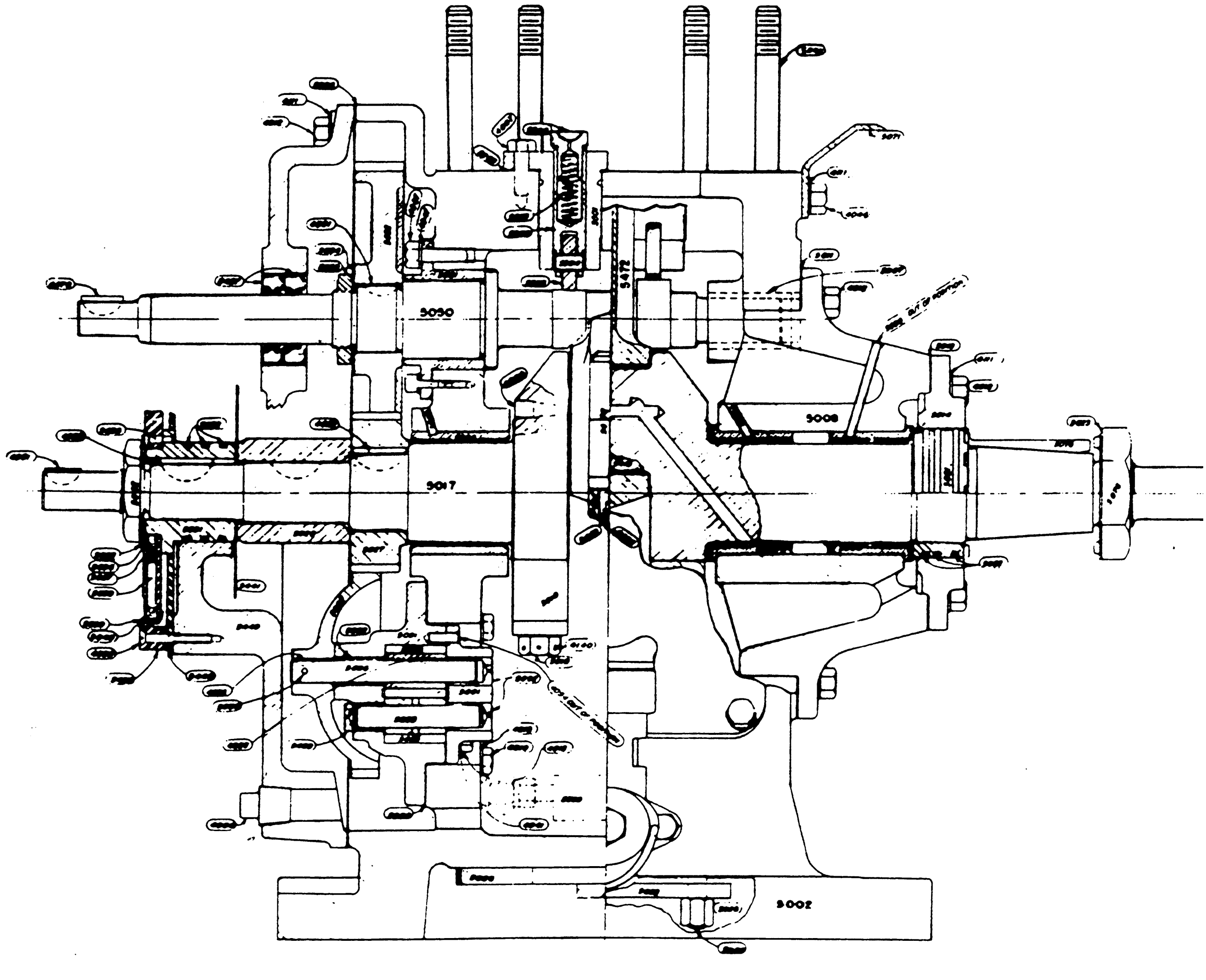

FIGURE 1B—THE 5000 ENGINE

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1. ***Scope—***This SAE Standard defines the standard engine to be used in determining spark plug preignition ratings. The engine is known as the SAE 17.6 Cubic Inch Spark Plug Rating Engine.

2. *References*

2.1 Applicable Publications—The following publications form a part of the specification to the extent specified herein. Unless otherwise indicated, the latest revision of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J973—Ignition System Measurement Procedure
SAE SP-243—Proceedings of the 28th Automotive Technology Development Contractors Coordination Meeting, 27
AS840—Manual, July 1964

3. *Abreviations*

abc	after bottom center
abs.	absolute
assy.	assembly
atc	after top center
bbc	before bottom center
bdc	bottom dead center
bp	boiling point
brg.	bearing
brkt	bracket
btc	before top center
cap	capscrew
°C	degrees Centigrade
C.B.	counterbalance
cc	cubic centimeters
cyl	cylinder
cm	centimeter
deg.	degrees
Dia.	diameter
etc.	and so forth
°F	degrees Fahrenheit
gal	gallons
HD	head
hex	hexagon
h	hours
Hg	mercury
/	per
ID	inside diameter
IMEP	indicated mean effective pressure
in	inches
K.O.	knock out
lb-ft	pounds-feet
M	Meter
mm	millimeter
Mach.	machine
Mfg.	manufacturer
min	minimum or minute
misc	miscellaneous

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mnt.	mounting
No.	number
NPT	National pipe thread
O.A.L.	overall length
OD	outside diameter
oz	ounces
P.F.	press fit
PSI	pounds per square inch
qt	quart
rd.	round
rpm	revolutions per minute
SAE	Society of Automotive Engineers, Inc.
s	seconds
soc	socket
spkt.	sprocket
std	standard
tdc	top dead center
V	volts
w	watts
X	by

4. Cylinder Assembly—The cylinder assembly consists of a cast iron barrel assembly and a detachable cast iron cylinder head assembly; the latter including integral rocker arm housings and covers completely enclosing the valve gear. The barrel assembly has a removable, centrifugally cast iron cylinder sleeve mounted in a cylinder housing and is attached to the head by ten 12.7 mm (1/2 in) diameter bolts that extend the length of the barrel. Coolant transfer from barrel jacket to head is through ten holes drilled in the head and communicating with water passages between the cylinder sleeve and the jacket. The head is located on the upper end of the barrel by a pilot extension on the barrel. The combustion chamber is sealed by a copper ring gasket that is compressed to a predetermined thickness when the ten bolts are tightened.

The combustion chamber is hemispherical in shape with the axis of the two valves intersecting at the center of the sphere. Valve seat inserts for both valves are expanded in the head.

A revision of the cylinder head has been made in the past few years and both the older 5573 integral type (Figure 2) and the newer 16001 insert-type (Figure 4) will be described. On the 5573 type, which is still being used at some agencies, two tapped holes for spark plugs are provided on opposite sides of the dome and in a plane at right angles to the plane through the valves. The included angle between the holes is 110 degrees. Standard combinations of spark plug thread diameters and reaches are shown on Labeco drawing No. 16100.

NOTE—The thermal plug used during spark plug rating is installed in one of the spark plug holes and contains a chromel-alumel thermocouple having a response rate of 7-1/2 s for a change from ambient room temperature to 620 °C ± 28 °C (1150 °F ± 50 °F) when dipped in a molten tin bath at 815 °C ± 5.6 °C (1500 °F ± 10 °F). The thermal plug temperature has a 4.5 s (max) travel time for the range of –18 to 860 °C (0 to 1500 °F).

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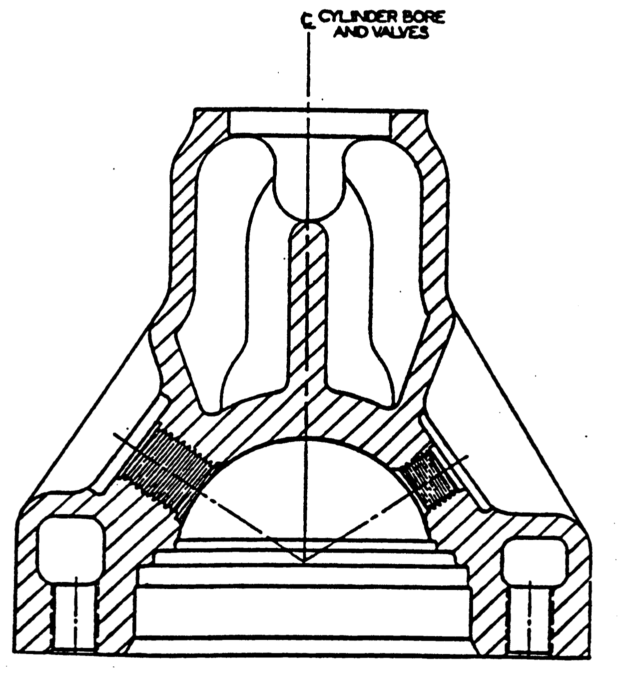

FIGURE 2—INTEGRAL TYPE HEAD (PART # 5573)

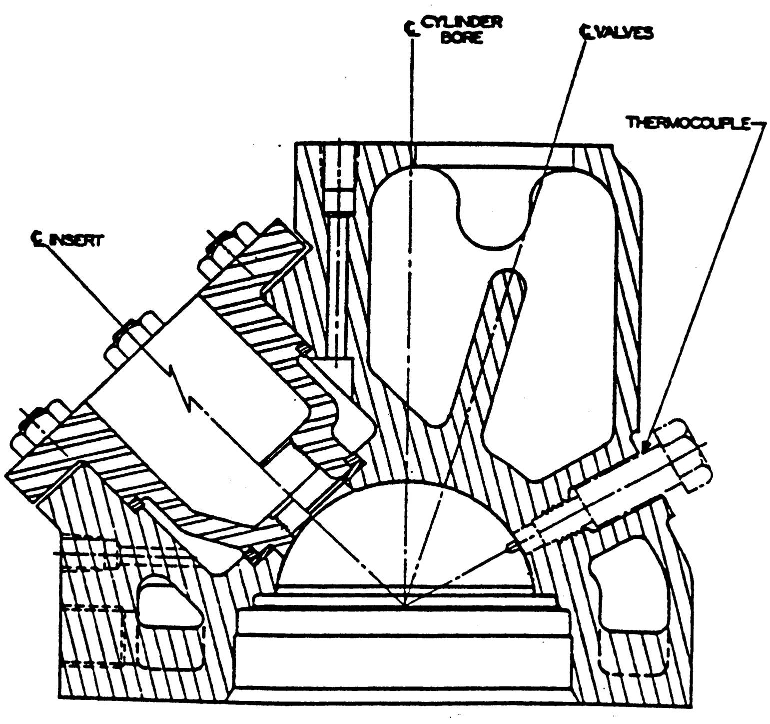

FIGURE 3—INSERT TYPE HEAD (PART # 16001)

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The 16001 head, which is now standard, incorporates spark plug boss inserts that are mounted into the cylinder head with six 8 mm (1/16 in) studs. This spark plug insert is sealed into the combustion chamber and from the atmosphere with two "O" rings. This provides a separate water jacket for the spark plug boss from the cylinder and head water jacket. This insert makes it possible to change from one size of spark plug to another size in a matter of minutes without disturbing the cylinder, cylinder head, or piston, which was necessary in the former 5573 head design. With the 16001 type head, the single thermal plug remains installed at all times.

The cylinder sleeve is of generally uniform thickness from top to bottom, except for a small outer flange near the lower end of the sleeve. This flange engages a steel ring flange that seals the sleeve to the cylinder housing and the head by gaskets and the same ten bolts that hold the barrel assembly to the head. The inner surface of the cylinder is knurled before finish honing; and after final honing, the surface is Parco-Lubrize treated.

Coolant enters the lower end of the cylinder housing at the timing gear end and leaves the assembly at the top of the head between the rocker boxes. Coolant for the spark plug boss insert in the type 16001 cylinder head enters the insert jacket immediately below the insert and leaves the insert jacket directly above the insert.

The cast iron rocker arms, providing an 8 mm (5/16 in) valve lift for a 6.33 mm (1/4 in) lift of the camshaft, are equipped with needle bearings operating on floating case-hardened solid steel rocker shafts, secured by cover plates bolted to the rocker box housings. Each rocker has a roller at the valve end and an adjusting screw at the push rod end. The valve gear is lubricated by pressure oil from the valve tappets, through a hole in the adjusting screw, with affords splash lubrication, supplemented by additional exhaust valve lubrication effected by projecting the push rod housing 12.7 mm (1/2 in) into the exhaust rocker box.

The valves, one intake and one exhaust, have valve stem diameters and lengths considerably greater than those generally provided for the valve head diameters used. Each valve is operated by two valve springs that provide satisfactory operation up to and including 3200 rpm.

5. ***Crankcase Assembly—***The gear end is considered the front end of the crankcase and the flywheel end, the rear of the crankcase. The crankcase consists of an extremely rigid iron casting with drilled oil passages allowing pressure lubrication to all bearing surfaces. The crankcase from the main bearing to the base houses the two counter-rotating, chain-driven counterbalance shafts. The timing gear case cover encloses the timing gears, the chain drive for the counterbalance shafts and the chain tension idler sprocket. An oil pump is mounted on the outside of the timing gear case cover and is driven through an Oldham coupling by the left-hand counterbalance shaft. Two large covers bolted to the sides of the crankcase provide means for inspection of the crankcase interior.

There are three main bearings; the front main bearing is pressed into the front supporting section of the crankcase deck and the rear two main bearings are pressed into a removable adapter. All three are locked in place by taper pins. All main bearings are of the one-piece, babbitt type and are precision bored in place; no adjustment is provided to compensate for wear. The end play of the crankshaft is controlled by dimensional machining of the thrust faces of the two inner main bearings, with the adapter secured in place on the crankcase with the proper gasket.

The crankshaft is a very rigid steel forging, has hardened bearing journals to insure minimum wear, and is counterweighted to balance the centrifugal weight in accordance with standard practice. Keyways are provided for flywheel and all the front end drives. Threads are provided for the crankshaft front lock nut. The rear end is machined to use a radial lip seal. The front ring seal is also a radial lip seal, sealing against the timing disc spacer sleeve.

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The lead weighted counterbalance shafts are mounted in the lower part of the case. Their unbalance weight dampens out the unbalanced forces generated by the upper portion of the rod and piston assembly. These shafts are mounted on bronze bushings pressed into the rear of the case and front bushings pressed into a piloted bearing adapter. They are driven in opposite directions at crankshaft speed by a triple chain drive. The tension of the chain is adjusted by an idler sprocket mounted on an eccentric bushing that may be locked in the position giving the desired tension. The forged steel flywheel bears directly on a tapered and hardened section at the rear of the crankshaft and is held by key and lock nut.

The camshaft, driven through helical gears, is carburized steel with case-hardened bearing journals and cams. The front of the camshaft extends through the timing gear case for an auxiliary drive. An oil seal is used at this point.

There are two bronze camshaft bearings: (a) the front bearing, which absorbs the camshaft end thrust, is bolted by a flange to the front supporting section of the crankcase; (b) the rear bearing is a bushing that is pressed into the rear crankcase supporting section. End play can be adjusted by removing metal from the inner face of the front bearing.

The valve lifters are of the roller-type. The guides are iron castings and are held to the top deck of the crankcase by capscrews, positive vertical alignment being assured by shoulders that fit in piloting holes drilled in the crankcase deck.

The connecting rod is a steel forging that has a precision shell-type split bearing, the cap being held by two bolts of generous proportions. The bearings are precision bored steel backed silver grid and no adjustment is possible for wear. The wrist pin bushing is a press fit in the rod and is hard cast bronze.

The piston pin is hardened carburized steel, is solid, employs a full diameter, and has 32.50 mm (1-9/32 in) spherical radii.

The piston is cast iron, has four compression rings and one oil control ring, all located above the piston pin boss, and incorporates a sodium-filled capsule in the head. This capsule, cooled by an oil spray from the small end of the connecting rod, is used to prevent localized overheating of the piston by more uniformly dissipating the heat to the cylinder wall through the rings and skirt and to the oil. The capsule consists of a two-piece, copper brazed chamber that totally encloses the sodium and is shrunk into the outer casting. Pressure on the middle of the piston head is directly transmitted to the piston bosses by the inner member of the capsule. The compression ratio of the engine is 5.6:1.

6. ***Air Induction System—***The induction system consists of an air receiver assembly and an intake pipe basically. The air receiver, a cylindrical aluminum casting, is mounted at the top of the intake pipe and functions as an equalizing chamber to provide a constant pressure at the entrance to the induction system. It contains a standpipe whose inside diameter, 22.2 mm (7/8 in), is equal to the pipe passage diameter and an air filter consisting of four layers of bronze screen (two of 110 mesh, and two of 22 mesh) to prevent pipe scale and the like from entering the cylinder. The air enters the receiver tangentially and is drawn off at the standpipe entrance near the top of the receiver. Two thermocouples are located in the air receiver; one is connected to a controller to maintain the air inlet temperature at 107.2 °C ± 2.8 °C (225 °F ± 5 °F) (see Section 12), and the other is used for indicating the temperature.

The intake pipe is an iron casting in the form of a 90 degree bend and is held to the cylinder head by four studs. Surrounding the pipe is a jacket that gives great rigidity to the section. Provisions are made for the mounting of the fuel injection nozzle on either side of the intake pipe between the cylinder head and the air receiver.

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7. Ignition System—The ignition system may consist of two alternate systems; one a magneto system and the other a condenser discharge ignition system.

7.1 Magneto Ignition System—The magneto ignition system consists of a low tension magneto, one high tension coil, and magneto drive coupling assembly. The magneto, mounted independently of the engine on a mounting bracket, is driven at engine speed through a drive coupling assembly connected to the front extension of the crankshaft. The magneto rotation is counterclockwise as viewed from the magneto drive end. The magneto generates and distributes low voltage current through low tension cables to the high tension coil. The low voltage by this coil is transformed to high voltage by this coil and is conducted through a short length of high tension cable to the spark plug in the engine. Negative polarity impulses shall be delivered to the spark plug.

The magneto drive coupling assembly consists of one adjustable coupling flange assembly, two flexible couplings, and a driving coupling flange that is keyed to the crankshaft. The adjustable coupling flange assembly has one disc with two fixed screws that can be positioned in the two circumferential slots in the other disc.

In timing the magneto to the engine, remove the breaker cover and the timing inspection plug from the magneto. With the crankshaft set at the desired spark advance on the compression stroke, position the adjustable coupling flange assembly so that the white dot on the chamfered tooth of the large distributor gear lines up with the pointer as seen through the inspection hole. In this position, the breaker points of the magneto are just opening.

7.2 Alternate Ignition Systems—Any commercially available automotive ignition system such as a capacitive discharge system, electronic breakerless system, or an inductive breaker type system will be satisfactory as long as it fulfills the following system specifications:

Open Circuit Voltage: 24 KV (minimum)
Rise Time: 50 µs (maximum)
Arc Duration: 60 µs (minimum)
Polarity: Negative

All measurements are to be taken with the spark plug firing at the following conditions:

Spark plug gap at 0.635 mm (0.025 in)
Engine running as follows: 2700 rpm
2540 mm (100 in) Hg-Supercharge
Spark Timing-30 degree B.T.D.C.

Voltage measurements are to be made in accordance with SAE J973.

8. Fuel System—The fuel system consists of a fuel supply pump, filter, fuel cooler, fuel injection pump assembly, injection nozzle, and fuel tank as shown in Figure 4.

The gear type, positive displacement fuel supply pump is driven at 600 rpm and has a capacity of 2.0 L/min ± 1.0 L/min (1/2 gal/min ± 1/4 gal/min) at this speed.

The filter is a multiple disc edge type with 0.038 mm (0.0015 in) spacing. To reduce difficulty during engine operation due to fuel contamination, it is suggested that the fuel be filtered through a 2 µm filter before delivery to the fuel system.

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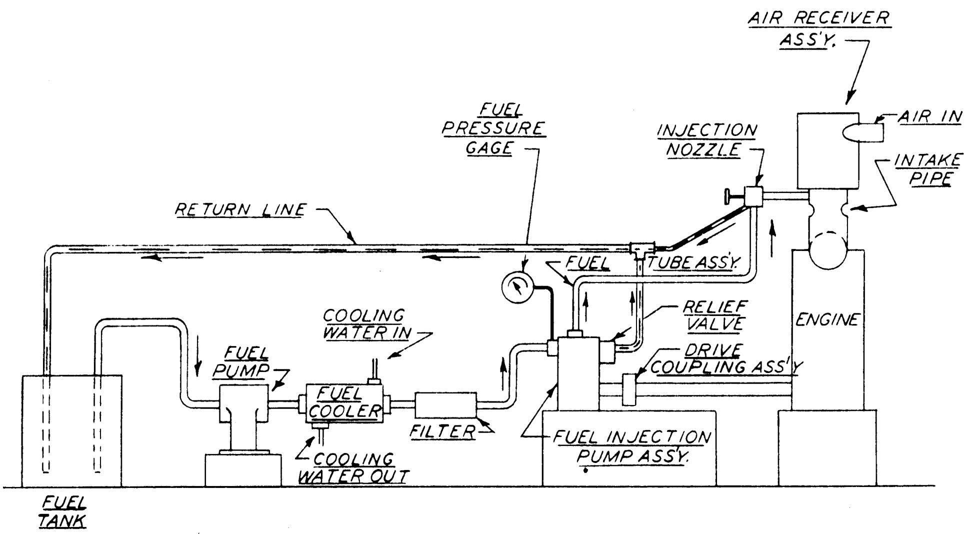

FIGURE 4—SUGGESTED FUEL SYSTEM

The fuel injection pump assembly, a single cylinder Robert Bosch type PES1A80C 300/3RSX01 (ref. Labeco 200026-1) is mounted on the same mounting bracket that supports the magneto. The pump has a variable delivery rate and is driven at half engine speed through a drive coupling assembly (similar to that used for the magneto) connected to the front extension of the engine camshaft. The pump outlet connection contains a spring loaded relief valve to maintain a pressure in the pump gallery of 100 kPa ± 15 kPa (15 psi ± 2 psi) to reduce vapor locking. A water cooling element is installed in the pump gallery through which cold water is circulated to maintain the fuel temperature within the desired range of 16 to 32 °C (60 to 90 °F).

A portion of the fuel, determined by the injection pump control rod setting, is passed to the injection nozzle and the balance is returned to the fuel tank. The injection pump lubricant, SAE 30 oil or castor oil, should be changed at least every 50 h. The timing of the injection pump is accomplished by setting the engine flywheel at 60 degree atc on the intake stroke, and coupling the injection pump to the engine camshaft with the scribed line on the tapered shaft of the pump aligned with the "R" line on the pump endplate, for clockwise rotation of the pump as viewed from the drive end. When aligned, the bypass port of the pump is closed and fuel delivery to the nozzle begins.

The injection nozzle is mounted on the upper end of the intake pipe and sprays fuel directly across the passage at right angles to the air flow direction.

9. Cooling System—With those agencies that still utilize the older integral type cylinder head wherein the coolant temperature must be maintained at 130 °C (265 °F), a pressure type cooling system is used. A detailed description of a suggested type when using the integral head is well documented in the AS840 Manual published in July 1964.

Where the spark plug insert type cylinder head configuration is utilized, the previously mentioned pressurized system may be used. However, experience has shown that since coolant temperatures required on this type head are only 88 °C (190 °F), a system operated at atmospheric pressure is the more desirable. Figure 5 illustrates a suggested cooling system of this type. It consists basically of a coolant pump, heat exchanger, and expansion tank with auxiliary plumbing to effect coolant distribution to both the spark plug insert and the combustion chamber jacket. The coolant pump may be of the centrifugal type with enough capacity to circulate coolant at a rate of approximately 19 L/min (5 gal/min) under operating conditions.

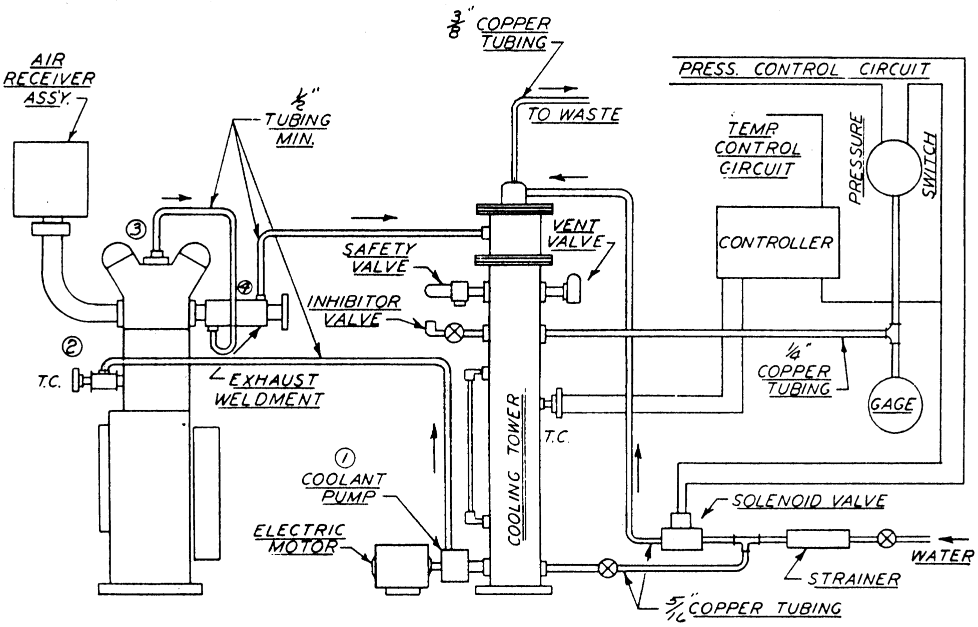

FIGURE 5—SUGGESTED COOLING SYSTEM

The heat exchanger may be a commercial unit which has a rating of approximately 95 000 Btu/h (6650 gr.-cal/s) to heat up tap water entering at room temperature to the required 88 °C (190 °F).

Adequate temperature controllers are to be placed at the inlet points to both the cylinder head jacket and the spark plug insert such that 88 °C (190 °F) inlet temperatures are maintained.

Distilled or treated water is used for the coolant to prevent formation of mineral deposits in the cooling system. Since this system operates at atmospheric pressure, the expansion tank should be elevated to a position such that the coolant level is above the highest point in the engine. Make-up coolant may be added as required.

10. Lubrication System—The schematic layout of the complete lubrication system for the 5750 engine is shown in Figure 6. The oil pump is mounted externally on the front timing gear case cover and driven through an Oldham coupling by the left-hand counterbalance shaft. All bearings are pressure lubricated through a single pressure relief valve set to 690 kPa ± 35 kPa (100 psi ± 5 psi). The timing gears and the counterbalance drive chain are lubricated by splash from a metered hole in the right-hand counterbalance driveshaft sprocket. The valves and rocker arms are lubricated by bleed-off oil that comes through the camshaft to the valve lifters and through the pushrod to the rocker arms. The pressure to the valve gear is 70 to 105 kPa (10 to 15 psi) depending on the clearance in the camshaft bearings and between the valve lifter and valve lifter guide.

The oil cooler is fabricated with steel tubing and is identical in detail to the coolant heat exchanger (Figure 5) with the exception of length.

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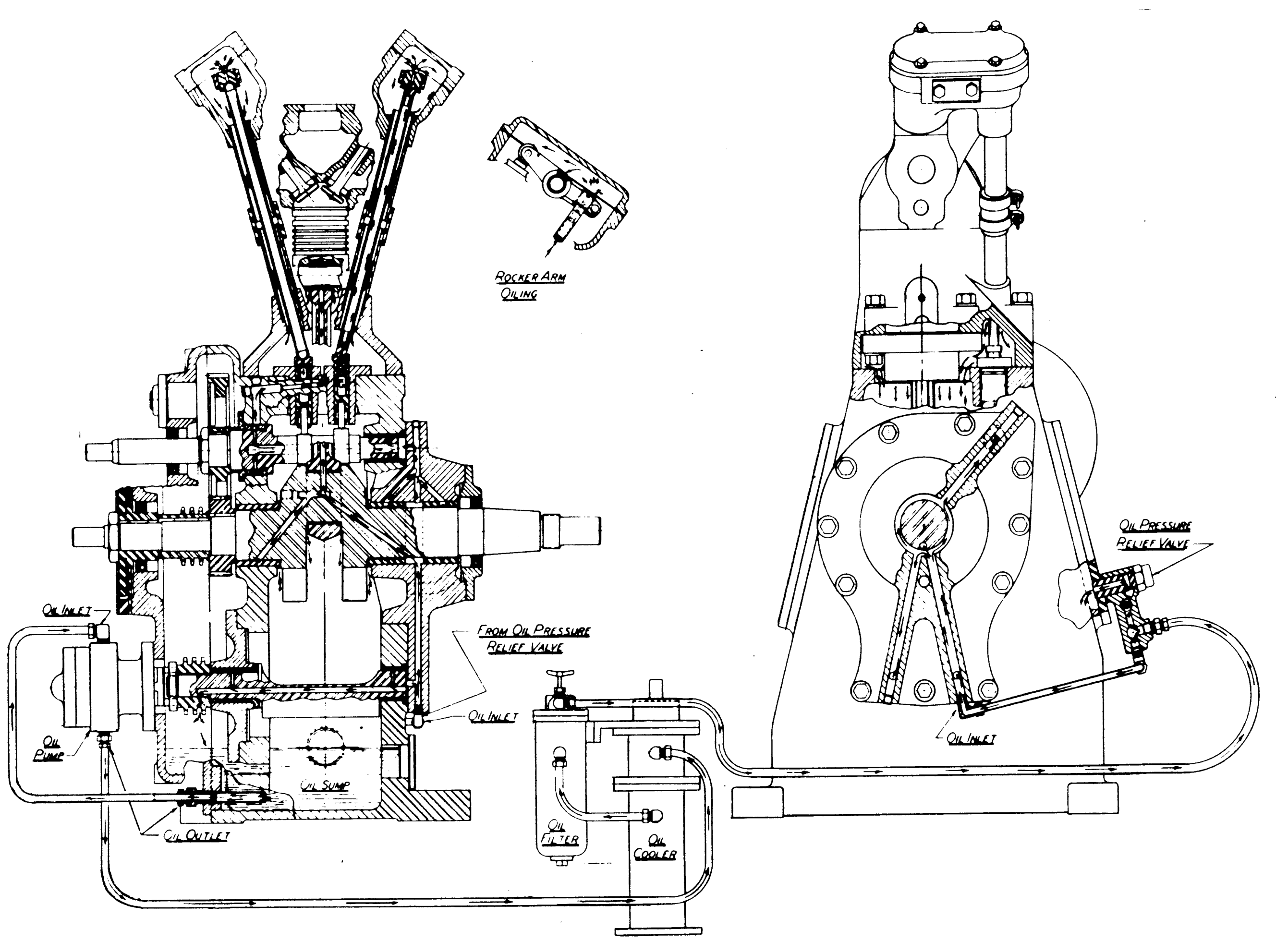

FIGURE 6—#5750 ENGINE LUBRICATION SYSTEM

10.1 The oil filter is a heavy-duty edge type design 0.1 mm (0.0035 in) spacing between discs to withstand high pressures and so made that the disc edges may be cleaned without disassembly. Three taps are provided for oil drain, oil entrance, and oil exit, respectively.

10.2 Alternate Oil Filter—An aircraft-style oil filter in conjunction with a remote filter head assembly may be used as an alternate to the disc-type originally supplied with the rating engine. The filter should have a burst pressure test value of 2760 kPa (400 psi) minimum and should not have an internal bypass system. The filter head should have a bypass system with a visual and electrical indicator to indicate when filter is being bypassed. These filters are a spin-on type and should be replaced at regular intervals. It is recommended these filters have a 45 µm or less particulate restriction.

Four tubular cartridge-type oil heaters are located on the front of the crankcase and extend into the base of the crankcase. Three crankcase heating capacities (285, 570, and 1140W) are available.

The lubricating oil is nonadditive aviation SAE 120 type. Twenty cc of DAG Dispersion NO. 2404 to each 2.2 L (2.5 qt) of oil may be used to reduce varnish formation on moving engine parts. The crankcase oil level indicator is incorporated in a casting that is bolted to the side of the crankcase, the oil level being maintained halfway up the sight glass with the engine at rest. (Crankcase capacity 2.2 L (2.5 qt)—entire system, approximately 5.7 L (6 qts). The oil sump should be drained, completely cleaned, and refilled every 50 h.

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11. Exhaust System—The exhaust pipe weldment, held to the cylinder head by four studs, consists of a 25.4 cm (10 in) long steel tube with steel flanges brazed to each end. The tube is jacketed approximately two-thirds of its length by another steel tube, the assembly to serve as a coolant heat exchanger.

Although the primary purpose of this coolant heat exchanger is to aid in maintaining cylinder jacket coolant inlet temperature when the engine is being operated at low boost and hence low power, it also is very effective in: (a) avoiding corrosion and cracking of the exhaust pipe weldment; (b) Removing exhaust heat from the immediate vicinity of the engine for the comfort of the operator; (c) in avoiding seizure of the nuts and studs holding it to the cylinder head.

A recommended system, which has given a minimum of trouble and has been widely used, is one in which the exhaust gasses are cooled by a water spray, the resultant mixture passing through a section of rubber covered steam hose to the exhaust pipe. Such a system has the double advantage of cooling the exhaust pipe for operator comfort and preventing exhaust pipe leaks occurring from cracking of seams or welds due to excessive temperatures. The water spray nozzle is welded to a flange, the unit being held to the exhaust weldment by stainless steel bolts and nuts. The elbow faces in a downward direction away from the operator, the water-exhaust mixture going into a 10.2 cm (4 in) pipe that is led outside the building into a 10.2 cm (4 in) tee. Two pieces of pipe are screwed into this tee; one extending vertically above the building parapet on which a muffler may be placed for quieting purposes, the other extending vertically downward to an exhaust sump. The water drain in the sump is held at a level approximately 12.7 cm (5 in) above the bottom end of this lower section and serves both as a water seal and as a back pressure relief valve in the event the upper vertical stack becomes plugged.

A simple back pressure alarm may be made by inserting a wire into each leg of a U-tube that contains a solution of water and salt, one wire immersed in and the second wire located above the electrolyte. A simple electrical circuit is made by connecting a bell, a 6 V power supply, and the U-tube “switch” in series. When the back pressure increases to raise the electrolyte sufficiently to contact the second wire, the circuit is completed to ring the bell.

The remainder of the exhaust system for the engine may be left to the discretion of the test laboratory provided a few precautions are taken. In general, it is recommended that precautions be taken to avoid any resonant effect that may cause alternating high and low back pressures. Such a resonant effect may be easily overcome by any of a variety of damping methods, such as elbows, surge chambers, and so on. Back pressure in the system should be limited to avoid difficulty in cylinder exhaust scavenging due to valve overlap resulting in abnormal cylinder head temperatures. Any possible water trap in the exhaust system should be avoided. It is recommended to slant the exhaust down from the weldment to prevent collection of moisture when the engine is not in operation. This pipe may be water jacketed for additional heat removal from the test area.

Provisions should be made so that the exhaust pipe may readily be disconnected and plugged in the event that the engine is not to be run for a prolonged period to avoid exhaust pipe weldment corrosion from exhaust acids.

12. Crankcase Breather System

12.1 Standard System—The 5750 engine has a casting attached to the left side cover plate. This casting is tapped for 12.7 mm (1/2 in) pipe. An elbow may be inserted here and a short length of pipe extended vertically or to an exhaust system. A baffle on the inside of the plate prevents splash leakage.

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13. Air Supply System—The air supply system consists of a compressor, an air/water separator tan, a float-operated valve, a water circulatory pump, a water level alarm, a normally closed solenoid valve, an air pressure regulator, two air heaters, an auto transformer, an air temperature controller, and miscellaneous electrical equipment.

The compressor used is of the centrifugal displacement type of pump (Nash MD574 or Nash 1251) and consists of a round, multiblade rotor that revolves freely in an elliptical casting partially filled with water. The rotor blades are curved and project radially from the hub and form, with the side shrouds, a series of pockets around the periphery. The rotor revolves at a speed high enough to throw the liquid out from the center by centrifugal force, resulting in a solid ring of liquid revolving in a casing at the same speed as the rotor, but following the elliptical shape of the casing. As the liquid follows the casing and withdraws from the rotor, the air is pulled in through two inlet ports located around the hub of the rotor and connected with the pump inlet. As the liquid is forced back into the rotor chamber by the casing, the air trapped in the chamber is compressed and forced out through two discharge ports located around the hub of the rotor and connected to the pump outlet. The water supplied to the pump takes up the heat of compression, the surplus water being discharged with the air.

The air/water separator consists of a tank that acts as a centrifugal separator by removing the sealing water from the air. As the mixture of air and water enters the separator tangentially, the water falls to the bottom and is dumped by a float-operated discharge valve located about one-third the way up the tank. Vertical baffles rise several inches above the water level and prevent the water in the base from spinning in a vortex and climbing the sides of the separator. Air is drawn off through a delivery pipe that projects some 3 in into the dome to prevent swirling water on the dome surface from creeping into the discharge air. The interior of the separator is galvanized as it is subjected to rather severe corrosive conditions due to being violently scrubbed with air-saturated water. Couplings are welded to the tank for drain, water level sight glass, thermocouples, and pressure taps.

The air delivered from the separator is in a saturated condition and may be cooled below its dew point and deposit water in the lines if the surrounding temperature conditions are suitable. In order to prevent such deposition of moisture, the air is discharged from the separator into a 3 kW line air heater. Current is supplied to an automatically-controlled heater to raise the temperature of the air a sufficient amount so that it will remain above the tank temperature to the next air heater located adjacent to the engine. Constant pressure is held at any predetermined value in the system by an air pressure regulator of the differential pressure diaphragm type, which bleeds off any excess air not used by the engine.

The air pressure delivered to the engine is controlled by a large valve 31.8 mm (1-1/4 in) gate and a small fine adjustment valve 3.18 to 12.7 mm (1/8 to 1/2 in) needle manually controlled. The throttle air passes through an inlet air heater into the engine air receiver assembly. With the equipment in this sequence, the expansion of the air at the throttle valves occurs before the heat is applied and regulation of manifold pressure and temperature is simplified. The inlet air heater consists of an enclosed 3 kW electric unit connected to the air receiver assembly by a flexible tube, preferably metallic, as rubber hose is likely to char. The inlet air heat is automatically controlled to 107.2 °C ± 2.8 °C (225 °F ± 5 °F) by suitable temperature control connected to a thermocouple located in the air receiver assembly. The across-the-line load of the heater is carried by a suitable normally open contactor, the holddown coil current being supplied by the controller.

The schematic layout of the air supply system is shown in Figure 7. As may be seen, the air is delivered to the compressor through a silencer and a check valve and fed together with the sealing water into the separator. The silencer is used to lower the noise level, the check valve to prevent the water from being blown back through the compressor when it is shut down. From the separator, the air goes through the line air heater to the engine throttle valves, through the inlet air heater into the engine. All the piping is 31.8 mm (1-1/4 in) galvanized and lagging is recommended for all long runs.

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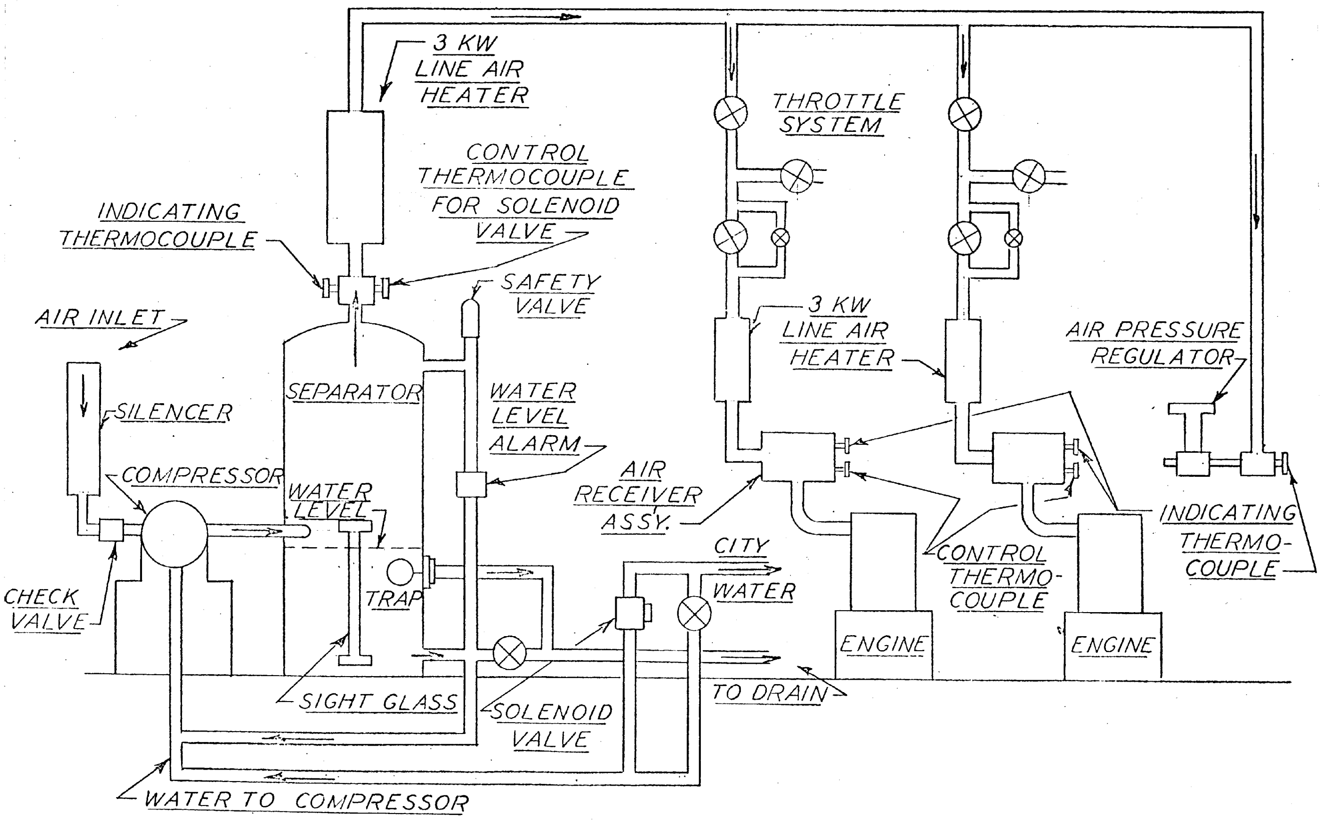

FIGURE 7—AIR SUPPLY SYSTEM

To control the moisture content of the supercharging air at 75 grains ± 25 grains (434 gms) of water per pound of dry air, the air pressure and air temperature in the tank must be held to essentially constant values. The temperature for various pressures to maintain this moisture content are as in Table 1:

TABLE 1—TEMPERATURE FOR VARIOUS PRESSURES TO MAINTAIN MOISTURE CONTENT

System Pressure	Separator Tank Air Temperatures	Separator Tank Air Temperatures
	°C	°F
310 kPa (45 psi)	38.9	102
380 kPa (55 psi)	41.7	107
468 kPa (65 psi)	44.4	112

These temperatures are controlled by automatic regulation of the amount of water being admitted to the inlet of the water circulating pump, which in turn supplies the water under pressure to the compressor. This circulating pump must be started and pressure developed before the compressor is started. The sealing water is now in circulation through the system; it warms up due to heat of compression in the compressor. When the discharge air temperature reaches the specified separator tank air temperature, a normally closed solenoid valve is opened and cold water enters the system. The water supply must be at least 69 kPa (10 psi) higher than the compressed air pressure. The excess water goes out through the water float in the separator to the drain. When the discharge air temperature drops below the specified value, the solenoid closes and the water is again warmed by the compressor. A thermocouple mounted in the exit air line leading from the separator actuates the solenoid valve.

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Two safety devices are incorporated in the installation. Mounted on the side of the separator is a water level alarm that rings a bell if the water rises in the tank and warns the operator that the water float valve has stuck. This can be connected to the compressor and/or the engine to automatically shut it off if desired.

To prevent the line air heater from burning up in the event the compressor fails, the line to the holding coil in the contactor for the heater is wired to the load side of the starter for the compressor motor. In this way, either seizure of the compressor or momentary power failure throws out the starter switch that has thermal overload protection and cuts the power to the heater.

WARNING—Extreme caution should be exercised in completely shutting off the throttle valves to the engine if the compressor is allowed to run while the engine is shut down for any length of time. If the throttle valve is just barely cracked to atmospheric pressure, the expansion of the humidified air results in the water falling out of the air in the pipe downstream from the valve and entering the air receiver assembly. Although this water may not be of sufficient depth to flow over the standpipe in the receiver and into the intake pipe with the engine stopped, there may readily be enough lying in the bottom of the receiver to climb its walls in a vortex as the airflow through the receiver increases due to its tangential air entry. As the engine is of such small displacement, sufficient water may collect in the inlet air heater or throttle valve assembly to wreck the engine if allowed to enter the cylinder. If there is the slightest doubt that water has collected in the system, first, drain the receiver by the plug provided at the bottom of the casting; second, remove the spark plug and motor the engine with gradually increasing air velocity into the intake pipe. Such a procedure will safely remove all water and bent connecting rods; caved-in pistons and broken cylinders will be avoided.

14. Maintenance and Overhaul Procedure

14.1 General—It is strongly recommended that inspection of engine components be avoided unless there are obvious signs of trouble. Frequent teardown of the engine not only is unnecessary and time-consuming, but greatly increases the possibility of damage to the engine parts through careless handling.

With proper attention, the crankcase should run 5000 h before teardown inspection and overhaul are required. The need of an overhaul or replacement of any engine part or assembly in most instances is quite evident. A deep rumbling type of knock usually denotes main bearing failure; a high-pitched rattle, a loose wrist pin, and a high-pitched howl or whine indicates timing gear trouble. Oil seepage at the camshaft or crankshaft extensions through the crankcase denotes oil seal failures. Excessive clatter in the rocker boxes indicates either wear of the rocker roller pin, wear of the rocker arm thrust washer, valve spring interference, or excessive tappet clearance. Loss of oil pressure may denote wear in the pump, loosening of the pump body from the crankcase, a plugged inlet line, a relief valve stuck open, or bearing failure. Runaway coolant temperatures may mean either vapor locking in the coolant pump, seizure of the pump, or failure of the driving motor. Missing may be caused by spark plug failure, ignition cable failure, magneto trouble, injection pump plunger sticking, vapor locking of the fuel in the injection pump, fuel supply pump failure or perhaps by simply being too lean. Continued experience with the engine will make the operator familiar with the general noise level of the unit and more able to diagnose any symptoms accurately. In the event of any sign of distress, the fault should be found and repaired immediately, not allowed to continue until major damage has been done to the engine.

The need for having a valve job or reringing is not usually as evident and will be covered in some detail. Under normal routine operation, valve reconditioning periods of 150 h are sufficiently conservative, but engine performance is still the best indication for the need of an overhaul as service under conditions of severe preignition at high IMEP may bring the time period under 100 h. It is desirable to check the compression pressure periodically. Compression pressure should be approximately 790 kPa (115 psi) at 900 rpm. At any fixed set of engine conditions, there is a definite boost-IMEP relationship that is a straight line function as shown in Figure 8 and should be used to determine when the engine is in good condition. At high power levels, plotted points will fall below this curve if valves or rings are bad. A positive valve check may be made by removing the intake pipe and exhaust pipe weldment, turning the engine flywheel by hand until the piston is at bdc on the compression stroke, pouring gasoline into the valve ports covering the valve heads, and bringing the piston to tdc on the compression stroke by turning the flywheel with the hands. If valves or seats are in bad condition, the leakage of air past the valve through the gasoline is readily visible.

The most positive check of oil pumping is inspection of the piston head by means of a light (a medical diagnostic type is best) inserted through a spark plug hole. If the cylinder bore looks scuffed or scored and the piston head flooded with oil, it can readily be assured that the rings are also scuffed and possibly either stuck or broken. If the cylinder bore looks good and more than a film of oil is present on the piston head after shutting down the engine from 2700 rpm, reringing is generally indicated providing the rings are not new or have not just been cleaned. If the rings are either new or have been recently removed from the piston for cleaning, additional running is necessary to establish a good seal between the ring faces and the cylinder bore. Usually this can be accomplished by operating the engine at 2.415 MPa (350 psi) IMEP for 2 to 3 h.

The most common reason for high oil consumption is excessive ring side and end clearance. The compression rings have a minimum of 0.1 mm (0.004 in) of chrome plate and can readily accept 0.05 mm (0.002 in) average wear on the face without possible danger of wearing through the plate. Thus, an end clearance increase of 0.3 mm (0.012 in) could be tolerated. The limits of the end and side clearances are listed in Appendix A. Rings that show any signs of scuffing should be replaced. If one ring requires replacement, all rings should be replaced.

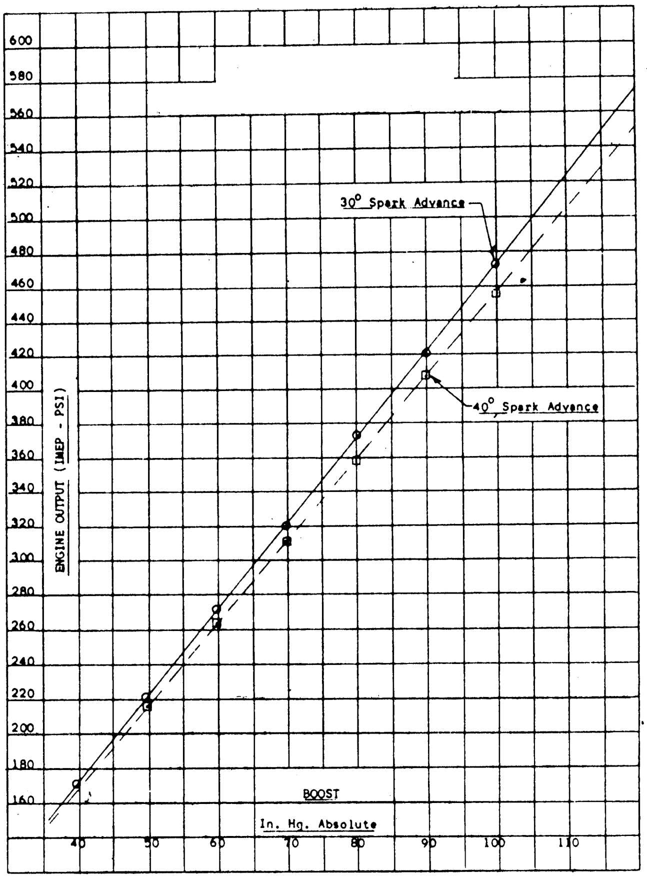

FIGURE 8—ENGINE BOOST VERSUS OUTPUT POWER CURVES AT MAXIMUM THERMAL PLUG TEMPERATURE

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14.2 Detailed Disassembly of 5750 Engine

14.2.1 REMOVAL OF CYLINDER ASSEMBLY

a. Disconnect all accessories.
b. Remove intake pipe and exhaust pipe weldment.
c. Remove rocker box covers.
d. Fasten a wire clip, Part No. 5700, to each push rod and its respective rocker arm to prevent the push rods from falling out as the cylinder is lifted.
e. Remove the six nuts holding the assembly to the crankcase.
f. Bring the engine to bdc.
g. Lift the assembly from the crankcase, being sure not to allow the piston to fall against the crankcase.
h. Remove the push rods.

14.2.2 REMOVAL OF THE PISTON

a. Repeat 14.2.1.
b. Push out full floating piston pin and remove piston.
c. Remove the piston rings being careful not to spread the rings more than necessary for removal. A perfect circle ring expander may be used.

14.2.3 REMOVAL OF CYLINDER HEAD ASSEMBLY

a. Repeat 14.2.1.
b. Loosen the clamps on the push rod housing hoses and push the hoses down onto the lower push rod housing.
c. Remove the ten bolts holding the head assembly to the cylinder.
d. Remove the head from the cylinder. These will pull apart easily once the gasket seals are broken loose.

14.2.4 REMOVAL OF THE CYLINDER SLEEVE[2]

a. Repeat 14.2.3.
b. Remove the 9.5 mm (3/8 in) socket heat cap. Screw on the lower face of the sleeve flange.
c. Remove the sleeve from its housing.

14.2.5 REMOVAL OF THE VALVE GEAR

a. Repeat 14.2.3.
b. Remove the rocker shaft cover.
c. Push out the full floating rocker shaft with the fingers.
d. Lift out the rocker arms and thrust washers.
e. Compress the valve springs and remove the valve spring retaining keys. Use compressing tool, Part No. 5254.
f. Remove valve springs, retainers, spacer, and valves.

14.2.6 REMOVAL OF THE IGNITION TIMING DISC

a. Remove the ignition timing disc quadrant support.
b. Bend back the ear of the lock washer that anchors the nut on the front end of the crankshaft.
c. Remove the front crankshaft nut and lock washer.
d. Remove the disc by pulling with the fingers.

2. Not to be done unless replacement is necessary.

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14.2.7 Removal of the Timing Disc Space Sleeve from the Crankshaft (if present)

a. Remove with puller, Part No. 5702.

14.2.8 Removal of the Oil Pump

a. Remove four 9.5 mm (3/8 in) nuts and washer.
b. Remove oil pump and Oldham coupling.

14.2.9 Removal of Timing Gear Case Cover

a. Repeat 14.2.7.
b. Remove the cap screws holding the casting to crankcase.
c. Remove the cover. Use cap screws in the two tapped holes provided and jack the cover loose.

14.2.10 Removal of the Counterbalance Drive Chain

a. Remove socket head locking screw from idler sprocket bushing bolt.
b. Remove idler sprocket bushing bolt.
c. Remove idler sprocket and bushing.
d. Remove drive chain.

14.2.11 Removal of the Camshaft Assembly

a. Repeat 14.2.1.
b. Repeat 14.2.9.
c. Remove the valve lifter guides from the crankcase top deck.
d. Remove the valve lifters through the crankcase.
e. Remove the cap screws holding the front shaft bearing to the crankcase.
f. Remove the camshaft together with its driving gear and front camshaft bearing.

14.2.12 Removal of the Camshaft[3]

a. Repeat Steps a, b, c, and d of 14.2.11.
b. Bend back the ear of the lock washer that anchors the nut on the front of the camshaft.
c. Remove the camshaft nut and lock washer. Use socket wrench, Part No. 5703.
d. Repeat Steps e and f of 14.2.11.
e. Remove the timing gear from the camshaft. Use an arbor press to press the camshaft out of gear, taking care not to foul the front bearing.

14.2.13 Removal of the Crankshaft Sprocket and Timing Gear

a. Repeat 14.2.9.
b. Remove crankshaft sprocket with suitable puller.
c. Remove timing gear. Use the puller, Part No. 5704.

14.2.14 Removal of the Flywheel

a. Bend back the ear of the lock washer that anchors the flywheel nut.
b. Remove the flywheel nut and lock washer. Use the socket Part No. 5705.
c. Thread on the collar, Part No. 5706, over the crankshaft threads.
d. Remove the flywheel. Use a suitable puller and do use a chain fall or get help to lift it off the shaft.

3. Only to be done if obviously damaged.

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14.2.15 REMOVAL OF THE CRANKSHAFT REAR OIL RETAINER

a. Remove the flywheel key.
b. Remove six cap screws and washers.
c. Remove crankshaft oil retainer. Use 9.5 mm (3/8 in) cap screws in the two holes tapped in the flange.
d. Remove gasket.

14.2.16 REMOVAL OF THE CONNECTING ROD

a. Repeat 14.2.2
b. Remove the crankcase side cover assembly (breather side).
c. Remove the cotter keys in the connecting rod bolts and the nuts.
d. Remove the connecting rod cap. Use a composition hammer and tap the cap lightly, first on one side and then on the other.
e. Remove the connecting rod.

14.2.17 REMOVAL OF THE CRANKSHAFT REAR BEARING ADAPTER

a. Repeat 14.2.14.
b. Repeat 14.2.15.

14.2.18 REMOVAL OF THE COUNTERBALANCE ASSEMBLY

a. Remove six cap screws and washers.
b. Remove assembly. Note locating dowel on top flange.

14.2.19 REMOVAL OF THE COUNTERBALANCE SHAFTS

a. Mount the counterbalance assembly in a soft jaw vise, using the flats on the counterbalance shafts.
b. Bend back ear of the lock washer on right-hand shaft.
c. Remove both nuts with suitable wrench.
d. Remove sprockets and bearing adapter.

14.3 Detailed Inspection and Assembly of 5750 Engine

14.3.1 COUNTERBALANCE ASSEMBLY

a. Inspect the counterbalance shaft bearing journals for galling and wear. See Appendix A for dimensions.
b. Inspect front and rear counterbalance shaft bushings for wear. See Appendix A for dimensions. Replace if required. Bushings are a push fit.
c. Inspect sprockets for excessive wear and replace, if required.
d. Insert counterbalance shafts in bearing adapter. Clamp in a soft jaw vise. (The shafts are interchangeable.)
e. Replace sprockets. Dowel pin hole in adapter indicates top. Use vertical keyway on left-hand shaft and horizontal keyway on right-hand shaft. This is to align the chain oiling hole in the sprocket and the shaft.
f. Replace nuts using a lock washer on the right-hand shaft only. The nut on the left-hand shaft has a slot for an Oldham coupling.
g. Install assembly in crankcase. No gasket used.

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14.3.2 CRANKSHAFT

a. Inspect the crankshaft for galling and for wear of the bearing journals. See Appendix A for dimensions.
b. Inspect main bearings for any sign of failure and wear. See Appendix A for dimensions.
c. Insert crankshaft through the front main bearing, being careful not to nick bearing with threads or shoulders of crankshaft.
d. Clean mating surfaces of crankcase and rear main bearing adapter, removing any nicks or burrs.
e. Install gasket dry or with soft soap.
f. Install rear main bearing adapter, being careful not to nick bearings on shoulders of crankshaft. Alignment is assured by the piloted shoulder on the adapter.

14.3.3 CRANKSHAFT REAR OIL RETAINER

a. Clean mating surfaces of crankcase, rear bearing adapter and rear oil retainer. Inspect oil seal and replace if necessary.
b. Install gasket.
c. Install retainer on adapter.

14.3.4 CRANKSHAFT TIMING GEAR

a. Inspect the gear teeth, bore and faces, and remove any nicks and burrs.
b. Insert the Woodruff drive key in the crankshaft.
c. Align the gear on the shaft with the side outward having an “X” on one tooth. Tap gently with a composition hammer to start.
d. Press the gear on the crankshaft. Push it on using the front crankshaft lock nut and the tool, Part No. 5708.
e. Install crankshaft chain sprocket.

14.3.5 CAMSHAFT

a. Inspect cams and bearing journals for signs of galling or wear and replace if necessary.
b. Inspect camshaft bearings. See Appendix A for clearance.
c. Install the camshaft and its front bearing.
d. Check end play. See Appendix A for clearance.

14.3.6 CAMSHAFT DRIVE GEAR

a. Install Woodruff key in the camshaft.
b. Reinstall gear using original keyway. Use arbor press.
c. Install camshaft assembly with the “X” marks on the gears mating.
d. Install the camshaft gear lock nut and lock washer.
e. Bend a shoulder of the lock washer over a flat on the camshaft nut.

When new timing gears are to be installed, the assembly procedure is as follows: Install the crankshaft timing gear on the crankshaft so that the puller holes on the front face of the gear face outward. Normally select the center keyway of the camshaft gear for the initial timing check. The front of the camshaft gear may be identified by the 9.5 mm (3/8 in) hub extending from the web to the face of the gear; the rear has a 3.2 mm (1/8 in) hub extending to the face of the gear. Install the Woodruff key in the camshaft and press the gear on to the camshaft, using the center keyway in the gear and the front of the gear extending outward.

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Set the crank angle and flywheel at 28 degrees atc on the flywheel indicator. Using the intake valve lifter and intake lobe of the camshaft for the initial setting, install the camshaft assembly mating with the crankshaft gear in such a position that the intake valve lifter is raised approximately 1.0 mm (0.040 in) on the ramp of the camshaft in the direction of engine rotation on the opening side of the intake cam lobe, with the camshaft bolted in the running position.

Then, using an indicator on the intake valve lifter, turn the flywheel toward tc or to a point before top center where there is no movement on the indicator needle. Then turn the flywheel in the direction of rotation and observe when you get 1.0 mm (0.040 in) lift on the intake valve lifter from the indicator and check flywheel degrees to see if the timing is within the limits listed in this section.

If the valve lifter rise does not fall within the limits, it will be necessary to shift the camshaft and gear assembly one or more teeth in the proper direction to bring the timing within the limits. If this operation does not bring the timing within the limits, then remove the camshaft gear and reinstall it on the camshaft, using one of the other two keyways of the gear; reassemble camshaft and gear assembly in the crankcase and repeat preceding procedure. Since this is a cut-and-try procedure, it may be necessary to try all three keyways of the cam gear before the timing will follow the timing data.

After the engine is timed correctly, set the engine on tdc of the firing stroke and make suitable markings on the teeth of the timing gears and camshaft gear keyway.

The camshaft timing, with the engine completely assembled and valve clearance set at 1.26 mm (0.050 in) is as follows (Figure 9):

Intake valve opens at 28 degrees atc ± 5 degrees atc
Intake valve closes at 22 degrees abc ± 5 degrees abc
Exhaust valve opens at 23 degrees bbc ± 5 degrees bbc
Exhaust valve closes at 1 degree btc ± 5 degrees btc
The valve clearance then must be reset to 0.46 mm (0.018 in) before running the engine.

NOTE—When checking the timing, some thought must be given that wear on the rocker arm rollers and pins, valve lifter rollers, hubs, and pins will cause some lag in the timing characteristics; so for a true check, all above parts should be within the recommended clearances. A 10-degree tolerance is allowed for a used cam before replacement is required.

14.3.7 VALVE LIFTER ASSEMBLIES AND GUIDES

a. Inspect parts for galling or wear. Replace if necessary. See Appendix A for clearance.
b. Install assembly and guide as a unit holding fingers under valve lifter during installation to prevent dropping into crankcase.

14.3.8 COUNTERBALANCE DRIVE CHAIN

a. Place crankshaft at top dead center.
b. Install counterbalance drive chain over crankshaft sprocket, under left-hand counterbalance driveshaft sprocket and over right-hand counterbalance driveshaft sprocket. Arrows on counterbalance shafts should point down.
c. Install idler sprocket bushing into idler sprocket.
d. Insert bolt. Tighten chain by turning eccentric bushing until it has 6.35 mm (1/4 in) deflection measured midway between the idler and crankshaft sprockets.
e. Lock idler sprocket bolt to idler sprocket bushing with Allen set screw. With chain tight, the arrows on the counterbalance shafts may not be exactly parallel.

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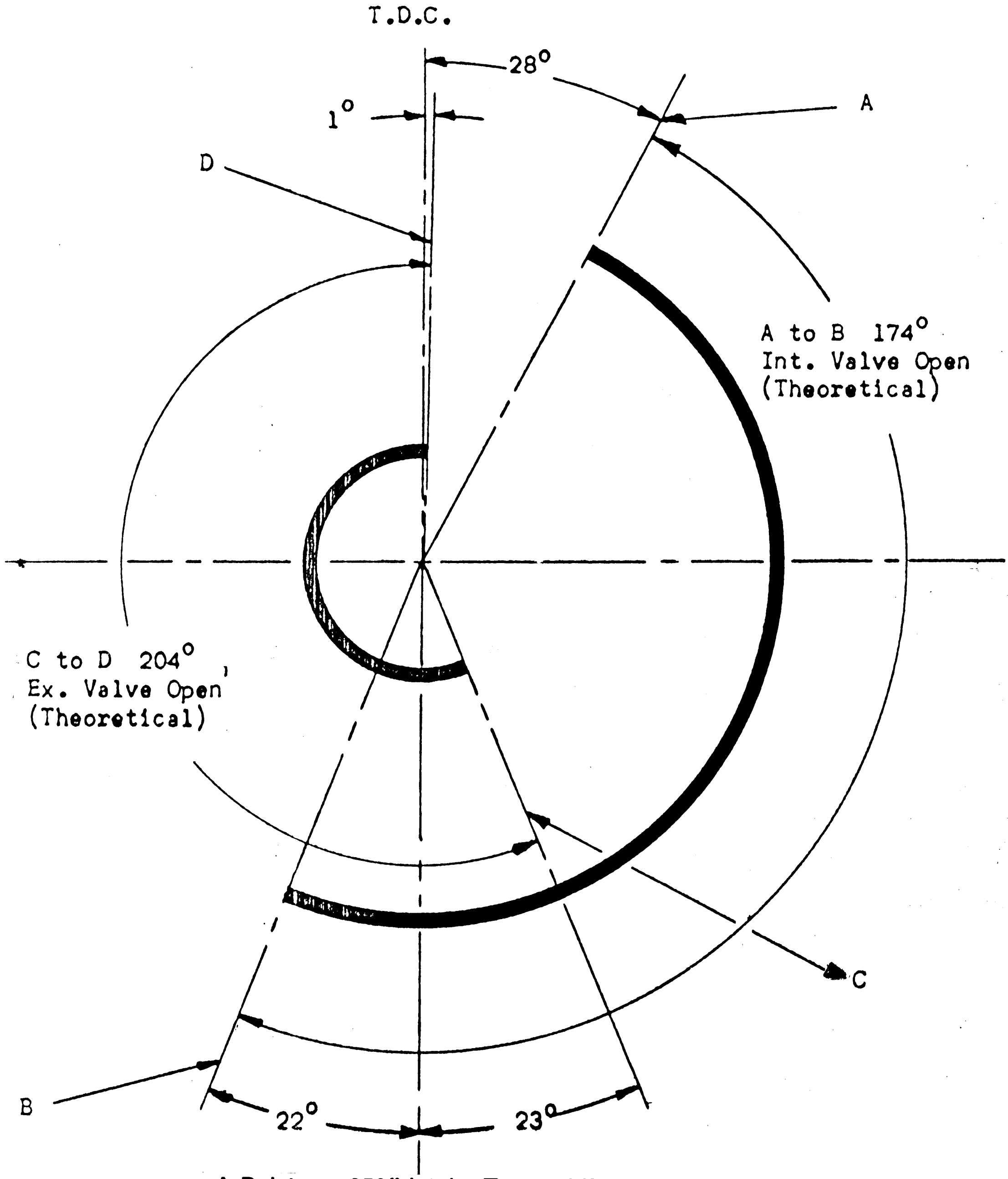

A Point .050″ Intake Tappet Lift
B Point .050″ Before End Intake Tappet Travel
C Point .050″ Exhaust Tappet Lift
D Point .050″ Before End Exhaust Tappet Travel
Maximum Cam Lift = Intake .274″, Exhaust .280″
Lift Angle Tolerances ±5°

FIGURE 9—VALVE TIMING DIAGRAM 1.26 mm (0.050 in) (VALVE CLEARANCE)
(COURTESY OF LABORATORY EQUIPMENT CORP.)

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14.3.9 TIMING GEAR CASE COVER

a. Inspect mating surfaces of crankcase and cover.
b. Inspect oil seals and replace if necessary.
c. Install gasket and timing gear case cover.

14.3.10 INSTALL TIMING DISC SPACER SLEEVE

14.3.11 OIL PUMP

a. Inspect pump for bushing wear and back lash. See Appendix A for clearances.
b. Insert Oldham coupling.
c. Inspect mating faces of pump and timing gear cover and install gasket.
d.Mount oil pump.

14.3.12 FLYWHEEL

a. Lift the flywheel and slip it on the crankshaft over the flywheel key with dummy nut, Part No. 5706, on threads. Remove dummy nut after the flywheel is in place.
b. Install the flywheel nut and lock washer. Tighten until the flywheel is well driven onto the crankshaft taper. Bend one side of the washer over the nut as an anchor.

14.3.13 CONNECTING ROD

a. Inspect the big end bearing and replace if scored or cracked. See Appendix A for dimensions. Avoid scratching the bearing during measurement. Use a snap gage, not inside calipers.
b. Inspect the wrist pin bushing. See Appendix A for fit.
c. Install by lowering upper end together with its bearing onto crankshaft journal and raising the cap with its bearing into place.
d. Draw up the connecting rod belts, using a torque wrench and 61.0 to 67.8 N·m (45 to 50 lb-ft) torque. Use cotter pins to secure the nuts to the bolts.

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14.3.14 CYLINDER HEAD

a. Remove spark plug insert and spark plug insert gaskets.
b. Remove combustion chamber deposits.
c. Inspect the valve seat inserts for looseness. This may be determined by inserting a close fitting pilot in the valve guide and measuring seat concentricity before and after tapping the insert on its back shoulder. Replace inserts if found loose.
d. Inspect the valve guides. Replace if scuffed, if bell-mouthed more than 0.6 mm (0.0025 in) or if I.D. of the intake and exhaust is greater than 10.9 mm (0.438 in). If new guides are needed, do not hammer them in. Do press them in with the tool, Part No. 5709, and finish ream to 10.9 mm (0.4365 in) for both the intake and exhaust.
e. Install a close fitting pilot in the valve guide and measure the runout of the inserts with a suitable indicator. If the runout exceeds 0.5 mm (0.002 in) or if the insert is pitted, burned, or corroded, refacing is necessary. Using a suitable grinder and 45 degree stones with true faces, grind the insert, first using a coarse stone and finishing with a fine stone, removing as little metal as necessary. Runout of the ground face should not exceed 0.025 mm (0.001 in). See Figures 10 to 13 for refacing limits and method of checking. Care should be exercised that intake valves are not installed in exhaust seats. To assist in identification, a dimple has been machined in the intake valve heads, and a bump has been left on the exhaust valve heads. The previously mentioned drawings illustrate these identifying markings.
f. Inspect the valves. Replace if bent, galled, or burned. See Appendix A for clearance. If the stems are lightly scuffed, remove the marks by stoning and lapping. Clean the valve heads and stems with fine steel wool. Do not clean them with a hard scraper. Reface, removing as little material as possible to provide a clean face having a 45 degree angle. If the valve face is 5.6 mm (7/32 in) or wider, replace.
g. Lap the valve face to the seat, first using a coarse regrinding compound and following with a fine compound. Lapping should be continued until blueing shows the seats on both valve and insert to be concentric. The valves shall withstand 690 kPa (100 psi) air pressure without leakage.
h. Completely and thoroughly wash the head in kerosene to remove all ground metal and grinding compound.
i. Inspect the rocker arm thrust washers and replace if galled.
j. Inspect the rocker arm needle bearings and replace if necessary. Press them in, using the tool, Part No. 5710, always with the lettered side of the bearing out.
k. Inspect the rocker arm shafts and replace if any Brinelling is evident.
l. Inspect the rocker arm rollers and pins. Replace if worn or galled.
m. Check valve springs for fractures. See Appendix A for load limits.
n. Place the thrust washer, and the lower retaining washer over the valve guide in each rocker box.
o. Compress the valve springs, slip in the valve, and place the retaining keys on the valve stem, release the valve springs. Use the tool, part No. 5245.
p. Push the rocker shaft from the lower side of the rocker box, through the rocker arm, the thrust washer, and the upper side of the rocker box. Use the drift, Part No. 5701.
q. Install rocker shaft covers, washers, and gaskets.
r. Check the thrust washer side clearance. If below 0.025 mm (0.001 in), lap the washer, if above 0.33 mm (0.013 in), replace it.
s. Check the mating surfaces between the head and cylinder housing and remove any nicks or burrs.

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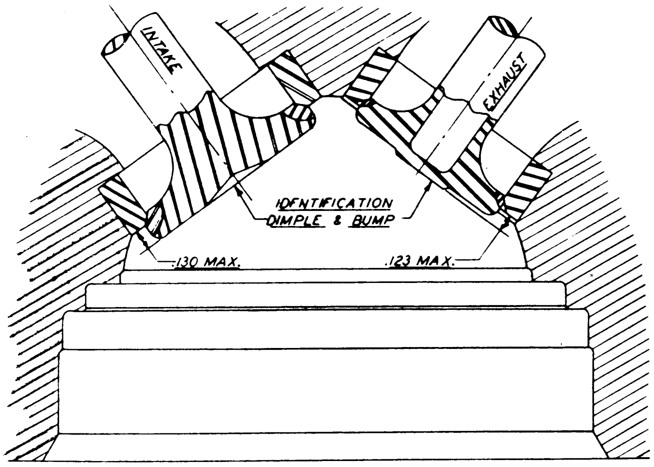

FIGURE 10——PROPER VALVE SEATING IN NEW CYLINDER HEAD

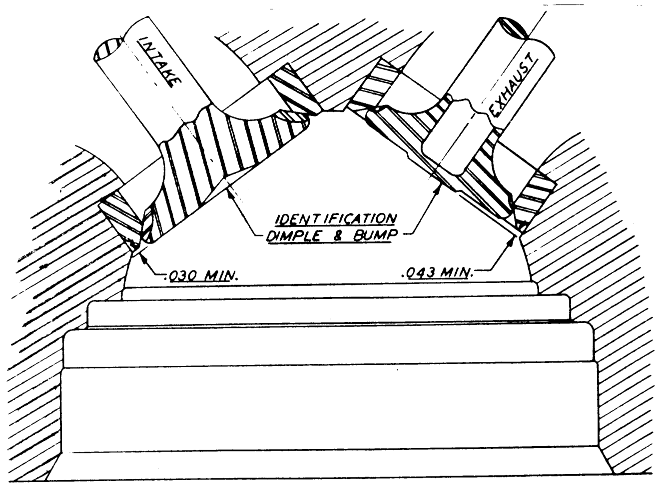

FIGURE 11——PROPER VALVE SEATING WITH REFACED VALVES AND REGROUND SEATS

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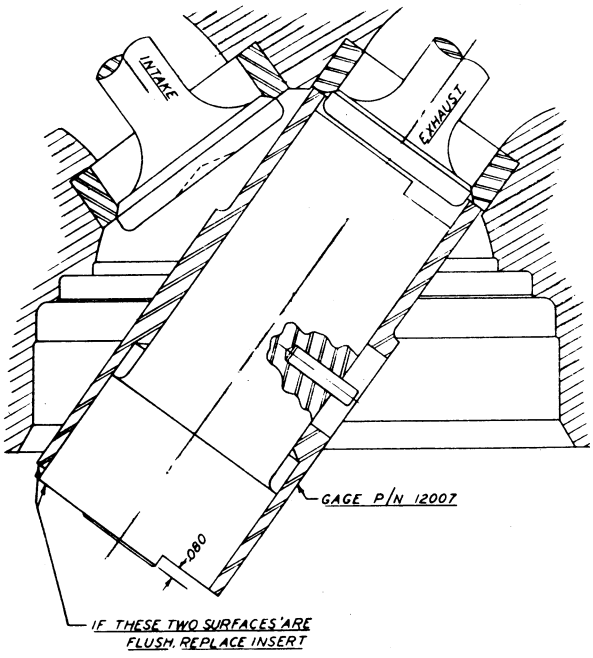

FIGURE 12——METHOD FOR CHECKING EXHAUST VALVE SEATING LIMITS

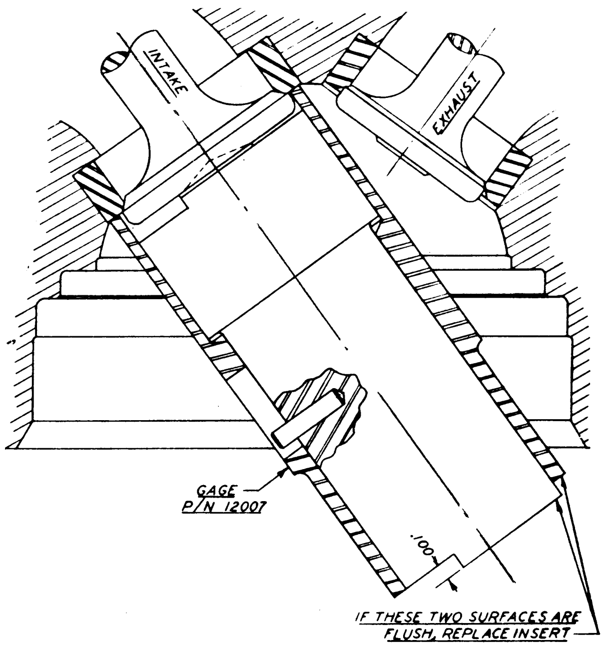

FIGURE 13——METHOD FOR CHECKING INTAKE VALVE SEATING LIMITS

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14.3.15 CYLINDER ASSEMBLY

a. Remove deposits with steel wool.
b. Inspect. See Appendix A for dimensions.
c. Check mating surfaces between sleeve flange and cylinder housing, removing all burrs and nicks.
d. Install copper gasket on sleeve outer ring sealing surface and 0.2 mm (0.007 in) thick nonmetallic gasket on sleeve flange.
e. Assemble sleeve and housing, using the two 3/8 in socket head cap screws.
f. Check all mating surfaces between cylinder housing and cylinder head, removing any burrs or nicks.
g. Install 0.2 mm (0.007 in) thick nonmetallic gasket between cylinder housing and cylinder head, and dry copper gasket between sleeve and cylinder head.
h. Fasten cylinder barrel assembly to cylinder head, using bolts with solid copper gaskets under the bolt heads, tighten the bolts evenly, using a torque wrench and 81.4 to 101.7 N·m (60 to 75 lb-ft) torque. Tighten bolts in an accepted sequence. Use a socket wrench with a torque measuring device.

14.3.16 PISTON ASSEMBLY

a. Remove deposits with a stiff brush, steel wool, or a scraper made by flattening the end of a copper tube. Do not use a wire brush or a buffing wheel.
b. Check piston for nicks and dents.
c. Check piston boss. Replace piston if scored or cracked.
d. Check for concentricity. Replace piston if skirt is more than 0.2 mm (0.007 in) out of round.
e. Inspect piston pin. Replace if worn or galled.
f. Remove ring deposits with steel wool.
g. See Appendix A for clearances.
h. If one ring is replaced, replace all rings.
i. Place the rings on the piston in the order removed. Install the compression rings with the inside bevel, if any, toward the piston head. Do not twist the rings and do not expand more than just enough to clear the piston. Do use a suitable expander and do expand them only enough to clear the piston.
j. Install the piston and its rings in the ring compressor, Part No. 5711.
k. Insert the piston pin through the piston bosses and connecting rod bushing. Do not drive it into position.

14.3.17 CYLINDER ASSEMBLY TO CRANKCASE

a. Examine mating surfaces of cylinder housing and crankcase deck.
b. Install the gasket on the crankcase deck.
c. Install the piston in the cylinder barrel by aligning the ring compressor I.D. with the bore of the cylinder and lowering the cylinder over the piston assembly. Remove ring compressor.
d. Insert the push rods and retain in position with wire clips.
e. Lower the assembly slowly, guiding all elements into proper alignment.
f. Tighten the assembly to the crankcase using a torque wrench and 61.0 to 67.8 N·m (45 to 50 lb-ft) torque on the hold-down nuts. Tighten bolts in an accepted sequence. Use a socket wrench with a torque measuring device.
g. Remove push rod wire clips and clamp the push rod housing hoses to the push rod housings.
h. Adjust the tappets to 0.45 to 0.50 mm (0.018 to 0.020 in) with engine hot and tighten the clamp screws.
i. Inspect mating surfaces on rocker boxes and covers.
j. Install rocker box cover gaskets.
k. Bolt covers to rocker boxes.
l. Install accessories.

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15. ***Engine Run-In Schedule***—The run-in schedule for a new or rebuilt engine is dictated by the rapidity with which the rings and cylinder sleeve bore run-in, provided bearing clearances follow recommendations and lubrication is adequate.

The engine schedule recommended for a new or rebuilt engine is shown in Table 2.

If the power absorption equipment is such that the speed schedules in Table 2 cannot be followed, the best compromise available is acceptable.

TABLE 2—ENGINE RUN-IN SCHEDULE FOR NEW OR REBUILT ENGINES PLUS USED CYLINDER AND NEW RINGS

Hr	RPM	Operating Conditions mm (in) Hg abs.	Operating Conditions Jacket Temp. °C (°F)	Operating Conditions Air Temp. °C (°F)
1	900 Firing	762 (30)	87.8 (190)	43.3 (110)
1	1800 Firing	762 (30)	87.8 (190)	43.3 (110)
2	2700 Firing	762 (30)	87.8 (190)	107.2 (225)
2	2700 Firing	1016 (40)	87.7 (190)	107.2 (225)
1	2700 Firing	1270 (50)	87.8 (190)	107.2 (225)
1	2700 Firing	1524 (60)	87.8 (190)	107.2 (225)
At this point, spark plugs may be rated at 200 IMEP or lower.				
1	2700 Firing	1778 (70)	87.8 (190)	107.2 (225)
1	2700 Firing	2032 (80)	87.8 (190)	107.2 (225)

Note—On installations equipped with pressure coolant control, jacket temperature should be maintained at 107.2 °C (225 °F).

The schedule shown in Table 2 is conservative for most cases as run-in can be accomplished in less time. It is recommended that the engine be shut down before each change of operating conditions and the cylinder inspected with a light through the spark plug hole for any signs of scratching or scuffing. Any indication of distress is considered to be sufficient reason to drop back on the run-in schedule and operate longer at less severe conditions. When the barrel has reached a proper run-in condition, the surface is free from grinding marks and scratches and presents a glazed or mirror-like appearance that is broken only by the knurling marks.

Such a schedule of run-in gives more than ample time to run-in any other bearing surfaces. Main bearings, connecting rod bearings, camshaft bearings, and gears require only 5 h running to be able to withstand severe duty and 1 h running is usually adequate for crankshaft oil seal rings, carriers, and races. One hour's running at 2700 rpm with 762 mm (30 in) Hg abs. boost and 1 h running at 2700 rpm with 1524 mm (60 in) Hg abs. boost is considered adequate for the run-in of valve gear after a carbon and valve job.

It is not considered advisable to operate the engine at high power levels with cold engine oil, as the viscosity of the oil will be too high at low temperatures to ensure proper lubrication of the bearing surfaces. The following warmup schedule is recommended:

900 rpm firing with no boost until oil temperature has reached 50 °C (120 °F).
1800 rpm firing with no boost until oil temperature has reached 60 °C (140 °F).
2700 rpm firing with no boost until oil temperature has reached 70 °C (160 °F).

If the proper absorption equipment prevents following the warmup schedule, any suitable compromise is acceptable as long as high power and/or high rpm operation are avoided until the oil temperature has reached 70 °C (160 °F).

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16. Operating Instructions

16.1 These operating instructions are for use with the 17.6 Spark Plug Rating Engine Standard Assembly as approved May 9, 1968. The operating conditions herein specified are subject to revision from time to time as approved by the majority of the members of the SAE Spark Plug Rating Engine Standardization Panel of the SAE Electrical Equipment Committee. It is recognized that individual laboratories will have slightly different operation requirements; however, the fundamental operations should follow these instructions as closely as possible so that the rating results will be comparable. Only those conditions that affect the rating of the spark plug or the safety of personnel and equipment are specified as required, but recommended procedures or conditions are indicated for information and guidance purposes.

16.1.1 REQUIRED OPERATING CONDITIONS

Speed: 2700 + 65-30 rpm
Compression Ratio: 5.6 to 1
Ignition Timing: 30 degree btc (automotive types)
40 degree btc (aviation or others not rateable at 30 degrees)
Fuel: 98%—1 degree Benzene, 2%—Specification MIL-L-6082D Grade 1100 NONADDITIVE SAE 60 aviation oil, with 0.8 ml/L (3 cc/gal) T.E.L. added
Fuel Injection Pressure: 5.17 Mpa (750 psi) minimum.
Fuel-Air Ratio: That which produces the maximum thermal plug temperature.
Air Inlet Temperature: 107.2 °C ± 2.8 °C (225 °F ± 5 °F).
Air Inlet Humidity: 75 + grains of water per pound of dry air.
Bushing Outlet Coolant Temperature: 87.8 °C ± 1.0 °C (190 °F ± 2 °F).
Engine Oil Temperature: 87.8 °C ± 5 °C (190 °F ± 10 °F).

16.2 Step-by-Step Procedure

16.2.1 Select the proper spark plug insert (see Appendix B).

16.2.2 After being sure that the cylinder head insert seat, as well as the spark plug insert itself, is clean, install the insert carefully into the cylinder head, using new O-rings. The O-rings should be assembled onto the insert and may be held in place with a small amount of petroleum jelly or light grease.

16.2.3 The hold-down nuts are to be alternately tightened so that the insert will seat evenly in the cylinder head. The nuts are to be tightened finally to a uniform 0.92 Kg-m (60 lb-in) torque.

16.2.4 Install a warmup spark plug similar to the type to be rated, using the specified installation torque (Appendix C). A new gasket is recommended for each installation, except conical, seating types.

16.2.5 Before starting the engine, be certain that it was the proper type and amount of lubricating oil in the crankcase, oil in the fuel injection pump base, cylinder jacket and spark plug insert cooling system filled, air pressure supply system filled to the proper water level, and the fuel supply tank filled with fuel. Be certain that the cylinder air pressure supply throttle valves are tightly closed and that the atmospheric air throttle valve is fully open. Turn on the electrical power to all units and set the switch on "high" for the base oil heaters. Turn on the water to the fuel cooler, the crankcase aspirator if used, and all temperature control valves. Turn on the control air supply.

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16.2.6 Because there are many installations that use dynamometers other than the frequency changer synchronous type now furnished as part of the standard assembly in the United States, only typical directions will be given here for the starting of the dynamometer. However, most installations include certain safety interlocks that must be bypassed during the initial starting of the engine. This is normally accomplished by holding the "start" button depressed until the oil pressure increases to above the safety setting. As long as the fuel injection pump control is in the closed position, no fuel will be delivered to the injection valve and the engine will not fire. Under no conditions should a cold engine be motored or run at speeds above 900 rpm.

16.2.7 After any required motoring is completed, the engine can be fired by gradually increasing the displacement of the fuel injection control by means of the micrometer screw until firing takes place. The displacement should continue until the thermal plug temperature reaches a maximum. By this time, the dynamometer will have changed from motoring to absorbing. The dynamometer can now be unlocked for power and friction readings. No ratings are to be attempted until the oil temperature has been stabilized at 88 °C (190 °F). Much warmup time may be saved by leaving the crankcase oil heaters turned on—even overnight.

CAUTION—Always be certain that the dynamometer shell is locked and that the atmospheric inlet air throttle valve is fully open and the cylinder air pressure throttle valves are completely closed before the engine is started or stopped.

16.2.8 When the engine is ready for testing, it is stopped by disengaging the fuel injection pump control from the micrometer screw and then disconnecting the electrical power from the dynamometer. As soon as the engine comes to a complete stop, disconnect the ignition cable from the warmup spark plug and remove it. Install the spark plug to be rated and connect the ignition cable. Bring the engine up to speed with the dynamometer and connect the fuel injection pump control to the micrometer screw. The engine will start firing immediately. Unlock the dynamometer shell. With the speed maintained at 2700 rpm, slowly open the main cylinder air pressure throttle valve while slowly closing the atmospheric air throttle valve, constantly watching the intake boost gauge. During the transfer of air supplies, the intake boost should remain at about atmospheric pressure.

16.2.9 After the transfer to pressurized air is complete, the engine can be operated with increasing boost pressure in regular steps until preignition of the spark plug takes place. This is evidenced by a rapid rise in the thermal plug temperature.

CAUTION—As soon as preignition occurs, the fuel should be cut off by disconnecting the linkage between the fuel injector pump control and the micrometer screw. Failure to act promptly can cause damage to the engine and especially to the spark plug on test. As soon as the fuel is cut off, the thermal plug temperature will decrease.

16.3 The plug rating is that IMEP value obtained on the engine at a point where the supercharge pressure is 3.37 kPa (1 in Hg) below the preignition point. The following steps are recommended to attain this point:

16.3.1 The supercharge pressure is increased in 13.5 kPa (4 in Hg) increments until preignition occurs as indicated by a rapid rise in thermal plug temperature. At each setting, the mixture strength is adjusted such that a maximum thermal plug temperature is obtained.

16.3.2 When preignition occurs, the fuel supply is instantly cut off and the supercharge pressure is decreased 6.7 kPa (2 in Hg) at which point the fuel is turned on and again adjusted for maximum thermal plug temperature. This condition should be held for 3 min or until preignition again occurs.

16.3.3 If preignition occurs after 16.3.2, the supercharge pressure should be reduced by 3.37 kPa (1 in Hg), again adjusting for optimum thermal temperature until stable engine operation for 3 min is obtained or preignition occurs. If preignition occurs, refer to 16.3.5.

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16.3.4 If after 16.3.2, stable engine operation is obtained, the supercharge pressure should be increased 3.37 kPa (1 in Hg), again adjusting for optimum thermal temperature until stable engine operation for 3 min is obtained or preignition occurs. If preignition occurs refer to 16.3.5.

16.3.5 Friction torque should be measured at supercharge pressure 3.37 kPa (1 in Hg) below the preignition point (or previous stabilized setting prior to preignition) and within 30 s after the engine ceases to fire.

16.3.6 Rating data may be verified using a plug that has a rating point at least 50 IMEP above the plugs that have been rated.

16.3.7 CALCULATION OF IMEP

(Eq. 1)

$$\text{Indicated HP} = \text{Friction HP} + \text{Brake HP}$$

$$\text{IHP} = \frac{2700}{5250} T_F + \frac{2700}{5252} T_B$$

$\text{IHP} = 0.51\ (T_F + T_B) = \text{Plan}/33{,}000$
$0.51(T_F + T_B) - (0.04)\ (0.01)\ P = \text{IMEP}$
$\text{IMEP} = 8.65\ (T_F + T_B)$
T_F—Friction Torque
T_B—Brake Torque
IMEP = Indicated Mean Effective Pressure

PREPARED BY THE SAE IGNITION STANDARDS COMMITTEE

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APPENDIX A

MANUFACTURING TOLERANCES AND REPLACEMENT LIMITS

A.1 See Table A1.

TABLE A1—MANUFACTURING TOLERANCES AND REPLACEMENT LIMITS
All dimensions not otherwise indicated are in millimeters
(All dimensions in parentheses are in inches)

		As Manufactured	Condemning
TAPPET SETTING (INTAKE VALVE)		0.457(0.018) Hot	
TAPPET SETTING (EXHAUST VALVE)		0.457(0.018) Hot	
VALVE STEM TO GUIDE (INTAKE) (HAND REAM GUIDE AT ASSEMBLY)			
5835 Intake Valve	11.05-11.07 (0.435-0.436)Dia.	0.0127-0.0381 (0.0005-0.0015)	0.08 (0.003)
5134 Intake Valve Guide	11.07-11.087 (0.436-0.4365) Bore		
VALVE STEM TO GUIDE (EXHAUST) (HAND REAM GUIDE AT ASSEMBLY)			
5836 Exhaust Valve	11.010-11.036 (0.4335-0.4345) Dia.	0.051-0.026 (0.002-0.003)	0.1143 (0.0045)
5135 Exhaust Value Guide	11.074-11.087 (0.436-0.4365) Bore		
VALVE GUIDES P.F. IN CYLINDER HEAD			
Cylinder Head	17.436-17.48 (0.6875-0.688)		
5134 Intake Valve Guide	17.488-17.495 (0.6885-0.6888)	0.0127-0.033 (0.0005-0.0013) P.F.	
5135 Exhaust Valve Guide			
VALVE SPRING LOAD			
5230 Inner Valve Spring	At 34.925 (1.375) Height	8.05-9.45 Kg (115-135 lb)	Under 7.7 Kg (110 lb)
	At 42.849 (1.687) Height	4.41-4.83 Kg (63-69 lb)	Under 4.06 Kg (58 lb)
5231 Outer Valve Spring	At 34.925 (1.375) Height	7.7-9.1 Kg (110-130 lb)	Under 7.35 Kg (105 lb)
	At 42.849 (1.687) Height	5.25-5.95 Kg (75-85 lb)	Under 4.90 kg (70 lb)
VALVE ROCKER ARM SIDE CLEARANCE			
Cylinder Head	41.986-42.139 (1.653-1.659)		
Rocker Area	39.649-39.725 (1.561-1.564)	0.051-0.330 (0.002-0.013)	
5223 Thrust Washer	2.159-2.209 (0.085-0.087)		
VALVE ROCKER ARM SHAFT TO CYLINDER HEAD (5750 ENGINE)(HAND REAM AT ASSEMBLY)			
Cylinder Head	15.875-15.808 (0.625-0.6255) Bore	0.0127-0.0254 (0.0005-0.001)	
Rocker Arm Shaft	15.862-15.875 (0.6245-0.625) dia.		
VALVE PUSHROD HOUSING TO CYLINDER HEAD			
Cylinder Head	25.095-25.146 (0.988-0.990) Bore	0.000-0.076 (0.000-0.003) P.F.	
Intake, Upper Push Rod Housing	25.146-25.171 (0.990-0.991)		
Exhaust, Upper Push Rod Housing	25.146-25.171 (0.990-0.991)		

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TABLE A1—MANUFACTURING TOLERANCES AND REPLACEMENT LIMITS (CONTINUED)
All dimensions not otherwise indicated are in millimeters
(All dimensions in parentheses are in inches)

		As Manufactured	**Condemning**
VALVE PUSHROAD HOUSING TO CYLINDER HOUSING			
5544 Cylinder Housing	25.349-25.146 (0.998-0.990) Bore	0.000-0.076 (0.000-0.003) P.F.	
5164 Lower Push Rod Housing	25.146-25.171 (0.990-0.991) dia.	0.000-0.076 (0.000-0.003) P.F.	
VALVE LIFTER ASSEMBLY TO GUIDE			
5501 Valve Lifter Guide	17.462-17.475 (0.6875-0.600) Bore	0.043-0.071 (0.0017-0.0028)	
5502 Tappet, Valve	17.404-17.419 (0.6852-0.6858) Dia.	0.043-0.071 (0.0017-0.0028)	
5740 CYLINDER SLEEVE		66.662-66.700 (2.6245-2.626) Bore	0.050 (0.002) Out of Round 0.127 (0.005) Variation
PISTON TOP LAND			
5474 Piston (Top Land)		66.395-66.421 (2.614-2.615) Dia.	66.015 (2.599) Dia.
PISTON SKIRT AND OTHER LANDS			66.269 (2.609) Dia.
5474 Piston (Skirt and Other Lands)	66.523-66.548 (2.619-2.620 (Dia.	66.523-66.548 (2.619-2.620) Dia.	0.178 (0.007) Out of Round
PISTON RING END CLEARANCE			
3296 Oil Control Ring	End Clearance at 66.675 (2.625)	0.178-0.181 (0.007-0.15)	0.686 (0.027) or
5863 Compression Ring	Gage Dia.		0.305 (0.012)
3387 Optional Compression Ring			Actual Increase
PISTON RING SIDE CLEARANCE NO. 1 (TOP)			
5474 Piston (Groove Width)	2.476-2.502 (0.0975-0.985)	0.102-0.1397 (0.004-0.0055)	
5863 Ring	2.362-2.375 (0.093-0.0935)	0.102-0.1397 (0.004-0.0055)	
3387 Ring (Optional)(Tungsten)	2.362-2.375 (0.093-0.0935)	0.102-0.1397 (0.004-0.0055)	
PISTON RING SIDE CLEARANCE NOS. 2, 3, AND 4			
5474 Piston (Groove Width)	2.451-2.477 (0.0965-0.0975)	0.076-0.1143 (0.003-0.0045)	0.1397 (0.0055)
5863 Ring	2.362-2.375 (0.093-0.0935)	0.076-0.1143 (0.003-0.0045)	
PISTON RING SIDE CLEARANCE NO. 5 (BOTTOM)			
5474 Piston (Groove Width)	4.788-4.813 (0.1885-0.1895)	0.050-0.089 (0.002-0.0035)	
3296 Ring	4.724-4.737 (0.186-0.1865)	0.050-0.089 (0.002-0.0035)	0.127 (0.005)
PISTON PIN TO PISTON CLEARANCE			
5474 Piston	25.4025-25.4152 (1.0001-1.0006) Bore	0.0025-0.0203 (0.0001-0.0008)	
5120 Piston Pin	25.0000-25.3949 (1.0000-0.9998) Dia.	0.0025-0.0203 (0.0001-0.0008)	0.0381 (0.0015)
PISTON PIN TO CONNECTING ROD BUSHING CLEARANCE			
5120 Piston Rod	25.4000-25.3949 (1.0000-.09998)	0.00635-0.0305 (0.00025-0.0012)	
5487 Connecting Rod Assembly	25.40635-25.4254 (1.00025-1.001) Bore	0.00635-0.0305 (0.00025-0.0012)	0.1143 (0.0045)

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TABLE A1—MANUFACTURING TOLERANCES AND REPLACEMENT LIMITS (CONTINUED)
All dimensions not otherwise indicated are in millimeters
(All dimensions in parentheses are in inches)

		As Manufactured	Condemning
CRANKSHAFT TO CONNECTING ROD BEARING CLEARANCE			
5641 Crankshaft Connecting Rod Journal	57.1373-57.1500 (2.2495-2.250) Dia.		
200072-1 Connecting Rod Bearings		0.076 (0.003)	0.127 (0.005)
CRANKSHAFT TO MAIN BEARINGS CLEARANCE			
5641 Crankshaft Main Bearing Journal	57.1373-57.1500 (2.2495-2.250) Dia.	0.76-0.1143 (0.003-0.0045)	
200071-1 Front Main Beraing	57.2262-57.2389 (2.253-2.2535) Bore	0.76-0.1143 (0.003-0.0045)	
200071-1 Rear Main Bearing	57.2262-57.2389 (2.253-2.2535) Bore	0.76-0.1143 (0.003-0.0045)	0.1397 (0.0055)
200071-1 Rear Main (Front) Bearing	(at assembly)	0.76-0.1143 (0.003-0.0045)	
CRANKSHAFT END CLEARANCE			
5641 Crankshaft (Between Surfaces)	101.041-101.092 (3.978-3.900)		
5681 Rear (Front) Main Bearing (Flange Thickness)			
5642 Front Main Bearing (Flange Thickness)	(Fitted at Assembly)	0.254-0.356 (0.010-0.014)	0.635 (0.025)
CRANKSHAFT BEARINGS P.F. IN CRANKCASE AND REAR ADAPTER			
5601 Crankcase	69.8627-69.8754 (2.7505-2.751) Bore		
5605 Rear Bearing Adapter	69.8627-69.8754 (2.7505-2.751) Bore		
5642 Front Main Bearing	Grind OD to Fit at Assembly		
5677 Rear Main Bearing	Grind OD to Fit at Assembly	0.0005-0.001 (0.0127-0.254) P.F.	
5681 Rear (Front) Main Bearing	Grind OD to Fit at Assembly		
CAMSHAFT TO BEARINGS			
5641 Camshaft - Front Journal	45.2120-45.2245 (1.780-1.7805) Dia.	0.0254-0.0635 (0.001-0.0025)	
Rear Journal	25.3746-25.3873 (0.999-0.9995) Dia.	0.0254-0.0635 (0.001-0.0025)	
5051 Front Bearing	45.2501-45.2755 (1.7815-1.7825) Bore	0.0254-0.0635 (0.001-0.0025)	0.102 (0.004)
5646 Rear Bearing	25.4127-25.4381 (1.0005-1.0015) Bore	0.0254-0.0635 (0.001-0.0025)	
CAMSHAFT END PLAY			
5640 Camshaft (Journal Length)	42.799-42.849 (1.685-1.687)	0.102-0.203 (0.004-0.008)	0.254 (0.010)
5051 Front Bearing (O.A.L.)	42.646-42.697 (1.679-1.681)	0.102-0.203 (0.004-0.008)	
CAMSHAFT FRONT BEARING TO CRANKCASE			
5601 Crankcase	57.150-57.175 (2.250-2.251) Bore	0.0127-0.508 (0.0005-0.002)	
5051 Front Beaering	57.124-57.137 (2.249-2.2495)	0.0127-0.508 (0.0005-0.002)	
CAMSHAFT REAR BEARING TO CRANKCASE (5750 ENGINE)			
5601 Crankcase	31.750-31.775 (1.250-1.251) Bore	0.0127-0.0508 (0.0005-0.002)	
5646 Rear Bearing	31.725-31.7373 (1.249-1.2495) Dia.	0.0127-0.0508 (0.0005-0.002)	
MAGNETO BREAKER POINT GAP		0.355-0.559 (0.014-0.022	
MAGNETO CAM FOLLOWER PRESSURE (WITH CAM ON DWELL)		0.83-2.2 N (3-8 oz)	

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TABLE A1—MANUFACTURING TOLERANCES AND REPLACEMENT LIMITS (CONTINUED)
All dimensions not otherwise indicated are in millimeters
(All dimensions in parentheses are in inches)

		As Manufactured	Condemning
MAGNETO-PRESSURE BETWEEN POINTS WITH FOLLOWER ON DWELL OF CAM		5.0-7.0 N (18-25 oz)	
COUNTERBALANCE SHAFTS TO BUSHINGS			
5608 Counterbalance Shafts (Bushing Journal)	31.699-31.711 (1.248-1.2485) Dia.	0.051-0.0889 (0.002-0.0035)	
5610 Rear Bushings	31.763-31.788 (1.2505-1.2515) Bore	0.051-0.0889 (0.002-0.0035)	0.1143 (0.0045)
5647 Front Bushings	31.763-31.788 (1.2505-1.2515) Bore		
COUNTERBALANCE SHAFT BUSHINGS TO CRANKCASE AND BEARING ADAPTER			
5601 Crankcase	38.0873-38.1127 (1.4995-1.5005) Bore	0.000-0.0889 (0.000-0.0035)	
5609 Bearing Adapter	38.0873-38.1127 (1.4995-1.5005) Bore	0.000-0.0889 (0.000-0.0035)	
5610 Rear Bushings	38.075-38.0873 (1.499-1.4995) OD	0.000-0.0889 (0.000-0.0035)	
5647 Front Bearings	38.075-38.0873 (1.499-1.4995) OD	0.000-0.0889 (0.000-0.0035)	
COUNTERBALANCE SHAFT END PLAY			
5608 Counterbalance Shaft (Shoulder Length)	55.093-55.219 (2.169-2.174)	0.076-0.279 (0.003-0.011)	
5609 Bearing Adapter (Length Through Bore)	50.800-50.749 (2.000-1.998)	0.076-0.279 (0.003-0.011)	0.508 (0.020)
5647 Front Bushing (Flange Thickness)	4.191-4.216 (0.165-0.166)	0.076-0.279 (0.003-0.011)	
5656 OIL PUMP ASSEMBLY (5650 ENGINE)			
Driveshaft to Bushing in Body at Drive End			
5651 Shaft	12.725-12.7381 (0.501-0.5015) Dia.	0.038-0.076 (0.0015-0.003)	0.127 (0.005)
5002 Bushing	12.776-12.802 (0.503-0.504) Dia.	0.038-0.076 (0.0015-0.003)	
Driveshaft to Bushing in Cover			
5651 Shaft	12.6619-12.6746 (0.4985-0.499) Dia.	0.051-0.076 (0.002-0.003)	0.127 (0.005)
5662 Bushing	12.725-12.738 (0.501-0.5015) Bore	0.051-0.076 (0.002-0.003)	
Idler Shaft to Bushings			
5782 Shaft	12.6619-12.6746 (0.4985-0.499) Dia.	0.051-0.076 (0.002-0.003)	
5652 Bushings	12.725-12.7381 (0.501-0.5015) Bore	0.051-0.076 (0.002-0.003)	
Bushings P.F. Into Body and Cover			
Housing Bores	15.8623-15.8877 (0.6245-0.6255) Bore	0.0381-0.0889 (0.0015-0.0035) P.F.	
Bushing OD	15.925-15.951 (0.627-0628) OD	0.031-0.0889 (0.0015-0.0035) P.F.	
Pump Gears Backlash		0.076-0.127 (0.003-0.005)	0.178 (0.007)

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APPENDIX B

STANDARD SPARK PLUG INSERTS

B.1 See Table B1.

TABLE B1—STANDARD SPARK PLUG INSERTS

Spark Plug Size Thread	Spark Plug Size Reach mm (in)	Labeco Part Numbers (Std.) Meehanite
8 mm	12.497 (0.492)	20001
10 mm	6.350 (0.250)	16200
10 mm	12.497 (0.492)	16201
10 mm	17.780 (0.700)	16202
12 mm	12.497 (0.492)	16204
12 mm	19.050 (0.750)	16205
14 mm	9.525 (0.375)	16206
14 mm	11.100 (0.437)	16207
14 mm	12.700 (0.500)	16208
14 mm	11.684 (0.460) (conical seat)	16209
14 mm	19.050 (0.750)	16210
14 mm	19.050 (0.750) (half thread)	16211
14 mm	17.780 (0.700) (conical seat)	16219
14 mm	17.272 (0.680)	16221
14 mm	9.525 (0.375) (conical seat)	16223
14 mm	17.780 (0.700) (conical seat) (1/2 Thread—Ford)	16232
14 mm	23.241 (0.915) (conical seat) (1/2 Thread—Autolite)	16233
14 mm	12.700 (0.500)	16154A
18 mm	11.303 (0.445)	16212
18 mm	12.700 (0.500)	16213
18 mm	11.684 (0.460) (conical seat)	16214
18 mm	20.625 (0.812)	15215
18 mm	25.400 (1.000) (Special)	16226
18 mm	29.718 (1.125)	16222
18 mm	38.100 (1.500) (conical seat)	16231
18 mm	29.718 (1.125) (3/16 thd relief)	16220
0.875 in	15.900 (0.625)	16216
0.875 in	20.625 (0.812)	16217
0.875 in	20.625 (0.812) (Special)	16218

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APPENDIX C

SPARK PLUG INSTALLATION TORQUE

C.1 See Table C1.

TABLE C1—SPARK PLUG INSTALLATION TORQUE

Plug Size	Torque N·m (lb-ft)
10 mm	10-15 (7-11)
12 mm	15-25 (11-18)
14 mm	35-40 (26-30)
14 mm (conical seat)	9-20 (7-15)
18 mm	43-52 (32-38)
18 mm (conical seat)	20-27 (15-20)
0.875 in x 18	47-58 (35-43)

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APPENDIX D

BILL OF MATERIAL FOR
5750 ENGINE ASSEMBLY, SAE SPARK PLUG
RATING W/INSERT TYPE HEAD

D.1 Control Items

REQUIRED

*SAE Control Item

1 5600 CRANKCASE ASSEMBLY, COUNTERBALANCED

1 5660 RETAINER, CRANKSHAFT OIL (REAR)
ASSEMBLY (REAR) N. D.

1 5653 RETAINER, CRANKSHAFT OIL (REAR)

1 5661 SEAL OIL

1 5630 BEARING ADAPTER ASSEMBLY
COUNTERBALANCE SHAFTS

1 5609 BEARING ADAPTER FOR COUNTERBALANCED SHAFT

2 5647 BUSHING, FRONT C-B SHAFT

2 4243 SCREW, SET, HEX SOCKET HEAD
0.375-16 UNC X 0.500 LONG CUP POINT

2 4260 PIN, DOWEL 0.1251/0.1253 DIA. X 0.375 LONG

1 5654 CAMSHAFT ASSEMBLY

1 5640 CAMSHAFT

1 5052 GEAR TIMING CAMSHAFT

1 5051 BEARING BUSHING CAMSHAFT FRONT

1 5053 NUT CAMSHAFT FRONT GEAR TO CAMSHAFT

1 4051 KEY, WOODRUFF 0.156 X 0.750 SAE #8, ANSI (506),

1 5054 WASHER, LOCK, GEAR TO CAMSHAFT

1 4076 KEY, WOODRUFF 0.250 X 0.875 SAE #A, ANSI (807)

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REQUIRED		
1	5631	COVER, GEAR CASE ASSEMBLY
1	5602	COVER, GEAR CASE
1	5457	SEAL, OIL, FRONT CAMSHAFT
1	5111	FILLER CAP, WING TYPE
1	5112	GASKET FOR FILLER CAP
1	5661	SEAL OIL
4	5634	STUD, OIL PUMP TO CASE
1	4246	SCREW, SET, HEX SOCKET HEAD 0.375-16 UNC X 2.625 LONG CUP POINT
1	4247	SCREW, SET, HEX SOCKET HEAD 0.375-16 UNC X 1.000 LONG CUP POINT
1	5635	CRANKCASE SUB-ASSEMBLY
1	5601	CRANKCASE
1	5605	BEARING ADAPTER CRANKSHAFT REAR
1	5642	BEARING FRONT MAIN
1	5677	BEARING, CRANKSHAFT, REAR ADAPTER
1	5681	BEARING, CRANKSHAFT, FRONT ADAPTER
3	4329	PIN, TAPER, #3 X 2.500 LONG
15	35105	SCREW, CAP, HEX HEAD, 0.375-16 UNC X 1.250 LONG, GRADE 5 CADMIUM PLATED
15	4111	WASHER, PLAIN 0.375 0.391 I. D. X 0.625 O. D. X 0.062 THICK, CADMIUM PLATED AN960-616
2	4243	SCREW, SET, HEX SOCKET HEAD 0.375-16 UNC X 0.500 LONG CUP POINT
1	4060	FITTING, TUBE, INV FLARE, MALE 90 ELBOW 0.250 NPT X 0.375 TUBE BRASS WEATHERHEAD #402X6

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REQUIRED

1 5621 CRANKSHAFT ASSEMBLY

1 5641 CRANKSHAFT

2 5639 COUNTERWEIGHT—CRANKSHAFT

4 5019 CAPSCREW COUNTERWEIGHT TO CRANKSHAFT

1 4000 PIPE PLUG, SOCKET HEAD, STEEL 0.125 PT
BLACK OXIDE FINISH
2' S11205 WIRE, SAFETY, 0.032 DIAMETER STAINLESS
STEEL, MS20995C32

1 5673 OIL OUTLET FLANGE ASSEMBLY

1 5664 HEATER TERMINAL PLATE ASSEMBLY

1 5665 PLATE HEATER TERMINAL

1 5685 COVER HEATER TERMINAL PLATE (REAR)

4 4038 SCREW, MACHINE, FLAT HEAD #10-32 UNF
X 0.750 LONG, PLATED

4 4030 WASHER, PLAIN #10 0.219 I. D. X 0.500 O. D.
X 0.049 THICK, ZINC PLATED

8 4031 NUT, HEX, MACHINE SCREW #10-32 UNF,
ZINC PLATED

1 5697 CONNECTOR TERMINAL

15 37729 TERMINAL, SOLDERLESS, RING, 16-14 AWG
X #10 STUD

1 5696 COVER, HEATER TERMINAL PLATE FRONT

2 4179 SCREW, MACHINE, FLAT HEAD #6-32 UNC X 0.500
LONG 18-8 STAINLESS STEEL

2 5698 SEPARATOR, WIRE

1 200003-1 CONTROL ASSEMBLY, OIL SUMP HEATER

1 200005-1 ENCLOSURE, SWITCH, OIL SUMP HEATER

1 200006-1 COVER, SWITCH ENCLOSURE, OIL SUMP HEATER

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REQUIRED

1 200007-1 NAMEPLATE, SWITCH, OIL SUMP HEATER

1 37547 SWITCH, SELECTOR

1 37548 JUMPER, SELECTOR SWITCH

2 30741 SCREW, MACHINE, ROUND HEAD #10-32 UNF X 0.250 LONG, PLATED

1 5549 RECEPTACLE SUMP HEATER

4 35602 SCREW, CAP, HEX SOCKET HEAD #4-40 UNC X 0.313 LONG

1 5656 OIL PUMP ASSEMBLY

1 5649 BODY, OIL PUMP

1 5650 COVER, OIL PUMP

1 5651 SHAFT, OIL PUMP DRIVE

1 5782 SHAFT IDLER, OIL PUMP

1 5761 GEAR, OIL PUMP DRIVER

1 5762 GEAR, OIL PUMP DRIVEN

1 5643 COUPLING FLANGE

3 5652 BUSHING OIL PUMP COVER

1 5082 BUSHING OIL PUMP MAIN SHAFT

6 35105 SCREW, CAP, HEX HEAD 0.375-16 UNC X 1.250 LONG, GRADE 5 CADMIUM PLATED

6 4111 WASHER, PLAIN 0.375 0.391 I. D. X 0.625 O. D. X 0.062 THICK, CADMIUM PLATED AN960-616

2 4026 KEY, WOODRUFF 0.094 X 0.500 SAE #2 ANSI (304)

2 4054 PIN, DOWEL 0.2501/0.2503 DIA. X 0.625 LONG

1 5519 OIL PRESSURE REGULATOR ASSEMBLY A. C. SPEC

1 5923 HOUSING, RELIEF VALVE PRESSURE REGULATOR

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REQUIRED		
1	5924	VALVE, RELIEF VALVE PRESSURE REGULATOR
1	5925	BOLT—RELIEF VALVE PRESSURE REGULATOR
1	5726	SCREW, OIL PRESSURE ADJUSTING
1	5938	SPRING—RELIEF VALVE, PRESSURE REGULATOR-SAE 17.6 3-7-62
2	4956	GASKET COPPER 0.750 I. D. 0.062 THICK SAME AS 5103 (“MCCORD” #511-A)
1	4339	NUT, HEX, LOCK, ELASTIC STOP
1	4340	GASKET 5/8 I. D. 7/8 O. D. COPPER CLAD ASBESTOS
1	5926	PLUG, RELIEF VALVE PRESSURE REGULATOR
8	35651	SCREW, CAP, HEX HEAD 0.313-18 UNC X 1.250 LONG GRADE 5 PLATED
6	35105	SCREW, CAP, HEX HEAD 0.375-16 UNC X 1.250 LONG GRADE 5 CADMIUM PLATED
3	4022	KEY, WOODRUFF 0.250 X 1.125 SAE #18, ANSI (809)
4	4030	WASHER, PLAIN #10 0.219 I. D. X 0.500 O. D. X 0.049 THICK, ZINC PLATED
4	4037	NUT, HEX 0.375-24 UNF ZINC PLATED
2	35066	SCREW, CAP, HEX HEAD 0.375-16 UNC X 0.750 LONG GRADE 5 CADMIUM PLATE
39	35024	SCREW, CAP, HEX HEAD 0.375-16 UNC X 0.875 LONG GRADE 5 CADMIUM PLATED
2	4047	WASHER, PLAIN 0.313 0.328 I. D. X 0.562 O. D. X 0.062 THICK, CADMIUM PLATED AN960-516
3	4051	KEY, WOODRUFF 0.156 X 0.750 SAE #8, ANSI (506)
8	35610	SCREW, CAP, HEX HEAD 0.250-20 UNC X 0.875 LONG GRADE 5 PLATED
74	4111	WASHER, PLAIN 0.375 0.391 I. D. X 0.625 O. D. X 0.062 THICK CADMIUM PLATED AN960-616

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REQUIRED		
4	4129	SCREW, MACHINE, FILLISTER HEAD #10-32 UNF X 0.500 LONG CADMIUM PLATED
6	35106	SCREW, CAP, HEX HEAD 0.375-16 UNC X 1.750 LONG GRADE 5 CADMIUM PLATED
11	35153	SCREW, CAP, HEX HEAD 0.375-16 UNC X 3.250 LONG GRADE 5 CADMIUM PLATE
2	4256	SCREW, CAP, HEX SOCKET HEAD 0.313-18 UNC X 1.000 LONG
1	4267	SCREW, SET, HEX SOCKET HEAD #10-32 UNF X 0.375 LONG CUP POINT
4	4331	SCREW, MACHINE, FILLISTER HEAD #10-32 UNF X 1.250 LONG PLATED (AN501-10-20)
1	4556	VALVE, RELIEF, PESCO PROD. #3V, 195, SET FOR 2 in (25.8 mm) Hg
2	4861	SIGHT GAUGE, OIL
1	5013	GASKET FOR 5163 TO 5002 CYL. BARREL TO CRANKCASE
1	5023	WASHER, LOCK, FLYWHEEL NUT
1	5027	GEAR CRANKSHAFT TIMING
2	5035	WASHER CLAMP, CRANKSHAFT TIMING DISC
2	5042	NUT, LOCK (1 in to 20) CRANKSHAFT FRONT
1	5071	POINTER FLYWHEEL
1	5076	NUT, FLYWHEEL, HEX, 1.500—18
1	5603	PLATE, CRANKCASE COVER
2	5604	GASKET, CRANKCASE COVER PLATE
2	5608	SHAFT, COUNTERBALANCE
1	5611	SPROCKET CRANKSHAFT
2	5612	SPROCKET COUNTERBALANCE SHAFT

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REQUIRED

1	5613	SPROCKET, IDLER
1	5614	BUSHING, IDLER SPROCKET
1	5615	BOLT, IDLER SPROCKET BUSHING
1	5616	CHAIN, TIMING
1	5629	GASKET, GEAR CASE
4	5632	WASHER FOR REMOVING HEAT UNIT
4	5638	HEATER CARTRIDGE, OIL SUMP
1	5644	COUPLING CONNECTOR
1	5645	NUT, HEX DRIVING
1	5648-A	SLEEVE TIMING DISC SPACER
1	5670	KEY STRAIGHT SPECIAL FLYWHEEL TO CRANKSHAFT
2	5680	COVER, INSPECTION
2	5686	FLANGE BREATHER
2	5687	GASKET BREATHER FLANGE
1	5691	GASKET, REAR BEARING ADAPTER TO CASE
1	5692	GASKET, OIL PUMP TO COVER
1	5693	GASKET, OIL FILTER FLANGE
1	5694	GASKET, INSPECTION COVER TO CASE
1	5695	COVER PLATE DRILLED AND TAPPED FOR RELIEF VALVE
2	5837	BAFFLE, CRANKCASE, COVER
4	5838	SPACER, CRANKCASE COVER BAFFLE
6	35025	SCREW, CAP, HEX HEAD 0.375-16 UNC X 1.000 LONG GRADE 5 CADMIUM PLATED
3	4000	PIPE PLUG, SOCKET HEAD, STEEL 0.125 NPT BLACK OXIDE FINISH

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REQUIRED

1 4001 PIPE PLUG, SOCKET HEAD, STEEL 0.250 NPT
BLACK OXIDE FINISH

1 5015 GASKET FOR 5014 TO 5008 RETAINER TO ADAPTER

2 36871 PIPE NIPPLE 0.250 NPTF X 0.375 NPTF
WEATHERHEAD C3069X6X4

2 5610 BUSHING, REAR COUNTERBALANCE SHAFT

1 5646 BUSHING REAR CAMSHAFT

6 5003 STUD (CYLINDER TO CRANKCASE) CRANKCASE
TO BARREL

4 4243 SCREW, SET, HEX SOCKET HEAD 0.375-16 UNC
X 0.500 LONG CUP POINT

2 4002 PIPE PLUG, SOCKET HEAD, STEEL 0.500 NPT
BLACK OXIDE FINISH

3 4318 SCREW, CAP, HEX SOCKET HEAD #10-32 UNF
X 0.375 LONG

2 5500 VALVE LIFTER ASSEMBLY

1 5502 VALVE LIFTER, BODY

1 5503 VALVE LIFTER ROLLER

1 5504 VALVE LIFTER ROLLER PIN

1 5506 VALVE LIFTER PUSH ROD SOCKET

2 35100 SCREW, CAP, HEX HEAD 0.313-18 UNC
X 1.000 LONG GRADE 5 CADMIUM PLATED

2 5501 VALVE LIFTER GUIDE

3 4242 PIN, DOWEL 0.3751/0.3753 DIA. X 1.000 LONG

*1 16018 CYLINDER HEAD ASSEMBLY, INSERT TYPE HEAD—
SAE SPARK PLUG RATING ENGINE/SUB-

1 16001 CYLINDER HEAD, INSERTED TYPE

1 5136 VALVE SEAT INSERT INTAKE

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REQUIRED	
1	5137 VALVE SEAT INSERT EXHAUST
1	5134 GUIDE, VALVE INTAKE
1	5135 GUIDE, VALVE EXHAUST
8	5138 STUD PORT FLANGE
1	16006 HOUSING, PUSH ROD, UPPER EXHAUST
1	16007 HOUSING, PUSH ROD, UPPER INTAKE
6	16013 STUD, 0.313 X 1.250, PLUG INSERT
10	16014 STUD, 0.250 X 1.250, ROCKER BOX
1	16020 ROCKER ARM, EXHAUST ASSEMBLY
1	5211 ROLLER, ROCKER ARMS
1	5212 HUB, ROCKER ARM ROLLER
1	5213 PIN, ROCKER ARM ROLLER AND HUB
1	5214 SCREW, ADJUSTING, ROCKER ARM
1	5215 LOCK FOR ROCKER ARM ADJUSTING SCREW
2	5216 BEARING, NEEDLE
1	16002 ROCKER ARM, EXHAUST
1	16021 ROCKER ARM, INTAKE ASSEMBLY
1	5211 ROLLER, ROCKER ARMS
1	5212 HUB, ROCKER ARM ROLLER
1	5213 PIN, ROCKER ARM ROLLER AND HUB
1	5214 SCREW, ADJUSTING, ROCKER ARM
1	5215 LOCK FOR ROCKER ARM ADJUSTING SCREW
2	5216 BEARING, NEEDLE
1	16003 ROCKER ARM, INTAKE, INSERTED HEAD

SAE J2203 Reaffirmed NOV1999

REQUIRED

2 16011 PUSH ROD, ASSEMBLY—INSERTED HEAD

2 16004 COVER, ROCKER BOX—INSERTED HEAD

2 16005 GASKET, ROCKER BOX—INSERTED HEAD

1 5143 GASKET FOR 5142 TO 5133

2 5223 WASHER, THRUST

1 5524 ADAPTER, COOLANT

2 5227 RETAINER, VALVE SPRING LOWER

2 5230 SPRING VALVE INNER

2 5231 SPRING VALVE OUTER

4 3864 PLUG, DRAIN 0.625-18 THD.

6 4015 NUT, HEX 0.313-24 UNF ZINC PLATED

2 4111 WASHER, PLAIN 0.375 0.391 I. D. X 0.625 O. D.
X 0.062 THICK CADMIUM PLATED AN960-616

2 35106 SCREW, CAP, HEX HEAD 0.375-16 UNC X 1.750 LONG
GRADE 5 CADMIUM PLATED

8 35133 SCREW, CAP, HEX HEAD 0.313-18 UNC X 0.625 LONG
GRADE 5 CADMIUM PLATE

10 4319 NUT, HEX 0.250-28 UNF ZINC PLATED

10 4341 WASHER, PLAIN 0.250 0.265 I. D. X 0.500 OC. D.
X 0.063 THICK CADMIUM PLATE AN960-416

2 5574 ROCKER ARM, SHAFT

4 5575 PLATE ROCKER ARM SHAFT

4 5576 GASKET, ROCKER ARM SHAFT RETAINING PLATE

2 5831 SPACKER, VALVE SPRING

2 5832 KEY, VALVE SPRING RETAINING

2 5833 CAP, VALVE SPRING RETAINING

SAE J2203 Reaffirmed NOV1999

REQUIRED

2 5834 RETAINER, VALVE SPRING (UPPER)

1 5835 VALVE, INTAKE

1 5836-2 VALVE, EXHAUST

1 36604 O-RING, 2-219, 1.296 I. D. X 0.139 W.
RED SILICONE RUBBER

1 31328 O-RING, 2-228, 2.228 I. D. X 0.139 W,

1 16034-C THERMOCOUPLE, INSERTED TYPE CYL. HD.

1 16048 THERMOCOUPLE GASKET

1 5587 CYLINDER HOUSING ASSEMBLY

2 5164 HOUSING LOWER FOR PUSH RODS IN
CYLINDER BARREL

1 5544 HOUSING CYLINDER

2 35687 SCREW, CAP, HEX HEAD 0.375-16 UNC X 2.000 LONG
GRADE 5 PLATED

2 35024 SCREW, CAP, HEX HEAD 0.375-16 UNC X 0.875 LONG
GRADE 5 CADMIUM PLATED

4 4111 WASHER, PLAIN 0.375 0.391 I. D. X 0.625 O. D.
X 0.062 THICK CADMIUM PLATED AN960-616

2 4293 SCREW, CAP, HEX SOCKET HEAD 0.375-16 UNC X 0.750
LONG

1 4359 GASKET, 3-7/16 I. D. 3-11/16 O. D. HcKIM #160
(SLEEVE TO CYL HOUSING)

1 5148 GASKET CYLINDER HEAD TO CYLINDER BARREL (“HEAD
TO SLEEVE”)

2 5207 HOSE FOR PUSH ROD HOUSING

4 3351 CLAMP, HOSE #16, 0.813 TO 1.500 CLAMP DIA

10 5546 CAPSCREW CYLINDER BARREL TO HEAD

2 5566 GASKET UPPER AND LOWER FOR 5567

SAE J2203 Reaffirmed NOV1999

REQUIRED

1 5569 ADAPTER COOLANT INLET

10 5577 GASKET, COPPER 1/2 in

2 5578 GASKET, COPPER 3/8 in

1 5579 PLATE FOR 5544

2 5581 GASKET, CRANKSHAFT OIL RETAINER

*1 5740 SLEEVE, CYLINDER REVISED 10-3-60

1 5741 FLANGE, CYLINDER SLEEVE

*1 5939 PISTON ASSEMBLY

1 5474 PISTON & SODIUM CHAMBER ASSEMBLY

1 5120 PISTON PIN (SOLID TYPE)

1 3296 RING, PISTON, OIL CONTROL (0.187 WIDE)

4 5863 RING, PISTON, CHROME (0.094 WIDE)

6 5177 NUT, FLANGED 1/2-20; CLASS 5; HI-TEMP, 50 FT/LBS TORQUE MIN

2 5187 GASKET FOR PORT FLANGES

1 5233 EXHAUST PIPE ASSEMBLY WITH COOLANT JACKET

2 5303 FLANGE FOR EXHAUST PIPE ASSEMBLY WITH COOLANT JACKET

2 5304 SPACER FOR EXHAUST PIPE ASSEMBLY WITH COOLANT JACKET

1 5305 JACKET FOR EXHAUST PIPE ASSEMBLY WITH COOLANT JACKET

1 5306 PIPE FOR EXHAUST PIPE ASSEMBLY WITH COOLANT JACKET

2 5234 BOSS 3/8 in NPT FOR WELDING

1 17050 NAMEPLATE, LABECO—FOR GENERAL USE

1 5487 CONNECTING ROD ASSEMBLY

SAE J2203 Reaffirmed NOV1999

REQUIRED

1	5472	CONNECTING ROD
2	5448	BOLT CONNECTING ROD
2	5117	NUT FOR CONNECTING ROD BOLT
2	4028	PIN, COTTER 0.094 DIA X 0.750 LONG
1	5445	SILVER GRID LINERS, HALF
1	5118	BUSHING, CONNECTING ROD, PISTON PIN END
*1	5496	INTAKE ASSEMBLY
*1	3128	INJECTION NOZZLE (BOSCH #ADN 12 SD12)
3	4002	PIPE PLUG, SOCKET HEAD, STEEL 0.500 NPT BLACK OXIDE FINISH
2	35100	SCREW, CAP, HEX HEAD 0.313-18 UNC X 1.000 LONG GRADE 5 CADMIUM PLATED
8	4015	NUT, HEX 0.313-24 UNF ZINC PLATED
2	36426	WASHER, LOCK HELICAL SPRING 0.313 MEDIUM PLATED
1	5179	AIR RECEIVER ASSEMBLY
1	5495	AIR RECEIVER SUB-ASSEMBLY
1	5180	AIR RECEIVER
6	5181	STUD FOR AIR RECEIVER COVER
10	5182	STUD FOR AIR RECEIVER FLANGES
1	4003	PIPE PLUG, SOCKET HEAD, STEEL 0.750 NPT BLACK OXIDE FINISH
1	4000	PIPE PLUG, SOCKET HEAD, STEEL 0.125 NPT BLACK OXIDE FINISH
1	5186	GASKET, AIR RECEIVER TO AIR RECEIVER COVER
1	5361	SCREEN ASSEMBLY
10	4015	NUT, HEX 0.313-24 UNF ZINC PLATED

SAE J2203 Reaffirmed NOV1999

REQUIRED

1	5185	GASKET, AIR RECEIVER TO AIR RECEIVER CONNECTION FLANGE
1	5184	CONNECTION FLANGE AIR FOR AIR RECEIVER
1	5190	STANDPIPE FOR AIR RECEIVER
2	3386	THERMOCOUPLE, IRON CONSTANTAN
2	3191	THERMOCOUPLE CONNECTOR, FEMALE, CONSTANTAN "J"
1	5188	GASKET FOR INTAKE PIPE TO AIR RECEIVER ASSEMBLY
1	5189	PIPE INTAKE
1	5192	GASKET FOR 5193 TO 5347
1	5194	FLANGE FOR FUEL INJECTOR NOZZLE HOLDER ASSEMBLY
2	5195	STUD FOR NOZZLE HOLDER
*1	5347	NOZZLE HOLDER ASSEMBLY (BOSCH #AKB50S6777A OPENING PRESSURE @ 1200 TO 1250 P. S. I.)
1	5493	BLANK TO COVER NOZZLE HOLDER FLANGE
1	5494	GASKET FOR BLANK COVER, NOZZLE HOLDER FLANGE
1	4000	PIPE PLUG, SOCKET HEAD, STEEL 0.125 NPT BLACK OXIDE FINISH
4	4099	SCREW, SELF-TAPPING, DRIVE #4 X 0.188 LONG TYPE "U" PLATED
8	5028	NUT, HEX, HIGH (BRASS) 0.375-16
1	5590	FLYWHEEL ASSEMBLY
1	5591	FLYWHEEL
1	5592	HUB, FLYWHEEL
6	35125	SCREW, HEX HEAD 0.500-13 UNC X 1.500 LONG GRADE 5
1	4322	TAPER PIN, #9 X 1.500 LONG
6	4362	WASHER, PLAIN 0.500 0.515 I. D. X 0.875 O. D. X 0.062 THICK CADMIUM PLATED AD960-816

SAE J2203 Reaffirmed NOV1999

REQUIRED

1 5235 EXHAUST HOSE NOZZLE WELDMENT
1 5259 FUEL COOLER ASSEMBLY

1 5416 FUEL TUBE ASSEMBLY

1 5947 PIEZOMETER (EXHAUST BACK PRESSURE PICKUP)

1 5300 BRACKET MOUNTING MAGNETO & FUEL PUMP

4 4067 SCREW, CAP, HEX SOCKET HEAD 0.375-16 UNC X 0.875 LONG

8 35667 SCREW, CAP, HEX HEAD 0.313-24 UNF X 0.750 LONG
GRADE 5 PLATED

1 5416 TUBE ASSEMBLY FUEL SHORT

2 5781 SPACER, FUEL PUMP AND MAGNETO MOUNTING BRACKET

4 35724 SCREW, CAP, HEX HEAD 0.500-13 UNC X 4.500 LONG
GRADE 5 PLATED

1 4051 KEY, WOODRUFF 0.156 X 0.750 SAE #8 ANSI (506)

2 35150 SCREW, CAP, HEX HEAD 0.375-16 UNC X 0.500 LONG
GRADE 5 CADMIUM PLATE

1 201016-1 COVER PLATE ASSEMBLY, MOUNTING BRACKET

6 3904 SCREW, MACHINE, ROUND HEAD #10-32 UNF X 0.500
LONG CADMIUM PLATED

6 36372 WASHER, LOCK, HELICAL SPRING #10 MEDIUM PLATED

1 202041 PUMP ASSEMBLY, FUEL INJECTION

1 5345 PUMP FUEL METERING, AMERICAN BOSCH
#APE 1B-70P-300/3

1 4060 FITTING, TUBE, INV FLARE, MALE 90 ELBOW
0.250 NPT X 0.375 TUBE BRASS WEATHERHEAD #402X6

1 4023 NUT, TUBE, INV FLARE 0.375 TUBE STEEL
WEATHERHEAD #105X6

1 5301 PLATE MOUNTING METERING PUMP

4 4065 SCREW, MACHINE, FLAT HEAD 0.375-16 UNC X 0.750
LONG, PLATED

SAE J2203 Reaffirmed NOV1999

REQUIRED

1 4113 WASHER, LOCK, INTERNAL TOOTH 0.563 PLATED

1 5370 NUT, HEX SPECIAL FOR COUPLING BOSCH #NMU-2024/1X

1 202038 BRACKET ASSEMBLY, FUEL CONTROL

1 202039 TRIGGER, FUEL CONTROL

1 202040 BRACKET, FUEL CONTROL

1 4085 SCREW, CAP, HEX SOCKET HEAD #10-32 UNF X 0.500 LONG

1 5978-1 SUPPORT SHAFT FOR FUEL MICROMETER - (FUEL INJECTOR PUMP)

1 5978-2 FITTING FOR FUEL MICROMETER SUPPORT SHAFT

1 3005 BUSHING 0.250 I.P.T. X 0.750 I.P.T. BOSCH #WRV/2A1X

1 5978-3 SHAFT FOR FUEL MICROMETER SUPPORT SHAFT

1 202038*005 PIN, CLEVIS 0.250 DIA. X 0.750 LONG

1 4080 PIN, COTTER 0.094 DIA X 1.250 LONG

1 202038*007 SPRING

1 5409 COVER BLIND END FOR “BOSCH” PUMP

4 5413 SCREW, MACHINE, OVAL HEAD, AMERICAN BOSCH #NSR 734/27X

1 5790*020 MAGNETO BENDIX 10-518501-25

1 5790*021 COIL BENDIX 10-382080-1

1 5790*022 CONNECTOR KIT BENDIX

1 5404 COUPLING ASSEMBLY CAMSHAFT TO BOSCH PUMP

1 5394 COUPLING SPACER

2 5369 COUPLING, FLEXIBLE DISC ASSEMBLY

SAE J2203 Reaffirmed NOV1999

REQUIRED

1 5372 FLANGE COUPLING TO CAMSHAFT

1 5371 FLANGE COUPLING TO “BOSCH” METERING PUMP

1 5418 FLANGE, ADJUSTABLE

2 35634 SCREW, CAP, HEX HEAD 0.250-28 UNF X 1.250 LONG GRADE 5 PLATED

2 35639 SCREW, CAP, HEX HEAD 0.250-28 UNF X 2.500 LONG GRADE 5 PLATED

6 4537 NUT, HEX, LOCK ELASTIC STOP 0.250-28 CADMIUM PLATED STEEL

2 4341 WASHER, PLAIN 0.250 0.265 I. D. X 0.500 OC. D. X 0.063 THICK CADMIUM PLATED AN960-416

2 35635 SCREW, CAP, HEX HEAD 0.250-28 UNF X 1.500 LONG GRADE 5 PLATED

2 4090 KEY, WOODRUFF 0.156 X 0.625 SAE #6, ANSI (505)

1 207001 INJECTOR PUMP-ACTUATOR ASSEMBLY

1 207003 BRACKET WELDMENT

1 207004 ROD, ACTUATOR

1 207005 ROD, ACTUATOR-BUSHING HOLDER

1 207006 BUSHING

1 207001*005 SPRING, TENSION

2 3552 NUT, HEX 0.250-20 UNC BRASS

1 201019 COVER INJECTOR PUMP ACTUATOR

1 201020 SPACER, SOLENOID

1 201021 ARM

1 201027 ARM, ACTUATOR

1 17050 NAMEPLATE, LABECO

1 207008 PIN

SAE J2203 Reaffirmed NOV1999

REQUIRED

1 207002*01301 MOTOR, STEPPING, 12 VDC

1 35323 SOLENOID

1 207001*015 COVER

1 31310 TERMINAL BLOCK

1 207001*017 ROLL PIN, 1/4 DIA X 0.75 LG.

1 207001*018 ROLL PIN, 1/16 DIA. X 0.44 LG.

2 35325 SCREW, SHOULDER 0.250 DIA. X 0.375 LONG
PIC 4330

12 32134 SCREW, MACHINE, ROUND HEAD #4-40 UNC X 0.250
LONG PLATED

4 31424 SCREW, MACHINE, ROUND HEAD #6-32 UNC X 0.750
LONG PLATED

3 3765 SCREW, MACHINE, ROUND HEAD #6-32 UNC X 0.250
LONG PLATED

4 4099 SCREW, SELF-TAPPING, DRIVE #4 X 0.188 LONG
TYPE “U” PLATED

2 30097 SCREW, SET, HEX SOCKET HEAD #8-32 UNC X 0.375
LONG, CUT POINT

6 31306 SCREW, MACHINE, ROUND HEAD #8-32 UNC X 0.375
LONG PLATED

2 207001*026 SCREW, HEX HEAD, 1/4-20 UNC X 1.50 LG., BRASS

4 4804 SCREW, CAP, HEX SOCKET HEAD #8-32 UNC X 0.625
LONG

4 3547 WASHER, PLAIN #8 0.188 I. D. X 0.438 O. D.
X 0.049 THICK, ZINC PLATED

7 3176 WASHER, LOCK, HELICAL SPRING #6 MEDIUM PLATED

6 36371 WASHER, LOCK, HELICAL SPRING #8 MEDIUM PLATED

2 4522 PIN, COTTER 0.032 DIA X 0.750 LONG

2 4826 NUT, HEX, LOCK, ELASTIC STOP #8-32 UNC PLATED

SAE J2203 Reaffirmed NOV1999

REQUIRED

1 20013-1 WIRE ASSEMBLY, SPARK PLUG, 17.6 ENGINE

1 5403-2 COUPLING ASSEMBLY, CRANKSHAFT TO BENDIX #10-518501-25 MAGNETO

1 5394 COUPLING SPACER FOR “MORFLEX”

2 5369 COUPLING, FLEXIBLE DISC ASSEMBLY “MORFLEX” #302 (CENTER MEMBER ONLY)

1 5380 FLANGE COUPLING TO CRANKSHAFT (“MORSE” *302 X 1/2 in BORE—BLANK)

2 35634 SCREW, CAP, HEX HEAD 0.250-28 UNF X 1.250 LONG GRADE 5 PLATED

2 35639 SCREW, CAP, HEX HEAD 0.250-28 UNF X 2.500 LONG GRADE 5 PLATED

6 5403-2*008 NUT, HEX, THIN 0.250-38 UNF

2 4341 WASHER, PLAIN 0.250 0.265 I. D. X 0.500 O.D. X 0.063 THICK CADMIUM PLATED AN960-416

2 35635 SCREW, CAP, HEX HEAD 0.250-28 UNF X 1.500 LONG GRADE 5 PLATED

1 207015 FLANGE, COUPLING

1 5801 OIL COOLER ASSEMBLY

1 5360 MAIN JACKET WELDMENT

5 5313 JACKET, FLANGE

1 5077 BASE PLATE

1 5236 INTERMEDIATE TUBE WELDMENT

1 5733-1 EXTENSION FLANGE WELDMENT

1 5362 CORE WELDMENT

1 5270 TAP WELDMENT

6 35700 SCREW, HEX HEAD, CAP 0.375-24 UNF X 0.875 LONG GRADE 5

SAE J2203 Reaffirmed NOV1999

REQUIRED

12 35702 SCREW, HEX HEAD, CAP 0.375-24 UNF X 1.750 LONG GRADE 5

18 4111 WASHER, PLAIN 0.375 0.391 I. D. X 0.625 O. D.

12 4037 NUT, HEX 0.375 X 24 UNF STEEL, ZINC PLATED

3 4108 PIPE PLUG, SQUARE HEAD 0.375 NPT GALVANIZED STEEL

2 5806 PIPE PLUG (SPECIAL)

1 201001 EXPANSION TANK

1 201002 WELDMENT

4 3393 ANGLE NEEDLE VALVE 0.250 N.P.T.

1 3386 THERMOCOUPLE, IRON CONSTANTAN, 1-3/8 IMMERSION LENGTH, 0.250 NPT BRASS BUSHING

1 34541 SIGHT GAUGE, OIL LINE

1 3661 VALVE, SOLENOID

1 34307 HEAT EXCHANGER

2 200011-1 BOX, JUNCTION

1 32827 COVER FOR FS PYLET W/GASKET

1 12394 PRESSURE CAP, 7 PSI

2 205010-1*021 VALVE, ANGLE, 1/2 in NPT

4 205010-1*031 U-BOLTS AND NUTS, 1/4-20 UNC X 0.75 INSIDE WIDTH

2 35101 SCREW, CAP, HEX HEAD 0.375-16 UNC X 1.250 LONG GRADE 5 CADMIUM PLATED

12 35025 SCREW, CAP, HEX HEAD 0.375-16 UNC X 1.000 LONG GRADE 5 CADMIUM PLATED

10 4814 SCREW, MACHINE, ROUND HEAD 0.250-20 UNC X 0.500 LONG PLATED

6 4248 NUT, HEX 0.375-16 UNC ZINC PLATED

SAE J2203 Reaffirmed NOV1999

REQUIRED

14 36375 WASHER, LOCK, HELICAL SPRING 0.375 MEDIUM PLATED

10 36374 WASHER, LOCK, HELICAL SPRING 0.250 MEDIUM PLATED

2 205010-1*038 VALVE, BALL SHUT OFF, 1/4 NPT

3 35283 VALVE, INK BLEEDER BOSCH #F-I-7621

1 31993 TWIST LOCK RECEPTACLE

1 31994 TWIST LOCK PLUG

1 3418 VALVE, GLOBE 0.500 NPT BRASS

1 3395 VALVE, GLOBE, ANGLE 0.375 NPT BRONZE

1 200012-1 COVER, THERMOCOUPLE JUNCTION BOX

1 32827 COVER FOR FS PYLET W/GASKET

1 205010-1*084 STRAINER, PIPE, 3/4 in, MASONELILAN INT'L #16

1 3500 VALVE, NEEDLE 0.375 NPT BRASS

1 205010-1*096 PUMP & MOTOR, CENTRIFUGAL—60 Hz, 1750 RPM,
1/3 HP, 115/230V, 1 PHASE, ALL BRONZE PUMP,
NON DRIP PROOF, SERIES 1522, 3/4 AAB
ITT BFLL & GOSSETT

1 205010-1*100 VALVE GATE, 1/2, 125 LB. BRONZE RISING STEM,
SOLID WEDGE DISC CRANE #428

1 207023 BOX, JUNCTION—THERMOCOUPLE WIRE

1 207020 BRACKET, SUPPORT—WATER AND DRAIN LINE

1 207021 BRACKET, MOUNTING—BALL VALVE

1 207022 BRACKET, MOUNTING—BALL VALVE

1 4600 VALVE, SWING CHECK K-105 STAND, 3/4 in PIPE ENDS
125# WORKING PRESSURE USED WITH 4557 (#37)

1 4557 EJECTOR HYDRAULIC, 3/4 in

SAE J2203 Reaffirmed NOV1999

Rationale—Not applicable.

Relationship of SAE Standard to ISO Standard—Not applicable.

Application—This SAE Standard defines the standard engine to be used in determining spark plug preignition ratings. The engine is known as the SAE 17.6 Cubic Inch Spark Plug Rating Engine.

Reference Section

SAE J973—Ignition System Measurement Procedure

SAE SP-243—Proceedings of the 28th Automotive Technology Development Contractors Coordination Meeting, 27

AS840—Manual, July 1964

Developed by the SAE Ignition Standards Committee

Annex C
(informative)

A French heat-rating method

C.1 Measurement method

The method consists of increasing the heat flow in the combustion chamber, slowly and steadily, until reaching a non-monitored ignition generated by the heating of the spark plug.

The reading of a reference temperature at a precise point in the combustion chamber characterizes the heat-rating value of the spark plug.

Self-ignition and ignition after the ignition point is detected by visualization on an oscilloscope of the ionization current generated between the electrodes of the measurement probe, see Figure C.1.

C.2 Definition of the heat-rating value of a spark plug

The heat rating of a spark plug is connected to the temperature value measured inside the combustion chamber as soon as self-ignition appears.

This temperature value can only be used to compare the heat-rating value of spark plugs tested during the same test session. No matter how much care is taken, it is not possible to guarantee the reproducibility of the measurement from day to day. This is due to the influence of numerous parameters, such as meteorological conditions, the working conditions of the engine and the mechanical condition of the engine. In practice, these parameters have no disturbing influences for eight successive measurements, which can thus be correlated.

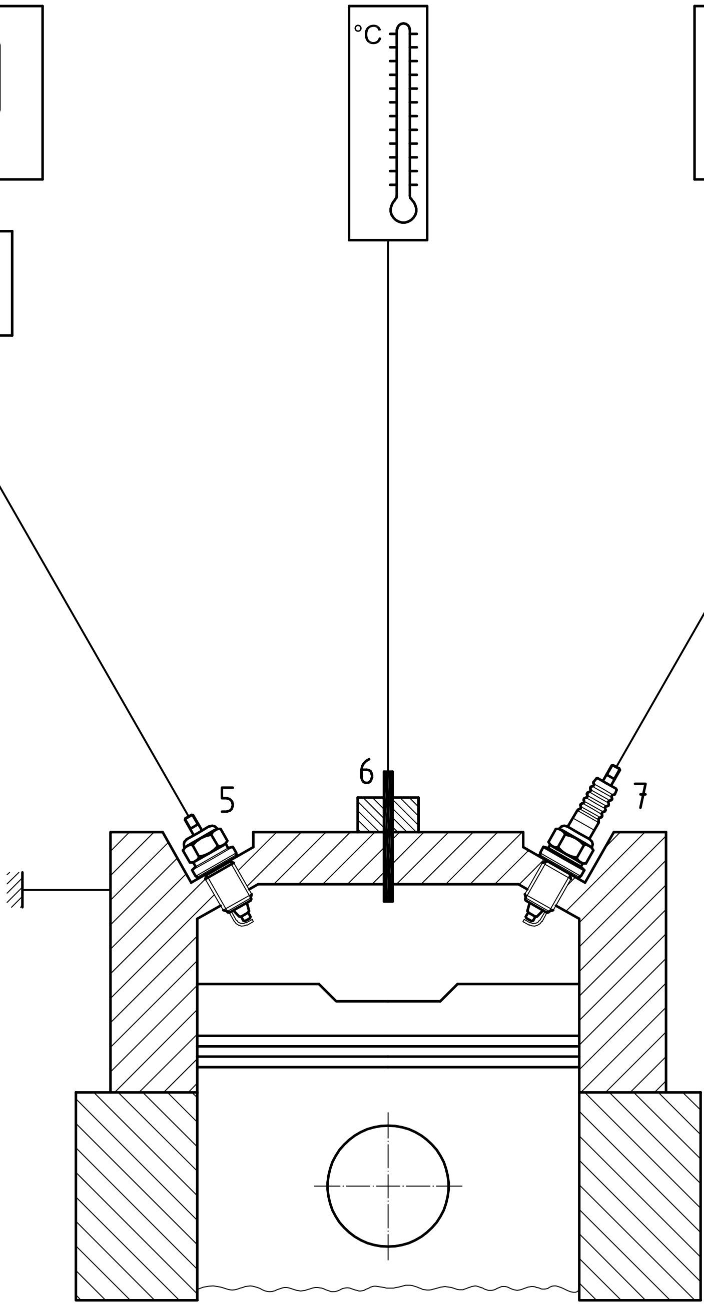
The test is performed by comparison between the values recorded with standard calibrated spark plugs and the values recorded with spark plugs sampled from the production line.

In order to validate the test while taking into account the unavoidable although very small dispersions, this test shall be performed at least with one standard spark plug and one sampled spark-plug, and at the maximum with three standard spark plugs, used several times during the same check session, and four sampled spark plugs.

The measurement is performed alternately with a standard spark plug and a sampled spark plug, see Table C1.

Table C.1 — Test scheme

Number of sampled spark plugs used	Number of calibrated standard spark plugs used	Sequence of tests
1	1	S1, P1, S1
2	2	S1, P1, S2, P2, S2
3	2	S1, P1, S2, P2, S2, P3, S1
4	3	S1, P1, S2, P2, S3, P3, S2, P4, S1
S = Standard calibrated spark plug, P = Sampled production spark plug.		



Key

1 Oscilloscope

2 Battery 270 V

3 High-tension input

4 Contact breaker device

5 Ionization probe

6 Thermocouple type K

7 Spark plug to be tested

Figure C.1 — Principle of heat rating

C.3 Test of heat rating of spark plugs

C.3.1 General data of test engine

Single cylinder	454 cm^3 piston swept volume
Bore x stroke	(85 x 80) mm
Engine speed	(2700 ± 15) min^{-1}
Compression ratio	8:1
Combustion chamber	two-volume, distributed between cylinder head and piston
Fuel	Aviation gas II
Supercharging boost pressure	adjustable to 2,2 bar (absolute)

C.3.2 Fuel supply — Carburation

Carburation is provided by an electronic injection device commonly used in automotive applications.

Pressurized sequential injection is adjusted and regulated by an electromagnetic fuel injector, with opening timing monitored by a processor.

Overboost and air pressure for the engine is supplied by compressed air (8 bar) as main supply, able to deliver up to 1,2 bar (relative) through a regulating device.

Air/fuel ratio related to overboost pressure is measured by a sensor working on the damping ability of the device.

C.3.3 Air/fuel mixture feeding

The air/fuel ratio, regulated by a potentiometer for a selected working point, is kept connected to a programmed curve. The slope of this curve can be modified by a second potentiometer.

C.3.4 Ignition

Electronic high-energy device (A.E.I.) with fixed ignition timing is set by a typical programme and synchronized by a missing tooth on the crankshaft.

C.3.5 Ignition and ignition breaking device

The ignition trigger device, adjustable by a potentiometer, gives the operator free choice of the frequency as well as the duration of the ignition breaking, in order to minimize the perturbations due to those cycles without ignition.

Annex D
(informative)

A German heat-rating method

D.1 General

This heat-rating method is a relative method, in which the test spark plugs are compared with master spark plugs of a known heat-rating value. During the measurement in a spark-plug heat-rating engine, the thermal load of the spark plugs is increased and the ignition behavior of the spark plug is observed by the ion current method. The thermal load can be varied by variation of the ignition timing, of the engine speed or of the charge-air pressure. In this annex, the first of these three possibilities is described.

D.2 Heat-rating engine

As this method is a relative method, generally any spark-ignited internal combustion engine can be used. Nevertheless, at least the cylinder head should be cooled by a thermostatically controlled water circuit, to obtain comparable engine temperatures at all operation points.

An electronically controlled fuel injection is preferred, because it allows simple adjustment or control of the air–fuel equivalence ratio λ.

For the heat rating of spark plugs with different threads and reaches in the same heat-rating engine, interchangeable thread inserts are used.

During the measurements, the engine is run at a predetermined constant load (e.g. full load, or full load with supercharging, or partial load). The engine speed is kept constant within a maximum variation of 1 %. The thermal load of the spark plug is changed by variation of the ignition timing. An increase in the spark advance results in a higher temperature at the spark plug.

When premium gasoline is used, the measurement of “cold” spark plugs (short insulator tip) is limited by the knock limit. To enlarge the operating range, fuels with higher octane number may be used.

The main characteristics of one of the heat-rating engines used are listed in Table D.1.

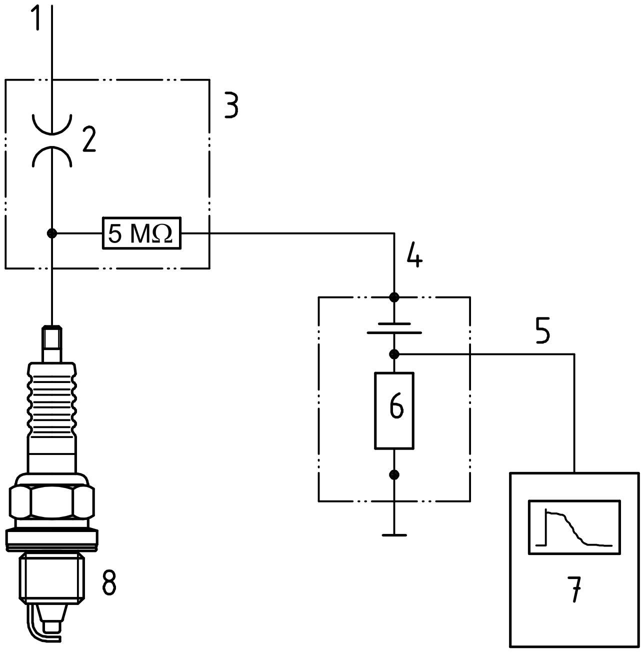
Table D.1 — Example of a heat-rating engine

Engine manufacturer	HATZ
Engine type	HE 673 LHK, 1 cylinder, 4–stroke, watercooled
Displacement	280 cm^3
Compression ratio	8,4 : 1
Maximum engine rotational speed	3 500/min
Power at the maximum rotational speed of 3500/min without supercharging	4,2 kW
Ignition system	Twin spark ignition, spark advance angle 0° to 60° Before Top Dead Centre (BTDC)
Air–fuel equivalence ratio λ	Approximately 0,92
Coolant temperature	80 °C

D.3 Determination of the thermal load of spark plugs

Under normal operating conditions in an engine, the ignition is initiated by the electric spark. Ignition may also be caused thermally by hot surfaces. Usually the highest surface temperature inside the combustion chamber occurs at the spark plug. During heat rating it shall be ensured that within the operation range the thermal ignition is only initiated by the hot surface of the spark plug.

With ion current measurement, the type of ignition can be detected. Figure D.1 shows a typical measurement set up.



Key

1 From ignition voltage supply

2 Booster gap[a)]

3 Ion current adapter

4 Ion current measuring unit

5 Voltage supply

6 Resistor

7 Oscilloscope

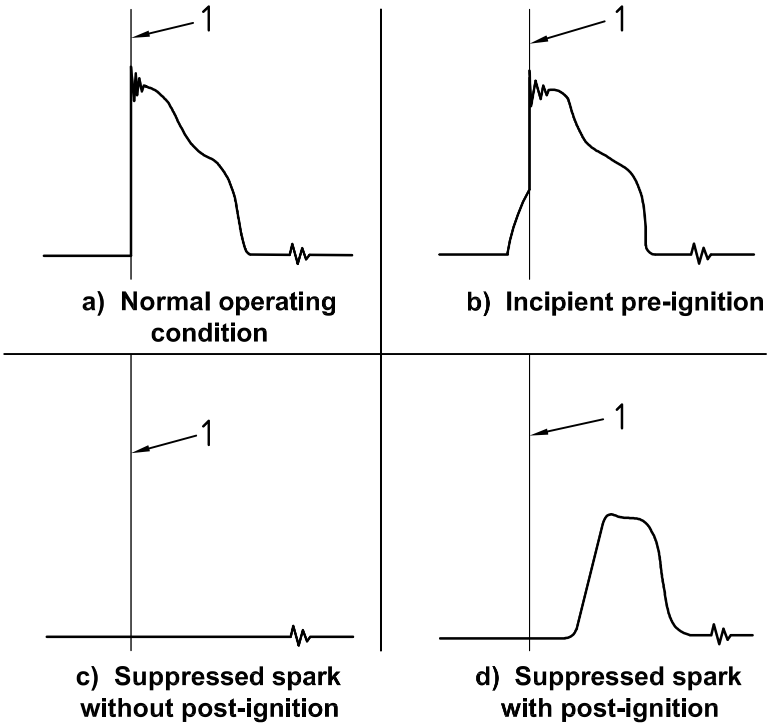
8 Spark plug (measuring probe)

a) Can be replaced by a Zener diode string

Figure D.1 — Ion current measurement

Thermal ignitions (self-ignitions) are called post-ignition or pre-ignition, depending on whether they occur after or before the electrical ignition point (see ISO 2542). Pre-ignitions can be detected by a rise in the ion current before the electrical ignition point. For the evaluation of post-ignitions, it is necessary to suppress individual sparks at specific intervals.

Figure D.2 shows typical ion current curve patterns for the above-mentioned ignition behaviour.



Key

1 Ignition point

Figure D.2 — Ion current oscilloscope patterns (ion current vs. time)

The pre-ignition rate is the ratio of the number of pre-ignitions to the number of the observed combustion cycles. The post-ignition rate is the ratio of the number of post-ignitions to the number of suppressed sparks. With suitable processing of the ion current signal, it is possible to indicate pre- and post-ignitions and pre- and post-ignition rates directly, and to stop the test-engine at a predetermined pre-ignition rate. Thus damage to the samples or the heat-rating engine may be prevented.

The thermal load of a spark plug may be expressed in terms of pre- or post-ignition rate.

Figure D.3 shows the development of the post- and the pre-ignition rates depending on the spark advance α_z.

After reaching 100 % post-ignition, some pre-ignitions may occur, caused by deposits on the spark plug or by the hot insulator surface. A stable range for the evaluation is at pre-ignition rates of 5 % to 10 %.

D.4 Master (calibrated) spark plugs

The comparison of the test spark plugs with master spark plugs makes the method independent of the specific engine, the engine conditions and other parameters which influence the combustion. The design of master spark-plugs is completely identical with that of production spark plugs, but they are machined with the minimum tolerances and highest precision; and finally the master spark plugs are selected by comparison of the heat ranges. Thus deviations from the master heat range are minimized.

D.5 Measurement and evaluation of the heat-rating value

D.5.1 General

Because of the influence of engine conditions, of fuel and of environment on thermal ignitions, the highest accuracy can be achieved by continuous measurements. The variance in the test spark plugs and the master spark plugs may be registered by using a higher number of spark plugs.

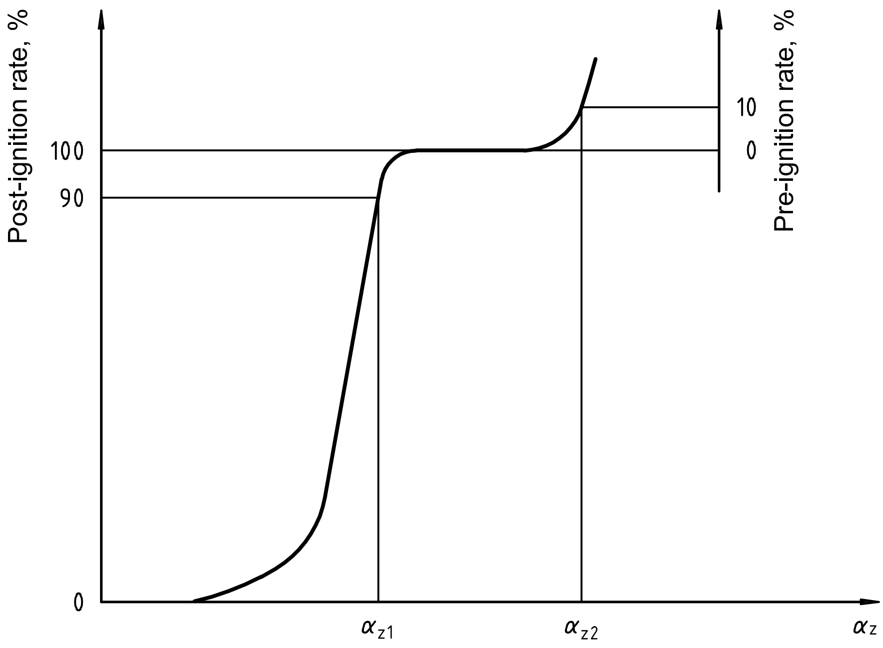


Figure D.3 — Post- and pre-ignition rates vs. spark advance α_z

First the operating conditions of the test engine must be chosen, e.g. with or without supercharging, kind of fuel (normally unleaded premium gasoline), etc.

The cylinder head must be equipped with an insert corresponding to the specific design of the test spark plug.

To precondition unused spark plugs before the measurement, they must be loaded thermally until the post-ignition range is reached.

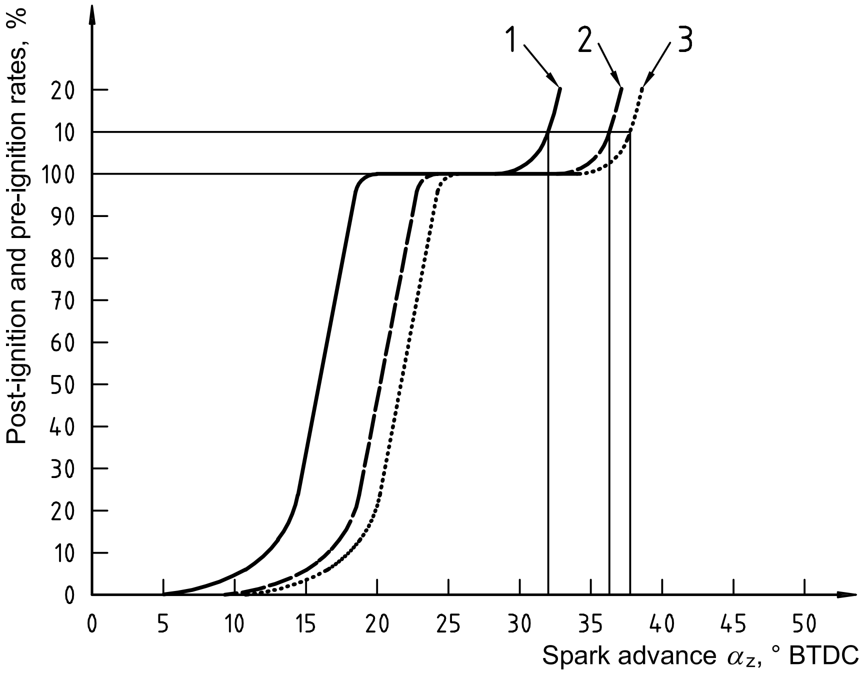
After the test spark plug is installed, the engine is run at constant speed with full load and constant air-fuel equivalence ratio λ. The measurement must be started at a late-ignition timing at which self-ignitions do not yet occur. By advancing the ignition timing, the thermal load is gradually increased. With the ion current measurement unit, the post-ignition rate is measured by suppressing sparks. The post-ignition rate may be recorded as a function of the spark advance (as shown in Figure D.3). After 100 % post-ignition rate is reached, the thermal load is further increased until the first pre-ignition occurs.

The spark advance that corresponds to the defined thermal load (5 % or 10 % pre-ignition rate or 90 % post-ignition rate) is used as the basis for the following evaluation.

To determine the unknown heat range of a test spark plug, additional measurements of master spark plugs with heat ranges below and above that of the test spark plug are necessary. The heat range of the test spark plug can be calculated by linear interpolation between the master spark plugs' heat ranges with the corresponding spark advances and the test spark plug with its spark advance. See Figure D.4.

Normally interpolation is used to determine the heat range (example 1). If necessary extrapolation may be used (example 2).

D.5.2 Example 1 (interpolation)



Key

1 Master spark plug with heat rating value 6

2 Test spark plug

3 Master spark plug with heat rating value 5

Figure D.4 — Post-ignition and pre-ignition rates vs. spark advance

Table D.2 — Measured spark advance

	Heat-rating value	Spark advance α_z ° BTDC
Master spark–plug	5	37,5
Test spark–plug	x	36,0
Master spark–plug	6	31,5

Heat-rating value x of the test spark plug can be calculated as follows (see Table D.2 and Figure D.5):

$x \quad = 5 + (\alpha_{z5} - \alpha_{zx}) / (\alpha_{z5} - \alpha_{z6}) =$

$= 5 + (37{,}5 - 36{,}0) / (37{,}5 - 31{,}5) = 5 + 1{,}5/6 = 5{,}25$

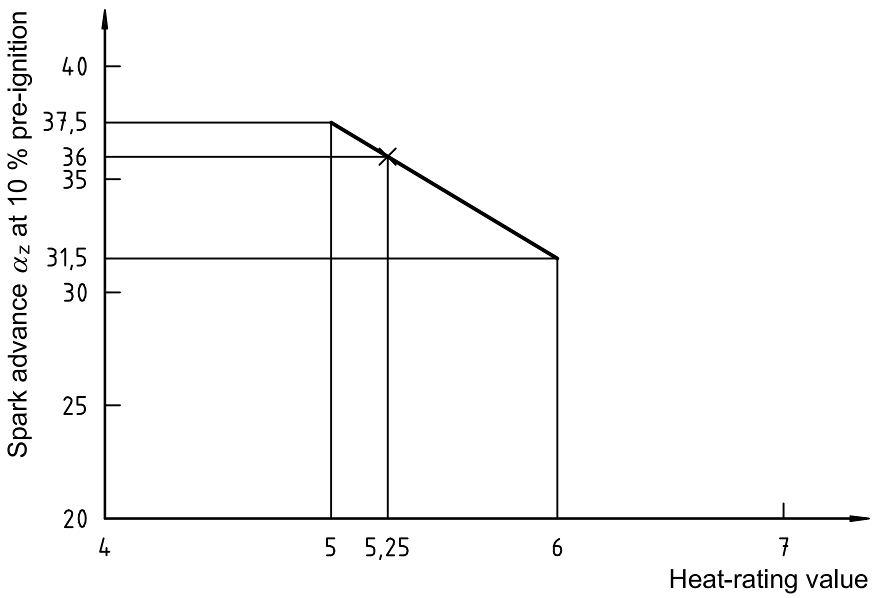


Figure D.5 — Determination of a heat-rating value by interpolation

D.5.3 Example 2 (extrapolation)

Table D.3 — Measured spark advance

	Heat-rating value	Spark advance α_z ° BTDC
Master spark plug	5	37,5
Test spark plug	x	38,7
Master spark plug	6	31,5

Heat-rating value x of the test spark plug can be calculated as follows (see Table D.3 and Figure D.6):

$$x = 5 + (\alpha_{z5} - \alpha_{zx}) / (\alpha_{z5} - \alpha_{z6})$$

$$= 5 + (37,5 - 38,7) / (37,5 - 31,5) = 5 - 1,2/6 = 4,8$$

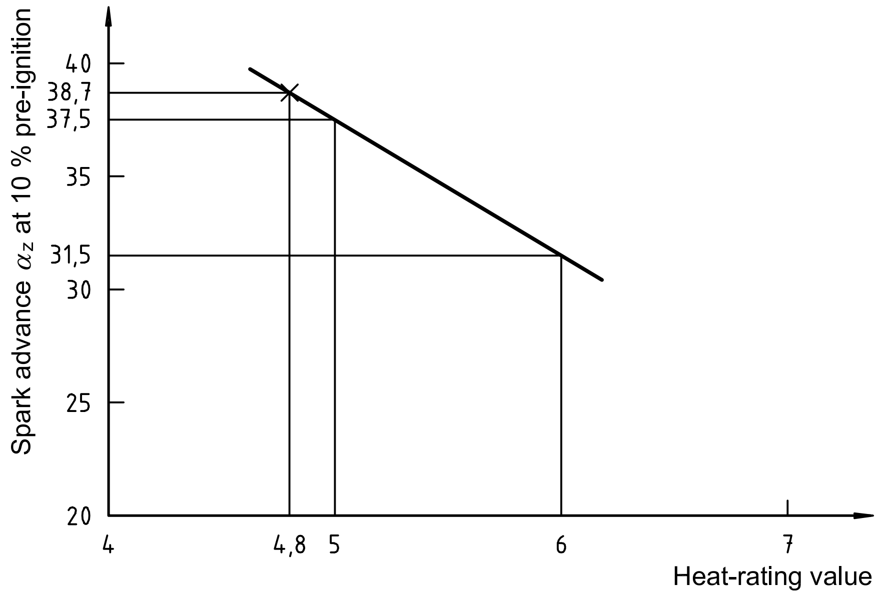


Figure D.6 — Determination of a heat-rating value by extrapolation

Annex E
(informative)

A Japanese heat-rating method

E.1 General

The temperature in the combustion chamber is controlled to remain below a maximum allowable limit by balancing the heat generated by the combustion process with the cooling effect imparted by the engine cooling system (oil and coolant flows) and incoming fuel change. The same is true for the spark-plug temperature.

The temperature of the firing end of the spark plug is highest at the ignition point in the combustion chamber. The temperature level depends on the electrode configuration and insulator design. Pre-ignition therefore often occurs from the insulator tip.

Moreover, when engines are up-rated under low-temperature (low-load) conditions, carbon can form as a product of the combustion process. If the carbon accumulates on the insulator surface of the spark plug, it is possible that the high terrain voltage could leak to ground. Therefore the insulator-tip temperature should be kept as high as possible in order to prevent carbon accumulation.

Spark plugs should be designed in consideration of the balance of heat input and heat dissipation, such that the plug never becomes the source of pre-ignition under heavy load, and carbon accumulation can be avoided under low-temperature low-load operation.

It is difficult for one plug specification to have the correct heat balance for all engines. The heat balance, therefore, must be changed according to the type of engine and the condition of use.

The heat balance of the spark plug is defined as the heat rating. Pre-ignition is a condition which causes engine damage and should never occur. Evaluation of anti-pre-ignition is used as a measure of the heat rating of the spark plug. In Japan a Labeco SAE 17.6 engine in accordance with the SAE standard is used to measure IMEP (Indicated Mean Effective Pressure) in pounds per square inch just prior to the occurrence of pre-ignition. For simplification, the IMEP is assigned a number between 2 and 9 (Maker A), 9 and 27 (Maker B) as shown in Figure E.1 which comprises the heat-rating value of the spark plug.

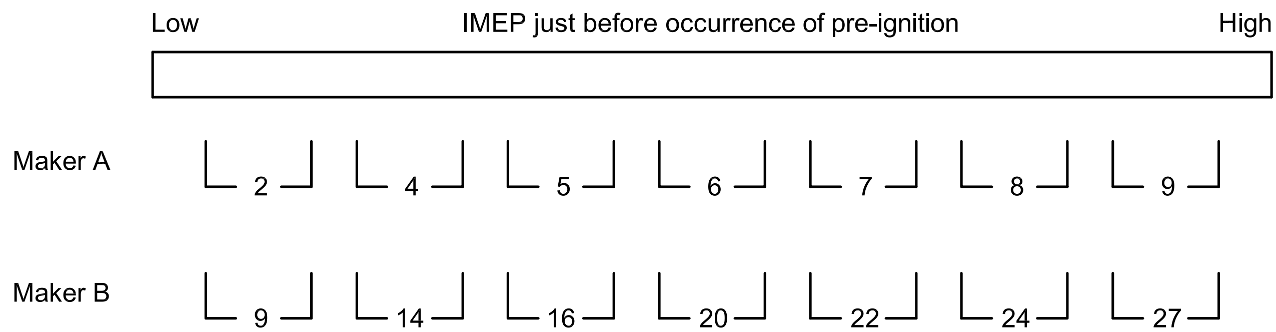


Figure E.1 — Evaluation of heat rating

E.2 Evaluation of heat rating

Using the SAE 17.6 engine, the heat rating of the spark plug is established using IMEP values taken at the maximum intake manifold pressure just prior to pre-ignition. This technique is described below.

The SAE 17.6 engine is very different from today's vehicle engines. With a relatively low maximum speed of 2700 min^{-1}, the intake manifold pressure is also quite high and benzene is used as the fuel. Therefore it is not always practical to evaluate heat rating using the SAE 17.6 engine. Figure E.2 shows the effect of a projected nose spark–plug (insulator projecting from the metal shell). In a conventional “modern” engine, as dimension H is increased anti-pre-ignition is also increased, however, anti-pre-ignition decreases in the SAE 17.6 engine.

Since the dimension H is relatively small for conventional spark plugs, the anti-pre-ignition level can be determined using the SAE 17.6 engine.

However, recent trends are for a more projecting insulator nose (larger H) and it has therefore become increasingly difficult to use the SAE 17.6 engine for actual measurement of anti-pre-ignition characteristics.

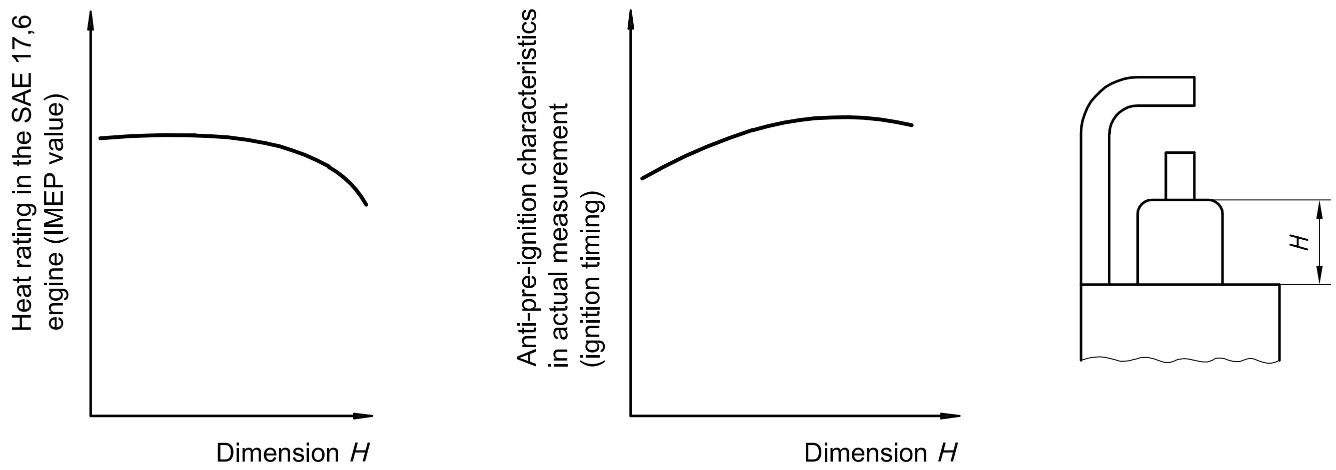


Figure E.2 — Variation of heat rating and anti-pre-ignition characteristic due to change in insulator projected length

In this case, the heat rating of the spark-plug with smaller H is evaluated on the SAE 17.6 engine and then on a conventional vehicle engine for anti-pre-ignition characteristics. Spark plugs with large nose projections are evaluated using a conventional vehicle engine. The heat rating is determined by comparing this result with the anti-pre-ignition characteristic of a spark plug with conventional nose projection. The same is true for other design features.

Regarding motorcycle engines, the maximum speed is generally above 9 000 min^{-1}, compared with that of automobile engines which are in the range of 5 000 min^{-1} to 6 000 min^{-1}. Therefore motorcycle engine conventional spark plugs are evaluated in the SAE 17.6 engine and then in a motorcycle engine. For specially designed types, the heat rating is established by comparing with a conventional type spark plug.

In summary, the SAE 17.6 engine is used to establish the heat rating of conventional spark plugs. However, for specially designed types, the heat rating is established by comparing the anti-pre-ignition characteristic with the standard spark plug.

Very high heat-rating spark plugs, such as racing types, cannot be measured because of the difficulties in reproducing the conditons under which pre-ignition is generated. Heat rating is therefore performed using the SAE 17.6 engine.

E.3 Heat-rating method

E.3.1 Heat rating using the SAE 17.6 engine

E.3.1.1 Test engine and operating conditions:

- Piston swept volume: 17,6 in^3 (Labeco SAE 17.6)
- Aspiration: Supercharged
- Fuel system: Mechanical fuel injection
- Compression ratio: 5.6
- Engine rotational speed: 2700 min^{-1}
- Ignition timing: 30° BTDC
- Fuel: 98 % benzene, 2 % SAE #120 oil

E.3.1.2 Measuring procedure

Heat rating is performed in accordance with the SAE J549a procedure. This is used for standard spark–plugs only.

Pre-ignition is detected by a sudden rapid rise in combustion chamber temperature.

As described in the following procedure, a stabilized condition is maintained just prior to pre-ignition and the IMEP shall be determined from the intake manifold pressure. A number is then assigned to the IMEP value to form the basis of the spark plug heat rating number.

a) Increase the intake manifold pressure maintaining 2 700 min^{-1}, adjust the fuel flow to maintain maximum combustion chamber temperature.

b) Increase the intake manifold pressure in steps of 13,546 kPa while adjusting the fuel flow to maintain maximum combustion chamber temperature.

NOTE 13,546 kPa = 4 inch Hg

c) Shut off the fuel as soon as pre-ignition occurs and reduce the intake manifold pressure by 6,773 kPa. Switch on the fuel again and adjust to the same fuel flow and maintain a stabilized operating condition for at least 3 min.

NOTE 6,773 kPa = 2 inch Hg.

d) If pre-ignition re-occurs in step c) above reduce the intake manifold pressure by a further 3,386 kPa until a 3 min stabilized operating condition can be achieved.

NOTE 3,386 kPa = 1 inch Hg.

e) If a 3 min stabilized operating condition was originally achieved in step c) then increase the intake manifold pressure by 3,386 kPa and adjust the fuel flow. Repeat until pre-ignition occurs. If pre-ignition occurs complete step d) above.

NOTE 3,386 kPa = 1 inch Hg.

f) Engine output and friction are measured by intake manifold pressure during the 3 min stabilization. Friction shall be measured within 30 s after fuel shut off.

E.3.2 Heat rating using a practical engine

E.3.2.1 General

Two kinds of heat-rating spark plug are prepared and measured in the SAE 17.6 engine. These plugs are used as masters. The ignition timing for pre-ignition is measured for the master plugs and test plugs on a conventional engine (details see below). The heat rating of the test plugs is established by comparison with the master plugs. The heat rating is established using a number so the test plug shall completely match the master plugs in ignition timing and pre-ignition levels. If they do not they shall be prepared again after design revision and measured by the method above.

Which of the following engines is used depends on the application of the test plugs in the market. According to the type of spark plugs, they are sometimes tested in several engines.

E.3.2.2 Passenger car engine

Configuration:	water-cooled, four-stroke, four cylinders, four valves per cylinder
Displacement:	1 600 cm^3
Engine rotational speed:	5 500 min^{-1}
Water temperature:	65 °C ± 5 °C
Oil temperature:	95 °C ± 5 °C
Fuel:	200 RON unleaded
Air:fuel ratio:	12,7 ± 0,2

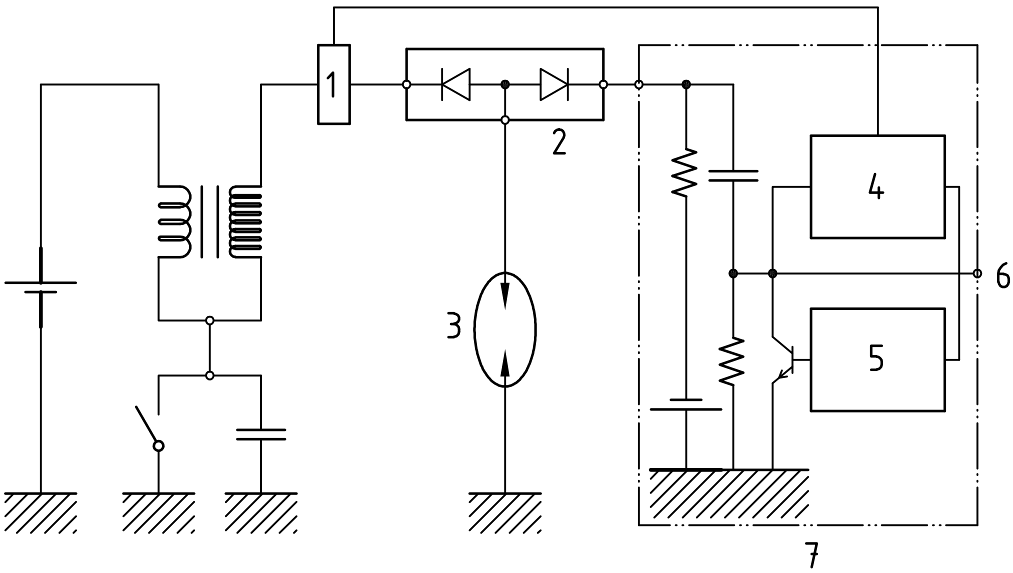
E.3.2.3 Motorcycle engine (1)

Configuration:	air-cooled, two-stroke, single cylinder
Displacement:	125 cm^3
Engine rotational speed:	9 000 min^{-1}
Oil temperature:	95 °C ± 5 °C
Fuel:	100 RON unleaded
Air:fuel ratio:	12,0 ± 0,2

E.3.2.4 Motorcycle engine (2)

Configuration:	air-cooled, two-stroke, single cylinder
Displacement:	125 cm^3
Engine rotational speed:	8 500 min^{-1}
Fuel:	100 RON unleaded
Air:fuel ratio:	11,5 ± 0,2

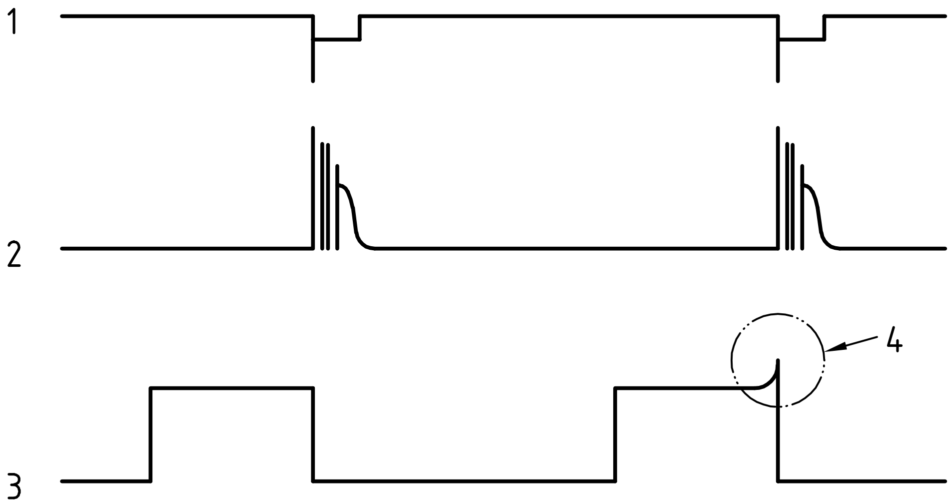
The same pre-ignition measurement technique is used for each engine. Ion current generated before ignition is detected by applying a negative voltage of 350 V to the centre electrode of the spark plug of the test cylinder, with an electrical circuit as in Figure E.3. Figure E.4 shows the concept. In order to minimize errors, the applied voltage is switched off just after spark ignition.



Key

1 Magnet pick-up
2 High voltage diode
3 Spark plug
4 Detection circuit of pre-ignition
5 Spark noise cut circuit
6 O.S.C.
7 Pre-ignition tester

Figure E.3 — Electrical circuit of pre-ignition test



Key

1 Ignition timing signal
2 Ion current
3 Monitor signal
4 Pre-ignition

Figure E.4 — Detection of pre-ignition

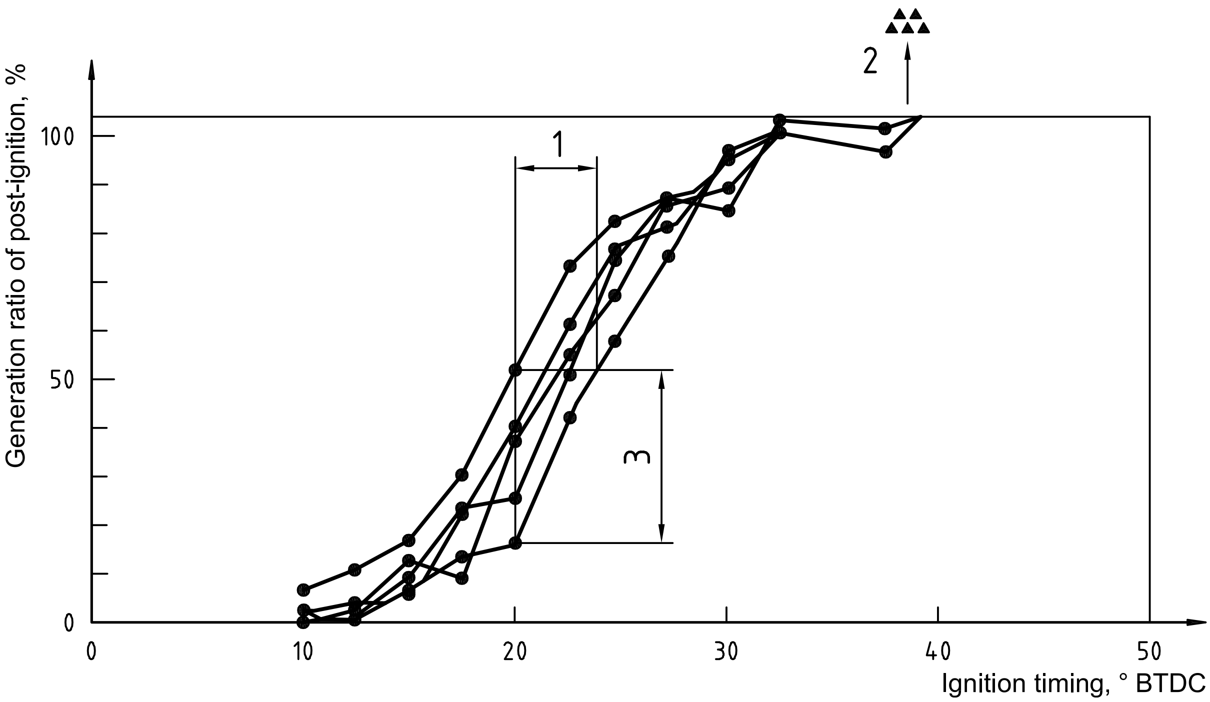
The ”occurrence of pre-ignition” is confirmed only after four pre-ignition signals have been detected on the monitor over a 2 min period. One to three pre-ignition signals would be classified as “there is a sign of pre-ignition”.

E.4 Comparison of pre-ignition and post-ignition methods for evaluation of adaptability

The heat rating or heat balance of the spark plug is required to avoid pre-ignition in practical engines. Therefore, the best way to select the heat rating for a test engine is to detect pre-ignition itself. The occurrence of pre-ignition can be monitored for every combustion cycle, therefore accurate evaluation is possible.

For example in a four-stroke engine at 6 000 min^{-1}, 3 000 power strokes/min can be monitered, therefore early pre–ignition can be quickly detected. With the post-ignition method, one spark every 50 power strokes is used to detect whether there is post-ignition and the ignition timing of post-ignition. Therefore, the number of power strokes sampled via post-ignition technique is less than that for pre-ignition measurement. For example only 60 power strokes/min can be monitored using the post-ignition method. The method is therefore worse in terms of accuracy for heat-rating evaluation.

Figure E.5 shows an example of data from post-ignition and pre-ignition tests for five repeat tests using the same spark plug.



Key

1 Fluctuation 4° CA

2 Pre-ignition

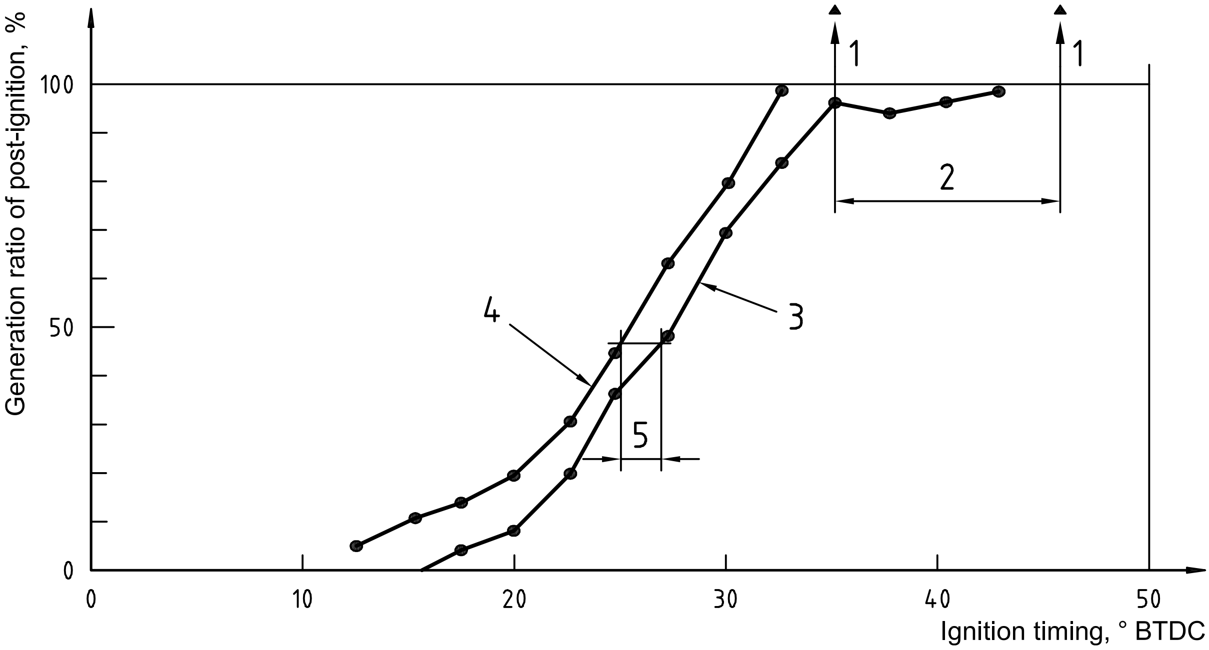
3 Fluctuation 36 %

NOTE Engine: 2 l, 4 cylinders; conditions: 5 000 min^{-1} X WOT

Figure E.5 — Variation of generation ratio of post-ignition

Although every occurrence of pre-ignition was 40° BTDC, there is a variation of 30 % to 40 % in the occurrence of post-ignition for the same ignition timing.

For the same occurrence of post-ignition, there is 3° to 5° crankshaft angle (CA) variation in ignition timing.



Key

1 Pre-ignition
2 Difference 10° CA
3 Spark-plug A
4 Spark-plug B
5 Difference 2° CA

NOTE Engine: 2 l, 4 cylinders; conditions: 5 000 min^{-1} X WOT

Figure E.6 — Variation of post-igniton due to spark-plug specification change

For post-ignition, when the basic frequency is 50 % the difference between the heat rating of spark plug A and spark plug B is only approximately 2 °CA in ignition timing. It is difficult to confirm this difference unless the number of tests is increased due to the variation in post-ignition measurement.

There is a difference of 10 °CA in the timing of pre-ignition, but this difference is not subject to the variation mentioned above. The same is true of the material of the insulator and the conductivity of the centre electrode, and for the technique of heat-range improvement through improved component accuracy.

In summary, it is considered that the best technique for evaluating spark plug suitability should be based on pre-ignition tests.

Annex F
(informative)

A U.K. heat-rating method

F.1 Heat rating engine

Engine type:	288 cm^3 SAE type rating engine
Rotational speed:	2 700 min^{-1} nom.
Speed control:	synchronous motor
Compression ratio:	5,6:1
Ignition:	magneto
Fuel:	toluene ELC to BS 805/1/2 1972 plus 2 % grade 120 oil
Fuel injection pressure:	(217,58 ± 7,25) kPa
Mixture strength:	that giving maximum thermal plug temperature.

F.2 Procedure

F.2.1 Step 1

Run engine until oil, air and water temperatures are correct (see SAE engine handbook).

Stop engine and install test plug.

F.2.2 Step 2

Start engine. Adjust boost pressure and fuel/air mixture to give thermal plug temperature of 400 °C.

The supercharge pressure is increased in 6,894 kPa increments until pre-ignition occurs as indicated by a rapid rise in the thermal plug temperature. At each setting the mixture strength is adjusted such that a maximum thermal plug temperature is obtained.

When pre-ignition occurs, the fuel supply is instantly cut off and the supercharge pressure is decreased 6,894 kPa at which point the fuel is turned on again, adjusted for maximum thermal plug temperature. This condition shall be held for three minutes or until pre-ignition again occurs.

F.2.3 Step 3

If pre-ignition occurs after step 2, the supercharge pressure should be reduced in 3,447 kPa increments until stable engine operation is attained.

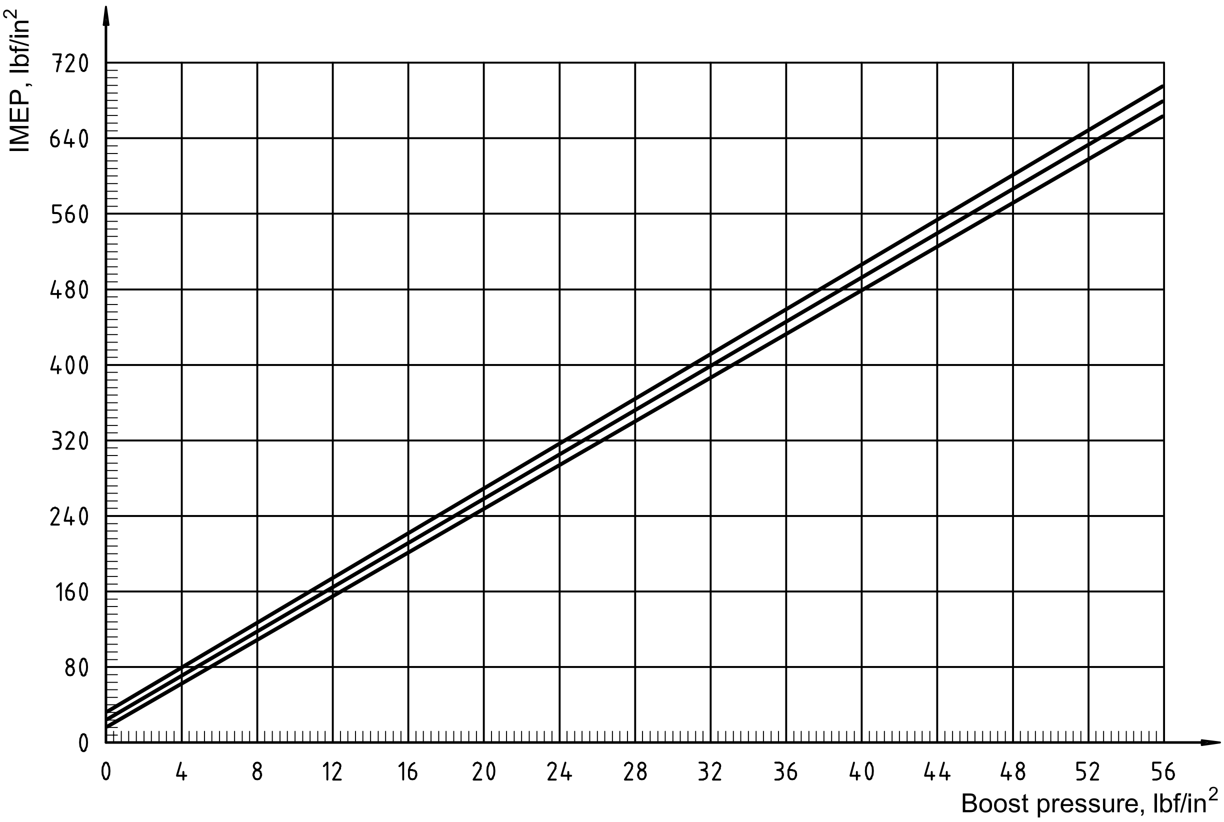
If after step 2, stable engine operation is attained, the supercharge pressure should be increased in 3,447 kPa increments again adjusting for optimum thermal plug temperature until stable engine operation for three minutes is obtained or pre-ignition again occurs.

F.3 Calculation and adjustment

A standard calibration curve for the engine is used to obtain the indicated mean effective pressure (IMEP) value corresponding to the "steady running" boost pressure and assigned as the rating of the spark plug. See the example in Figure F.1.

The plug rating is that IMEP value obtained on the engine at a point when the supercharge pressure is 3,447 kPa below the pre–ignition point. The preceding steps are recommended to attain this point.

A reference plug of the same type as that being tested should be rated during or at the end of the test period. Differences of 6,894 kPa, which can be accounted for by day-to-day changes in atmosphere and engine operating conditions, can be ignored but for greater differences the subject plug ratings should be corrected by a factor derived from the current reference-plug rating, divided by its previous rating. If the difference is greater than can reasonably be expected, then a second reference plug should be tested and the first discarded. In any case, reference plugs should not be re-rated more than six times.



NOTE 6,894 kPa = 1 lbf/in^2 (= 0,689 mbar).

Figure F.1 — Example calibration curve

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