Recommended Practice for Installation, Maintenance, and Operation of Internal-Combustion Engines

API RECOMMENDED PRACTICE 7C-11F
FIFTH EDITION, NOVEMBER 1, 1994

REAFFIRMED: APRIL 2008

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Exploration and Production Department

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FOREWORD

This recommended practice is under the jurisdiction of the API Committee on Standardization of Production Equipment.

A related specification issued by the Division of Production, American Petroleum Institute, is: "Spec7B-11C Specification for Internal-Combustion Reciprocating Engines for Oil-Field Service". It covers methods of testing and rating internal-combustion reciprocating engines for application to specific oil-field service.

This standard shall become effective on the date printed on the cover but may be used voluntarily from the date of distribution.

Recommended Practice for Installation, Maintenance, and Operation of Internal-Combustion Engines

1 Scope

1.1 The purpose of this recommended practice for installation, maintenance, and operation of internal-combustion engines is threefold, viz.:

a. To present information of a general nature pertaining to their installation and to emphasize installation recommendations for specific types of service, observation of which is often overlooked.
b. To present maintenance check-off lists for daily, weekly, and monthly maintenance of such engines.
c. To present trouble-shooting recommendations with which the causes of most common engine troubles can be determined. This publication does not purport to be a detailed instruction manual; and, in cases where additional information is required on a particular piece of equipment, the manufacturer should be consulted.

1.2 To present (see Appendix A) recommendations for minimizing potential fires and/or explosions.

1.3 The information presented under installation and maintenance has been classified as:

a. Applicable generally to all types of internal-combustion engines in all types of service.
b. Particularly applicable to engines in drilling or semi-portable plant service.

1.4 Particularly applicable to engines in oil-well pumping, oil-pump, or similar service where the engines may or may not be under daily observation. Both multiple-cylinder and single- or two-cylinder engines are considered in the latter category.

2 General

2.1 MOUNTING

All engines should have solid vibration-free mounting. Installation of box-base type engines without full-length support of the base is not desirable. Shims or other precision methods should be used to avoid uneven support and distortion of the engine structure.

2.2 LEVELLING

Engines, particularly the box-base type, should be as level as possible.

2.3 ALIGNMENT

The alignment of the engine with the driven equipment should comply with the recommendations of the manufacturer for both the engine and the driven equipment. Before aligning, both engine flywheel and flywheel housing, as well as the driven equipment, should be checked for runout resulting from handling or service.

2.4 FLEXIBLE COUPLINGS

In the initial installation of equipment, flexible couplings should be used when checking the correct belt tension and the gap between shafts.

2.5 SHEAVES, BEARINGS, AND CLUTCH SHAFTS

Drive pulleys should be mounted as close to the engine as possible. This places the load near the clutch main bearing and tends to reduce the side-pull load on the bearings. Heavy tools should not be used to drive sheaves or similar equipment on the clutch shafts. Such procedure can damage bearings and cause difficulty in the removal of sheaves. Caution should be exercised in installing excessively large-diameter or heavy drive pulleys. The recommendations of the manufacturer for such installation should be carefully followed.

2.6 ENGINE EXHAUST

Each engine-exhaust system should be of sufficient size that back pressure at the engines does not exceed that recommended by the manufacturer, and each engine should have a separate exhaust. It is required to include in the exhaust piping a short section of flexible tubing for vibration isolation, thermal expansion, and ease of alignment on installation. Exhaust piping should be independently supported to prevent damage to the engine. Care should be exercised to prevent welding slag or any foreign material from entering the engine during installation. Do not connect exhaust from several engines to a common header. All exhaust systems should be protected against water entry and a suitable trap and drain provided to prevent condensate from returning to the engine.

2.7 PROTECTION AGAINST WEATHER

Proper protection against weather should be provided during storage or installation. For storage longer than a few days, use the protective materials and methods recommended by the engine manufacturer.

2.8 ENGINE COOLING SYSTEM

Only clean water, soft or treated, should be used in the engine cooling system. The use of corrosion inhibitors should

be considered. Consult manufacturer's recommendations for appropriate inhibitors. Provide and mark suitable system drains. Unless anti-freeze is to be used, drain complete system including air intercoolers and intercooler circulating lines in cold weather. All water system piping should comply with engine builder's size recommendations. Provide suitable vents at high points in system.

2.9 COOLING AIR

Engines should be oriented to take advantage of prevailing winds. Suction or blower fans should be used as best suited to conditions. When engines are installed inside buildings, sufficient openings should be provided for the intake and exhaust of cooling air. Any danger of recirculating the cooling air should be eliminated by the use of ducts. Where thermally actuated cooling-water control valves are used, the capillary tubing should be as short as practical in order to prevent interference from outside temperature sources.

2.10 FUEL SYSTEM

When installing fuel piping, all foreign material should be removed from lines before they are connected to the engine. Lines of adequate size should be installed and adherence to safety codes should be observed. Adequate strainers and liquid traps should be provided in the fuel system. It is desirable to include a section of flexible tubing for vibration isolation. Non-restricting shut-off valves should be provided in the fuel lines immediately adjacent to the engine. Gas regulators and their orifices and springs should comply with the engine builder's recommendations.

2.11 BATTERY STARTING SYSTEMS

The battery should be installed in a clean, cool, accessible, and vibration-free location, which is as close to the starting motor as practicable. Before installation, the battery should be checked for correct polarity.

2.12 GAS STARTERS

Where gas starters are used, exhaust gas should be piped a safe distance from the engine.

2.13 CONTROL EQUIPMENT AND SAFETY DEVICES

Consideration should be given to the use of engine temperature-control equipment and to the use of safety devices such as low oil-pressure and high-temperature cutoffs. Such devices should be operable and not blocked out.

2.14 LOADING OR UNLOADING

Engines can suffer twisted frames or other harm from careless handling. During loading and unloading operations, adequate tools for skidding, or non-crushing slings should be used to prevent such damage. Lifting by winch lines hooked around the engine is not recommended. Jacking or pushing against the vibration damper or flywheel can cause severe damage. Always check runout after moving engine to new location.

2.15 FIRES AND/OR EXPLOSIONS

Consideration should be given to minimize potential fires and/or explosions. See Appendix A for recommendations.

3 Drilling or Other Large Internal-Combustion Engines

3.1 ENGINE-FLYWHEEL ALIGNMENT

When open-type air clutches are used, the alignment of the engine flywheel with the clutch is very important since misalignment can result in severe damage to the engine.

3.2 DIESEL-ENGINE FUEL-PUMP LINES

In order to eliminate the possibility of air locking the fuel pump, diesel-engine fuel-pump overflow and leakage lines should be returned to the fuel tank and not piped directly back into the pump suction. The return area must be properly baffled and vented to permit escape of vapor and air. Also, the return should be directed against a baffle or in a manner which avoids continuous agitation of the fuel in the tank. Injector return fuel may require cooling prior to return to fuel tank.

3.3 ELEVATION OF DIESEL FUEL TANK

The elevation of the diesel fuel tank should be in accordance with the recommendations of the engine manufacturer.

4 Multiple-Cylinder Pumping Engines

4.1 WET STACKING

Unburned diesel fuel may accumulate in the exhaust system if the load on the engine is reduced below a minimum design point. This condition known as *wet stacking* should be considered when sizing a diesel-engine in accordance with recommendations from the engine manufacturer.

4.2 DESIGN OF V-BELT DRIVE

Care should be exercised to design the V-belt drive for the probable engine speed range.

4.3 INSPECTION PRIOR TO STARTING

New pumping engine installations should be inspected by a competent mechanic prior to starting.

5 Single-Cylinder and Two-Cylinder Pumping Engines

5.1 FOUNDATION

Generally, a heavier, more rigid foundation is required for single-cylinder and two-cylinder pumping engines.

5.2 GAS VOLUME TANK AND FUEL CONNECTION

An adequate gas volume tank and a flexible fuel connection to the engine are desirable.

5.3 EXHAUST LINES

Exhaust lines of adequate size and correct length should be provided, particularly for two-cycle engines.

6 General Maintenance

6.1 DAILY INSPECTION

A daily inspection of engines should be made by the pumper or qualified engine operator who should also record each inspection performed as follows:

6.1.1 Coolant Temperature and Oil Pressure

Before shutting down, coolant temperature and oil pressure should be observed under normal load. If the engine is a diesel equipped with pyrometers, all cylinders should be checked. Check and record vacuum reading on spark ignition engines.

6.1.2 Lubrication

The crankcase oil level in both main and starting engines should be checked and oil added if needed. Sufficient time should be allowed for the oil to drain back to the crankcase from the upper engine parts before checking the oil level. Oil should be replaced as recommended by the engine manufacturer, or when it is obviously thickened, diluted, or dirty beyond normal conditions. Filter elements should be replaced and the oil strainer cleaned during the change of oil, or more frequently if so recommended by the engine manufacturer. All points recommended by the manufacturers as requiring daily attention should be checked, but care should be exercised that the proper lubricants are used and that these points are not over-lubricated.

6.1.3 Cooling System

Coolant-water supply should be checked, and clean, soft water added as needed. In winter, lost coolant should be replaced with the proper anti-freeze mixture. The cooling-system vent-valve, when provided, should be opened before adding water and closed after water has been added. Water showing rust or scum may indicate need for replacement of the cleaning system, hose, or gaskets. A manufacturer approved cooling water treatment agent should be used. On air-cooled engines, the flywheel air screen and air intake stack should be checked, and any foreign material removed. If flywheel air screen or intake stack is very dirty, the fins on heads and cylinder blocks should be inspected, and cleaned if necessary. If cylinder block fins are rusty, they should be thoroughly cleaned with a wire brush.

6.1.4 Air Cleaners

Air cleaners on engine air-supply and breather openings should be checked and cleaned as required according to the design and condition of the cleaner. Pay particular attention on turbo-charged engines to any indications of metallic filtering media breaking up or holes and breaks in paper element cleaners.

6.1.5 Fuel-Supply System

The fuel-supply system should be checked by draining the sump traps and strainers; also the fuel-oil line filters, if the engine is a diesel. All collections of dirt and dust around the tank filler caps and vents should be removed.

6.1.6 Leaks or Damage

A visual inspection should be made of all water, fuel, lubricant lines, fittings, and valves for indications of leaks or damage. Special attention should be directed to turbocharger oil and water lines, mountings, and air and exhaust line connections and seals.

6.1.7 Daily Engine Report

All work done, the hours of engine operation, and the amounts of oil, anti-freeze, and special lubricants used should be recorded on the daily engine report.

6.1.8 Malfunctioning or Needed Repair

Any malfunctioning of the engine or any needed repairs should be reported to the mechanic.

6.2 WEEKLY INSPECTION

The following weekly inspection of engines should be made by the pumper or qualified engine operator, who should also record each inspection performed.

6.2.1 Daily Inspection Items

All of the daily inspection items as given in 6.1 should also be performed in the weekly inspection.

6.2.2 Cleaning

If necessary, the engine exterior should be thoroughly cleaned with a mild solvent (not gasoline), and compressed air or hot water should be used for flushing and drying. Care should be taken not to wash or blow dirt into inaccessible locations behind filler openings or into ignition or injection equipment; or on air-cooled engines, into the fins on heads and cylinder blocks. Always dry and relubricate governor and control linkage joints after flushing engine.

6.2.3 Water Pump

Water-pump seals should be inspected and packing on packed-type pumps should be tightened or replaced, if necessary.

6.2.4 Fan Belts

Fan belts should be checked for proper tension and tightened or loosened, if needed.

6.2.5 Lubrication of Generator and Accessories

The generator should be lubricated with a few drops of oil and the accessories lubricated according to the instructions of the manufacturer.

6.2.6 Power Take-Off Clutch

The power take-off clutch should be lubricated and adjusted, if required, according to the instructions of the manufacturer, but care should be taken not to over-lubricate.

6.2.7 Gas Regulators

Gas engines should be checked for gas pressure at the primary and final regulators.

6.2.8 Breather Elements

All removable breather elements should be carefully cleaned and washed in mild solvent (not gasoline), and the oil changed on those elements requiring re-oiling. Follow instructions carefully on dry type element service.

6.2.9 Fuel Strainers

Diesel fuel system strainers should be cleaned and filters replaced if scheduled.

6.3 MONTHLY INSPECTION

The following monthly inspection should be performed by an expert mechanic who should also record each inspection performed.

6.3.1 Daily and Weekly Inspection Items

All of the daily and weekly inspection items as given in 6.1 and 6.2, respectively, should also be performed in the monthly inspection.

6.3.2 Ignition System

On spark-ignition engines the following ignition devices, depending upon the type used, should be checked:

a. magneto-point condition and clearance timing
b. the impulse functioning
c. the spark-plug gap and heat range
d. the distributor condition with respect to the automatic advance mechanism

6.3.3 Valves

The external appearance of the valve mechanism should be checked, as well as the condition of valve springs and the proper lubrication of valve rockers, push-rod ends, and valve stems. All valve clearances should be set according to the instructions of the engine manufacturer. Valve timing should be checked if an adjustable timing device is provided. The compression on all cylinders should be measured, if the engine lacks power or if the condition of the valves and rings is questionable. The functioning of the compression release device should be checked on diesel-engines, if it is used. Engines using hydraulic valve lifters should be checked for sounds of lifter malfunction and the manufacturer's inspection procedure followed.

6.3.4 Starting Equipment

The starting equipment should be carefully tested and inspected. Starting engines should be checked for lubrication and general condition; special attention being given to the mounting bolts, bendix-drive lubrication, engagement linkage, pinion-gear teeth mesh and adjustment, and fuel tank strainer. Manufacturer recommendations for specific makes and types of engines should be observed. Add the recommended lubricant to air starter lubricant reservoirs and clean air traps of dirt.

6.3.5 Engine Mounts

Engine mounts should be inspected and tightened, if required. A check should be made for signs of engine shifting, misalignment, loosening of coupling or pulley, or improper loading. Any shifting should be corrected and all points of alignment rechecked.

6.3.6 Cooling Fan

The cooling fan should be examined for evidence of physical damage or cracking in the hub or spider area. If the fan-hub bearings require lubrication by disassembly and packing or by installation of a special grease fitting, this operation should be performed.

6.3.7 Safety Shields

All fan belt and shaft safety shields should be repaired and reinstalled.

6.3.8 Rocker Covers and Inspection Doors

New gaskets should be used on all rocker covers and inspection doors.

6.3.9 Seasonal Check of Cooling System

Particularly at the changes of season and when starting to use or remove anti-freeze, the cooling system should be flushed thoroughly. The thermostats should also be removed and tested for correct functioning. Evidence of scale, sludge, or rust deposits in the cooling system warrants further investigation, and a special cleaning of oil coolers and heat exchangers may be necessary.

6.3.10 Crankcase

Inspection plates should be removed, if the crankcase is so equipped, and a check made for sludge in the crankcase. The oil-pump screen should be checked, and cleaned if necessary.

6.3.11 Safety Devices, Generator, and Battery

A check should be made of safety devices, generator, and battery (or gas starter, if used). Check the actual function of overtemperature, low oil pressure, and overspeed shutdowns.

6.3.12 Vibration Damper

Inspect the vibration damper for damage, runout, signs of deterioration or loss of viscous material, or looseness.

6.3.13 Turbocharger Impeller

Inspect turbocharger compressor impeller for accumulations of dirt, dust and oil. Clean according to manufacturer's recommendations.

6.3.14 Records

The work done, materials used, and time required should be recorded.

7 Drilling or Other Large Internal-Combustion Engines

7.1 DAILY INSPECTION

A qualified engine operator, thoroughly familiar with the details of servicing and lubricating the engine as outlined in the applicable instruction book, should make and record the following daily inspection.

7.1.1 General Daily Inspection

All of the general daily-inspection items as given in 6.1 should also be performed for drilling or other large internal-combustion engines.

7.1.2 Oil Level

The oil level in the transfer case (or gear box, if provided) should be checked and lubricant added as needed.

7.1.3 Air Cleaners

Severe conditions may make it necessary to check air cleaners several times during the day. Such elements should be serviced as specified and the oil replaced to the marked level with clean lubricating oil. Diesel air filters should not be saturated with cleaning solvent or oil. Follow the manufacturer's recommendations closely with dry cleaners and inspect for holes or breaks.

7.1.4 Protection Against Water Entrance

Protection against water entrance to exhaust manifolds, covers, valves, or other devices should be checked.

7.1.5 Air-Box Drains

Air-box drains should be checked for proper functioning.

7.1.6 Turbocharger Sounds

Listen to sound of turbocharger and note any variation from normal. Note intake manifold pressure and record same.

7.2 WEEKLY INSPECTION

A qualified engine operator, thoroughly familiar with the details of servicing and lubricating the engine as outlined in the applicable instruction book, should make and record the following weekly inspection.

7.2.1 Daily and Weekly Inspection Items

All of the daily and weekly inspection items as given in 6.1, 6.2 and 7.1 should also be performed for drilling or other large internal-combustion engines.

7.2.2 Diesel Fuel-Filter Elements

Diesel fuel-filter elements should be replaced, if scheduled.

7.2.3 Starting Engine

If a starting engine is used, the clutch controls should be lubricated and adjusted and the oil level checked in the starting-engine transmission.

7.2.4 Air Starter

Add oil to air starter reservoir and clean air traps.

7.2.5 Oil for Fuel-Injection Pump and Governor

If a fuel-injection pump is used, its oil level should be checked and also that of the governor, if a separate lubrication supply is required. Badly diluted oil should be replaced with clean mineral oil and the governor oil level maintained by using the type of oil specified by the manufacturer.

7.2.6 Leaks, Damaged Gaskets, and Loose Bolts and Seals

The general engine condition should be checked for signs of leaks, damaged gaskets, loose bolts and seals. Head bolts should be tightened with a torque wrench to the correct value on new or recently overhauled engines. Any leakages resulting from missing copper washers, torn or cracked gaskets, or misplaced filler caps should be corrected.

7.2.7 Top Oilers

Top oilers, if used, should be filled and the flow adjusted to the proper rate.

7.2.8 Safety-Shutdown Controls

Safety-shutdown controls should be examined for evidences of leakage, binding, mechanical damage, broken or collapsed connecting lines, and bent or wired-open controls. If a doubt exists, the engine should be started and both temperature and oil-pressure units adjusted to function properly.

7.2.9 Electrical Equipment

All ignition, shutdown, voltage-control, and auxiliary electrical systems should be checked throughout for loose connections, worn wires, or make-shift repairs. Ignition leads to spark plugs should be examined for signs of cracking and breakdown; and brushes, holder springs, and commutators on all electrical equipment should be inspected.

7.2.10 Backfire Valves

Backfire valves should be checked for condition and evidence of damage.

7.2.11 Crankcase Explosion-Relief Valves

Crankcase explosion-relief valves, if installed, should be checked.

7.2.12 Throttle and Governor

The governor linkage and butterfly-shaft end should be checked for free movement through their full range. Minor governor adjustments should be made, if needed; and throttle and governor controls should be lubricated.

7.3 Monthly Inspection

The monthly inspection should be performed by an expert mechanic, trained for maintenance work on the specific engines involved. This mechanic should be thoroughly acquainted with the following equipment and procedure: magneto or injection pump, timing, injector inspection and testing (if engine is a diesel), carburetor and governor adjustment, gas-regulator maintenance, and compounding of multiple-engine drives. A record should be made of each inspection, adjustment, and repair which is performed.

7.3.1 Daily, Weekly, and Monthly Inspection

All of the daily, weekly, and monthly inspection items as given in 6.1-7.2, incl., should also be performed for drilling or other large internal-combustion engines.

7.3.2 Inspect turbocharger for cleanliness and bearing condition in accordance with maker's recommendations.

7.3.3 Inspect vibration damper for run-out, wobble, damage from impact or jacking, loss of viscous material or shifting of inner and outer members relative to each other.

7.3.4 Functioning of Miscellaneous Equipment

Compounded engines should be synchronized and a careful check made for proper functioning of vacuum gauges, pyrometers, tachometers, oil-pressure gauges, torque-converter pressures, and generator outputs.

7.3.5 Inspection for Leakage, Damage, and Wear

All manifolding and exhaust systems should be inspected for security and freedom from fire hazard or leakage, particularly in closed structures. A check should be made for evidence of corrosion, intermixing, or impeded flow in heat exchangers and special cooling systems. If extra coolant pumps are used, the pump, connections, and drive motor or belt should be checked. On turbo intercooled engines, check drive, bearings, seals, and coolant flow of intercooler water pump. Clean intercoolers according to manufacturer's instructions.

8 Pumping Engines

8.1 DAILY INSPECTION

The daily inspection of pumping engines should be made by the pumper or engine operator, who should also record each inspection performed. These inspection items are given in 6.1.

8.2 WEEKLY INSPECTION

The weekly inspection of pumping engines should be made by the pumper or engine operator, who should also record each inspection performed. These inspection items are given in Par. 6.1 and 6.2.

8.3 MONTHLY INSPECTION

The following monthly inspection should be performed and recorded by a qualified mechanic with a servicing truck equipped for the work.

8.3.1 Daily, Weekly, and Monthly Inspection Items

All of the daily, weekly, and monthly inspection items given in 6.1, 61.2 and 6.3 and should also be performed for pumping engines.

8.3.2 Tune-Up Check

A general tune-up check should be made; and spark plugs, magnetos, tappets, fuel pressure, and carburetor fuel-air mixture should be properly adjusted.

8.3.3 Throttle Linkage

The throttle linkage should be lubricated.

8.3.4 Clutch and Auxiliaries

The clutch and auxiliaries should be greased.

8.3.5 Radiator Water and Anti-Freeze Solutions

A check should be made of the pH of the radiator water. Anti-freeze solutions should be maintained. Maintain pH 7.4 to 9.5.

8.3.6 Cylinder Compression

Check compression of all cylinders if engine lacks power, or the condition of valves and rings is questionable.

8.3.7 Vacuum Measurement

The load and no-load vacuum should be measured at the operating speed.

8.3.8 General Check

Safety switches, belts, generator, battery, clutch, starting equipment, oil-consumption records, and foundation bolts should be checked.

9 Operating Troubles and Their Causes

Note: When an internal-combustion engine fails to function properly, the cause must be found and corrected promptly, often when an experienced mechanic is not readily available. Since most internal-combustion engines react in much the same way to specific maladjustments, a check list of possible causes of trouble often will be helpful in locating the difficulty. Following are trouble-shooting hints for gas/gasoline internal-combustion engines and for diesel-engines.

9.1 GAS-GASOLINE ENGINES

9.1.1 Difficulty in Starting

If the engine fails to start or does not start readily, the following possible causes of trouble should be checked in an effort to locate the difficulty.

a. Ignition switch off.
b. Lack of fuel, closed valve, or stuck regulator.
c. Oiled or fouled spark plugs.
d. Spark-plug gap too wide.
e. Low compression due to leaking valve.
f Magneto points stuck open or held apart.
g. Dirty magneto points.
h. Magneto ground wire broken or grounded.
i. Engine flooded.
j. Water in carburetor or fuel.
k. Wet ignition system (spark plugs, magneto, wires).
l. Incorrect throttle setting.
m. Choke open (natural gas, except where metering valve is used).
n. Incorrect timing of magneto.
o. Incorrect valve clearance.
p. Air leaks in intake system.
q. Fuel system obstructed.
r. Improper fuel mixture.
s. Automatic safety devices not reset.
t. Vapor lock.
u. Ignition wires to wrong spark plugs.
v. Excessive exhaust back pressure.
w. Inadequate starter speed.
x. Engine locked by water or oil above piston.

9.1.2 Failure to Idle

If the engine fails to idle, the following possible causes of trouble should be checked in an effort to locate the difficulty.

a. Idling jet restricted.
b. Incorrect idling mixture adjustment.
c. Throttle valve closed too far.
d. Cracked intake manifold.
e. Air leak in intake system.
f. Improper valve clearance.
g. Play in carburetor controls.
h. Faulty governor.
i. Incorrect float level (gasoline).

9.1.3 Failure to Develop Full Power

If the engine fails to develop full power, the following possible causes of trouble should be checked in an effort to locate the difficulty.

a. Faulty Ignition.
   1. Ignition out of time.
   2. Weak magneto magnets.
   3. Burned or pitted points.

4. Defective or improper spark plugs.
5. Ignition wires crossed.

b. Incorrect carburetion.
1. Mixture too rich or too lean.
2. Throttle valve not fully open.
3. Air leak in manifold, backfire valves open.
4. Incorrect fuel pressure.
5. Incorrect regulator, spring, orifice, or two or more engines on one regulator.

c. Improper lubrication.
1. Improper oil.
2. Oil temperature too high or too low.
3. Overhead valves not properly lubricated.
4. Oil cooler bypasses engine.
5. Stuck relief valve.
6. Clogged screens, filters, or coolers.

d. Miscellaneous.
1. Incorrect valve-clearance adjustment.
2. Weak valve springs.
3. Compression too low (rings and valves).
4. Exhaust or intake manifold restricted.
5. Engine stiff or tight (new engine).
6. Exhaust line restricted or of improper length or size, or both.
7. Air cleaner restrictive or not serviced properly.
8. Turbocharger dirty or damaged.
9. Governor linkage or spring out of adjustment.
10. Torque converter mismatched.
11. Excessive air intercooler temperature.
12. Wrong turbocharger for altitude involved.

9.1.4 Engine Stops Running

If the engine suddenly stops running, the following possible causes of trouble should be checked in an effort to locate the difficulty.

a. Magneto grounded.
b. Lack of fuel.
c. Fuel lines obstructed.
d. Carburetor jets clogged.
e. Automatic safety devices for high water temperature, low oil pressure, or overspeed may have operated.
f. Vent for fuel tanks clogged.

9.1.5 Missing on One or More Cylinders

If the engine is missing on one or more cylinders, the following possible causes of trouble should be checked in an effort to locate the difficulty.

a. Fouled spark plug.
b. Defective spark plug.
c. Broken or grounded plug wire.
d. Improper valve clearance.
e. Low compression on one or more cylinders.
f. Damaged distributor head.
g. Intake manifold or head gasket.

9.1.6 Improper Oil Pressure

If the engine develops improper oil pressure, the following possible causes of trouble should be checked in an effort to locate the difficulty.

a. Improperly adjusted relief valve.
b. Clogged strainer.
c. Improper grade of oil.
d. Excessive bearing clearance.
e. Oil too hot.
f. Clogged oil-pressure line.
g. Restricted oil cooler, filter, or screen.
h. Defective oil gage.
i. Insufficient oil.

9.1.7 Excessive Oil Consumption

If the engine develops excessive oil consumption, the following possible causes of trouble should be checked in an effort to locate the difficulty.

a. Improper grade of oil.
b. Worn piston rings.
c. Stuck or broken piston rings.
d. Worn bearing.
e. Crankcase compression.
f. Overheating.
g. Leaking valve guides.
h. Excessive oil to intake valves.
i. Clogged oil ring or piston drain holes.
j. Worn oil seals on crankcase or piston rods.
k. Cracked crankcase.
l. Lubricator overfeeding (2 cycles).
m. Abnormally low operating temperature, particularly from underloading.
n. High oil level in crankcase.

9.1.8 Failure to Stop When Switch is Turned Off

If the engine fails to stop when the switch is turned off, the following possible causes of trouble should be checked in an effort to locate the difficulty.

a. Magneto ground wire broken.
b. Engine excessively hot.
c. Excessive amount of carbon in combustion chamber.
d. Spark plug thread wrong length or plug incorrect.

9.1.9 Overheating

If the engine overheats, the following possible causes of trouble should be checked in an effort to locate the difficulty.

a. Insufficient coolant.

b. Radiator frozen or clogged (tubes and tanks).
c. Radiator core dirty (external).
d. Water hose clogged.
e. Slipping fan belt.
f. Leaky valves.
g. Improper fuel mixture (lean).
h. Carburetor choke closed.
i. Spark retarded.
j. Improper timing (valves and ignition).
k. Lack of oil.
l. Oil diluted or too light.
m. Thermostat stuck.
n. Cooling system inadequate.
o. Engine overloaded.
p. Excessive air recirculation.
q. Aeration of water from leaking gaskets or pump.
r. Defective water pump.
s. Excessive back pressure on external cooling system.
t. Improper synchronization of two or more engines.
u. Air shroud, air stack, cylinder-head fins, or cylinder-block fins plugged with debris.
v. Turbo intercooler not functioning properly.

9.1.10 Excessive Black Smoke from Exhaust Pipe

If excessive black smoke from the exhaust pipe of the engine is observed, the following possible causes of trouble should be checked in an effort to locate the difficulty.

a. Carburetor float sticking.
b. Mixture too rich.
c. Wet gas or crude oil in the fuel gas.
d. Choke closed.

9.1.11 Excessive Blue Smoke from Exhaust Pipe

Excessive blue smoke from the exhaust pipe of the engine is an indication of excessive lubricating-oil consumption, and the following possible causes of trouble should be checked in an effort to locate the difficulty.

a. Faulty piston rings.
b. Lubricating oil too thin.
c. Too much oil in crankcase.
d. Upper-lube feed too fast.
e. Worn valve guides.
f. Excessive idling.
g. Turbocharger seal leakage.

9.2 DIESEL ENGINES

9.2.1 Starting Difficulty

If a diesel engine fails to start or does not start readily, the following possible causes of trouble should be checked in an effort to locate the difficulty.

a. Fuel failure, low-pressure side.
   1. Line valves not open; tank empty.
   2. Ice in lines or traps.
   3. Cold fuel.
   4. Plugged fuel filters, or dirt in lines between filter and pump.
   5. Fuel tank too low in relation to transfer pump.
   6. Dirt under transfer-pump valves or worn valves.
   7. Air lock in fuel pump or injection pump.
   8. Safety switch not being held open by operator.

Note: The foregoing items may be checked by opening the bleeder valve and cranking the engine. A pressure gage should be used in the bleeder-valve hole to check for primary pump pressure. A hand plunger may be used on the transfer pump, if desired. A substantial flow of fuel without air bubbles should exit from the bleeder opening.

b. Fuel failure, high-pressure side.
   1. Enrichment lever not in proper position; rack partly closed in cold weather.
   2. Stop control in wrong position.
   3. Air locks in high-pressure lines.
4. Broken or disconnected pump-drive coupling.

Note: The foregoing items may be checked by loosening line-coupling nuts a few turns at each nozzle and cranking engine. A substantial flow of fuel should occur at each injection impulse. If no fuel appears and an adequate flow of fuel is known to have reached the plungers, either the plungers or delivery valves may be stuck as a result of poor fuel, improper storage, or inadequate lubrication.

c. Poor nozzle spray pattern or gummed or corroded nozzles.
d. Faulty injection timing.
e. Glow plugs too cold.
f. Battery voltage low. (A fully charged 12-volt heavy-duty battery at normal temperatures will show 10.5 volts while cranking.)
g. Air cleaners may be clogged or protective covers accidentally drawn into the manifold.
h. Poor compression. (Check each cylinder.)
i. Liquid lock between piston crown and cylinder-head due to flushing oil from storage, leaking head gasket, or leaking injector.
j. Low cranking speed due to weak batteries, poor starter condition, or thick, cold oil.

9.2.2 Engine Stops Running

If the diesel engine suddenly stops running, the following possible causes of trouble should be checked in an effort to locate the difficulty.

a. Lack of fuel.
b. Fuel lines obstructed or broken.
c. Automatic low oil-pressure or high water-temperature safety control may have operated.
d. Excessive overload or improper governor adjustment may cause the engine to stall.

e. Plugged fuel-tank vent.
f. Damaged transfer or injection pump drive.

9.2.3 Low Power

If the diesel engine has low power and runs unevenly, the following possible causes of trouble should be checked in an effort to locate the difficulty.

a. Inadequate supply of fuel to pump.
b. Fuel-tank vent partially plugged.
c. Faulty timing.
d. Delivery valves not operating properly.
e. Dirty or damaged injection plunger.
f. Leaking fuel lines or air in lines.
g. Damaged or excessive clearance in blowers.
h. Overflow valve or injector drain line feeding back into primary pump inlet.
i. Dirty or clogged nozzles.
j. Air cleaner or manifold obstructed.
k. Low or uneven compression.
   1. Broken valve spring.
   2. Sticking valves.
   3 Badly worn rocker arms.
   4 Sticking cam followers.
   5. Bent throttle control linkage.
   6. Binding of injector-rack control tube or injector racks.
l. Fuel oil not to specification.
m. Improper exhaust line.
n. Leaking turbocharger air connections.
o. Dirty or damaged turbocharger.
p. Improper intercooler operation.

9.2.4 Surging or Irregular Speed

If the diesel engine develops a surging or irregular speed, the following possible causes of trouble should be checked in an effort to locate the difficulty.

a. Governor needs lubrication.
b. Improper grade of governor oil (hydraulic governors).
c. Governor improperly adjusted.
d. Injection pump.
   1. Lack of lubrication.
   2. Insufficient fuel supply for primary system.
   3. Irregular operation of automatic bleeder valve; air entrainment in pump and lines, valves, or nozzles.
   4. Inaccurate pump timing.
e. Slipping clutch or belt drive; wide variation in loads or poor regulation on electrical equipment.
f. Dirty or damaged turbocharger system.

9.2.5 Overheating

If the diesel engine overheats, the following possible causes of trouble should be checked in an effort to locate the difficulty.

a. Excessive exhaust back pressure.
   1. Restricted muffler or loose baffles in muffler.
b. Cooling system.
   1. Insufficient coolant.
   2. Radiator frozen or clogged (tubes and tanks).
   3. Radiator core dirty (external).
   4. Water hose clogged.
   5. Slipping fan belt.
   6. Thermostat stuck.
   7. Cooling system inadequate.
   8. Improper air recirculation.
   9. Aeration of water from leaking gaskets or pump.
   10. Defective water pump.
   11. Excessive back pressure on external cooling system.
   12. Air shroud, air stack, cylinder-head fins, or cylinder-block fins blocked with debris.
c. Combustion.
   1. Improper fuel.
   2. Faulty injection timing, retarded or wrong cycle.
   3. Faulty injection nozzles.
   4. pump setting incorrect.
d. Lubrication.
   1. Improper or excessive time between oil changes.
   2. Air-locked or plugged oil filter, cooler, or screen.
e. Load.
   1. Prolonged service at excessive load.
   2. Improper synchronization of two or more engines.
f. Installation.
   1. High exhaust back pressure due to improper piping or muffling.
   2. Insufficient air circulation when engines are operating in closed spaces.
   3. Improper turbocharging; intercooler too hot.

9.2.6 Low or Fluctuating Oil Pressure

If the diesel engine develops a low or fluctuating oil pressure, the engine should be stopped at once and the following possible causes of trouble should be checked in an effort to locate the difficulty.

a. Oil.
   1. Insufficient oil.
   2. Dirty filters, oil coolers, or sump screen.
   3. Improper grade of oil.
   4. Foaming oil due to water leakage.
b. Pressure Regulation.
   1. Worn, sticking, or loose relief valve.
   2. Vent behind relief valve plugged.
   3. Inaccurate pressure gage.
c. Pump.
   1. Inlet-strainer screen clogged.
   2. Damaged or worn pump gears.
   3. Clogged oil lines or passages.

d. Mechanical.
   1. Excessive bearing clearances on camshaft or crankshaft.
   2. Cracked or broken oil line.
   3. Leaking gasket on suction side.

9.2.7 Knocking or Unusual Noises

If the diesel engine starts knocking or develops other unusual noises, the following possible causes of trouble should be checked in an effort to locate the difficulty.

a. Operation.
   1. Unsatisfactory fuels.
   2. Overloading (heavy black smoke).
   3. Improper timing.
b. Installation.
   1. Engine loose on mounts.
   2. Vibrational disturbances of loose control rods, air cleaner, muffler, or similar parts.
   3. Loose accessories as generators, fans, compressors, etc.
c. Mechanical.
   1. Loose bearings on connecting rods, piston pins, camshaft, or crankshaft.
   2. Loose flywheel or distorted housing.
   3. Damage, looseness, or wear in water-pump, oil-pump, or fuel-pump drive.
   4. Excessive crankshaft end play.
   5. Improperly adjusted valves, sticking valves, rocker arms, or tappets.
   6. Excessive time since overhaul (worn pistons, stuck or broken rings, carbon on piston crown).
   7. Defective vibration damper.

APPENDIX A—RECOMMENDED PRACTICE FOR MINIMIZING POTENTIAL FIRES AND/OR EXPLOSIONS IN THE OPERATION OF INTERNAL-COMBUSTION ENGINES

Note: The purpose of this recommended practice is to present a list of precautionary measures to be observed in the operation of internal-combustion engines along with a list of auxiliary equipment, with minimum electrical arcing characteristics, that should be used with these engines for the minimizing of fires and explosions. The information presented is applicable generally to all types of internal-combustion engines used in drilling, well-servicing, oil-well pumping, and pipeline services, and particularly to engines used in drilling and well servicing.

A.1 Areas of Application

The recommendations given herein should be particularly considered for:

a. Areas within a radius of 50 ft. of the casing head of all drilling wells.
b. Areas within a radius of 25 ft. from the casing head of all wells, other than drilling wells, where there is a probability of light oil or flammable gas being released to the atmosphere in sufficient quantity to ignite or explode; except that internal combustion engines located within these described hazardous areas, which are usually shut down in expectation of and prior to the existence of hazardous conditions, need not be equipped with nor use a water injection system, or other equally effective device to prevent the discharge of flame or sparks from the exhaust pipe.
c. Inside any building where the conditions or operations are such that there is a probability of light oil or flammable gas being released to the atmosphere in sufficient quantity to ignite or explode.
d. At any location where conditions or operations are such that there is a probability of flammable gas being released to the atmosphere in sufficient quantities to ignite or explode.

A.2 Engine Fuel Fires and Explosions

The following check list gives the common causes of fuel fires and explosions, and recommendations for minimizing their potential.

Causes	Recommended Procedures for Their Elimination
a. Leaks in butane, natural gas, gasoline, or diesel oil engine fuel systems.	Proper installation of the best materials in original installations and in necessary replacements of worn fuel line components should be insisted upon, and flexible fuel lines or other anti-vibration devices or procedures should be used.
b. Failure of fuel lines due to improper fuel pressure regulation.	Adequate and well designed regulating devices should be properly installed to minimize fuel line failures resulting from excessive fuel supply pressures.
c. Accumulation of condensate in fuel lines.	Proper drips should be installed at low places in lines to aid in the elimination of condensate accumulation and carry over into engine carburetors.
d. Improper procedure in the installation or servicing of butane storage tanks.	Accepted safe practices for the installation and servicing of butane fuel tanks should be insisted upon.
e. Improper transfer of fuel from one tank to another.	Fuel should be moved from tank to tank by pumping and not by forced transfer with compressed air.
f. "Firing" of butane tanks to increase vapor pressure.	Maintenance of adequate butane tank levels and proper servicing by suppliers should be insisted

	upon for maintaining sufficient gas pressure and elimination of firing of tanks when required. In extreme cold weather, an approved tank heating device should be used.
g. Open fires, lighted matches, cigarettes, cigars, and pipes.	Strict prohibition of open fires, lighted matches, cigarettes, cigars, and pipes should be insisted upon near internal-combustion engines. See A.5 on regulations.
h. "Drying out" wet engines with open fires.	Compressed air, or wiping with clean rags should be used to dry out wet engines. Open fires should never be used.
i. Ignition of waste fuel or lubricants in engine drip pans.	Engine drip pans should be covered to minimize the risk of ignition of the contents by sparks from the engine, or by lighted matches, cigarettes, cigars, and pipes, or by open fires.
j. Intake of combustible mixture through engine air intake.	The engine manufacturer should be consulted on methods for prevention of intake of flammable mixtures, instead of normal air charge, through engine air inlet.
k. Ignition of combustible material.	Combustible material should be kept at a reasonably safe distance from the hot surfaces of engines and their exhaust systems, or should be adequately insulated against ignition.

A.3 Gas and Oil Fires and Explosions

The following check list gives the common causes of fires and explosions due to ignition of uncontrolled flow of gas and oil, and recommendations for minimizing their potential.

Causes	Suggested Procedures for Their Prevention
a. Lack of proper equipment for shutting down engines in an emergency.	Switches or other equipment should be provided for emergency stopping of engines. This is especially true for drilling engines. Remote controls, and controls at the engines should be installed so that the driller or engine operator can immediately shut down the engines during a blowout or drill-stem test.
b. Hot exhaust manifolds and piping.	Water cooled exhaust manifolds or covering for exhaust manifolds and piping of fireproof insulating material should be installed. (California law requires that insulating material be prevented from directly contacting exhaust systems.)
c. Flame from leaky exhaust manifold or piping.	Exhaust manifolds should have fireproof gaskets between bolted connections, or should be made from pipe with screwed or welded connections.
d. Improper installation of exhaust outlet with regard to direction from well.	Properly installed exhaust piping relative to the direction of the end of the exhaust pipe from the centerline of the well, while of somewhat minor importance, should be considered as follows:

	Exhaust piping should be of strong pipe with screw connections, and should be installed in a direction pointing away from the centerline of well; also should be installed horizontally when permitted by engine exhaust manifold connections.
e. Sparks or fire from end of engine exhaust stack.	A spark-arrester type exhaust silencer should be installed, or water should be sprayed through an exhaust stack, providing the stack is horizontal (thus preventing water drain back to the engine).
f. Opening of engine cylinder cocks.	Cylinder cocks of engines should not be opened when a flame or spark may be discharged from them into a gas-laden atmosphere.
g. Sparking from engine electrical systems.	The elements of an engine electrical system should never be manipulated so as to create a spark in gas-laden atmosphere.

A.4 Engine Accessories

The following check list is of items of accessory equipment that may cause fires and explosions and the precautions to be observed in their operation.

Items	Operational Precautions
a. Electrical storage batteries	Should be provided with suitable covers to prevent accidental contacting of battery terminals and consequent electrical arcing when stored or used in gas laden atmosphere. Batteries of this type can explode if a contact terminal happens to arc while the battery is charging, because a charging battery emits a mixture of hydrogen and oxygen gases which will explode if exposed to a spark or flame. When using charging equipment, always throw the switch to off prior to disturbing the battery connections. Another source of explosion lies in the reverse connection of charging equipment to the battery. Always check carefully to be certain the connections are in order prior to throwing the operating switch. Improper use of a booster battery, when the normal battery is inadequate, presents a definite explosion hazard. To minimize this hazard, the following procedure is recommended: 1. When possible, use cables with a switch in the lines connecting the booster battery to the installed battery. 2. Always rock the connecting clips to assure secure clip contact. 3. If plain jumper cable equipment is used, always securely connect the installed battery first. When connecting clips to the booster battery, extreme care should be exercised in handling the clips. When disconnecting, always break the connecting clips at the booster battery first.

	4. Batteries should be equipped with spark arresting vents.
b. Spark plugs	Should be of the self-shielding type, or completely enclosed in a metal shield to minimize exposed arcing. In addition, the spark plug conductor wires should be replaced as required to prevent sparking through cracked or weathered insulation.
c. Magnetos	Should be of the shielded type, protected with rubber or neoprene grommets fitting tightly around the high-tension conductor wires leading to the spark plugs. In some cases low-tension magnetos may be used, which reduce the chances of arcing, but even with these the conductor wires should be covered.
d. Electric starters	Should be protected with a tight-fitting cover band, or a cover band gasket to shield the commutator arcing.
e. Engine generators	Should be of the non-ventilated type for shielding of the commutator arc. However, this type generator is available only on special order and is seldom used in other than military usage. The ventilated generator in general use is not designed to prevent the ignition of flammable gases by the arcing from the generator commutator.
f. Generator voltage regulators	Should have the cover gasket maintained in good order for shielding of arcing from the make and break contact points of regulator.
g. Distributors	Should be protected, if used instead of magnetos, with a radio shielding type covering
h. Fan belts	Should be of the static-proof type.
i. Mud pump drive belts	Should be considered as a possible source of arcing from static electricity. Static proof belts for the minimizing of this hazard are ordinarily available on special order from the manufacturer's factory stock.
j. Engine starter pinion and ring gear	Should be considered as a source of arcing upon initial engagement, and thus far no type of pinion or ring gear has been developed to prevent this, nor is this arcing shielded in present type engines.

A.5 Regulations

Following are recommendations concerning the posting and enforcement of regulations for the minimizing of fires and explosions.

a. Anti-fire and anti-explosion regulations.	A list of anti-fire and anti-explosion regulations, such as the foregoing or modeled upon it to fit specific conditions, is recommended for posting in conspicuous locations in areas in which engines are operated. These should be rigidly adhered to by all concerned, and uncompromisingly enforced by all persons in positions of authority for the minimizing of fires and explosions that may result form the operation of internal-combustion engines.

APPENDIX B—RECOMMENDED PRACTICE FOR USE OF INTAKE VACUUM VS. LOAD CURVES FOR NATURALLY ASPIRATED INTERNAL-COMBUSTION ENGINES

B.1

The recommendations given herein are for use on four cycle engines of two or more cylinders equipped with carburetors for liquid or gaseous fuels.

B.2

The vacuum-load curves shown in Fig. B-1 are an index of the approximate percentage of maximum brake horsepower (within 3 percent on new engines), that an average engine in proper adjustment will develop at a given location. These curves cannot be used on supercharged engines.

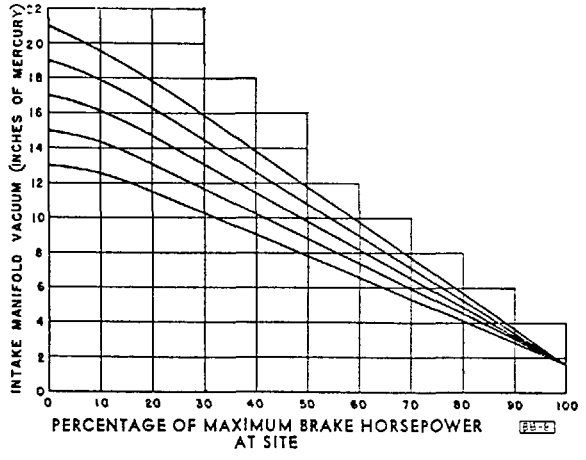

Figure B-1—Intake Vacuum vs. Load Curves

Note: The curves shown in Fig. B-1 are the average of curves obtained from six representative engine manufacturers covering many models having cylinder bores varying from $2^1/_2$ to 8 in.

INSTRUCTIONS FOR USE

B.3

The engine to be tested should be checked to make certain that it is properly adjusted before any vacuum readings are taken. The spark, gas supply, gas pressure, and carburetor should particularly be checked and any necessary adjustments made.

B.4

A conventional vacuum gage with a dial graduated in inches of mercury should be used.

B.5

The engine should be run at its normal operating speed with no load and a reading taken of the intake manifold vacuum.

B.6

The engine should then be run at normal operating speed with its normal loading and a reading taken of the intake manifold vacuum.

B.7

The curve should then be selected (see Fig. B-1) whose ordinate at no load most nearly corresponds to the intake manifold vacuum reading taken at no load for the engine being tested. From the intake manifold vacuum reading taken at normal loading, a point on this curve is located whose abscissa indicates the percentage of maximum brake horsepower at which the engine is operating.

Note: 100% maximum brake horsepower on abscissa of Fig. B-1 is the rating at site conditions of altitude and ambient temperature. The horsepower developed by a naturally aspirated engine decreases about 3 percent with each 1,000 ft. increase in altitude, and around 1% with each 10°F increase in temperature, above the base altitude and ambient temperature at which the manufacturer tested and rated the engine.

Likewise, the no load intake manifold vacuum decreases about 5% for each 1,000 ft. increase in altitude. For example, an engine that develops 20 inch vacuum at no load at sea level, will develop about 14 inch vacuum at 6,000 ft. altitude.

EXAMPLE:

Test conditions:

a. Intake manifold vacuum at no load: 17 in. of mercury.

b. Intake manifold vacuum at normal loading: 10 in. of mercury.

Solution:

a. From Fig. B-1 select the curve which shows 17 in. vacuum at no load.

b. Follow down this curve to a point whose ordinate is 10-in. vacuum. Determine that the engine is developing 48 percent of maximum brake horsepower.

B.8

Failure to duplicate former readings at no load and normal speed indicates poor engine condition due to poor gas supply, loss of compression, ignition timing, etc.

B.9

Failure to duplicate former readings at normal load and speed indicates either a change in engine efficiency or a change in load.

B.10

Field men should become familiar with the vacuum-curve readings taken when their engines are properly adjusted and in good operating condition in order to enable them to detect variations in either load or engine condition.

10/94—2M (Johnston)

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