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TECHNICAL MANUAL

AUTOMOTIVE LUBRICATION

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AUTOMOTIVE LUBRICATION

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SECTION I

THEORIES OF LUBRICATION

1. General.—*a.* Lubrication of a motor vehicle is perhaps the chief single factor in ensuring longer vehicle life, greater freedom from operating trouble, and minimum maintenance and repair work. While inspection, adjustment, and minor repairs are essential, lubrication is the most vital factor in preventive maintenance.

b. Lubrication minimizes the destructive effect of the motor vehicle's greatest enemy—friction. All surfaces, no matter how smooth they may appear to the unaided eye, are actually rough and uneven. Under a microscope or a high-powered magnifying glass, all surfaces have a hilly or mountainous appearance; that is, both peaks and valleys are represented on surfaces usually accepted as being finely machined and perfectly smooth. (See fig. 1.) Any surfaces moving against each other without a slippery substance between them to minimize friction soon get excessively hot and wear away by abrasion.

c. Lubrication neutralizes or minimizes corrosive action. Chemical corrosion, like abrasion, can destroy surfaces. Abrasive wear can only occur between moving surfaces in contact, but corrosion, such as rust, can occur at any time in any place and without any movement, because it is the result of chemical reaction or decomposition.

2. Friction.—*a.* Friction is the resistance or drag between the surfaces of bodies in contact which retards or prevents them from moving against each other. When brakes are applied, the friction between the surfaces of brake drums, which are attached to vehicle wheels, and the surfaces of linings on the brake shoes, which are fastened to the brake backing plates (or dust shields), retards movement of the wheels. When the clutch is engaged, the frictional drag existing between the driving surface (usually on or fastened to the flywheel of an engine), the clutch lining surfaces, and the driven plate surface prevents them from slipping and makes the three move together as one unit.

b. Without friction, life as we know it could not exist. Any moving object would continue moving indefinitely because there would be no friction to stop it. Locomotives would not be able to move or when in motion, could not be stopped, because there would be no friction between their driving wheels and the rails. Without friction (road traction) between tires and road surfaces, it would be impossible to move, steer, or stop a vehicle.

c. Friction absorbs power and generates heat in proportion to the amount of effort required to overcome it. For example, when a sled is drawn over a dry pavement, friction exists between the runners of the sled and the ground. The drag is apparent. The sled runners will be warm, indicating that heat has been generated.

d. Before a piston can be moved in a cylinder, energy (or power) must be used to overcome its resistance to being started (static friction) and its inertia. After the piston has been started in motion, energy must still be exerted to overcome the piston's resistance to being kept in motion (kinetic friction).

e. In lubrication, the friction of motion (kinetic friction) may be divided as follows:

(1) Solid friction is the dry, rubbing friction which exists when two unlubricated surfaces in contact move against each other. If this type of friction is not reduced, the surfaces wear (abrade) against each other, heat is generated, and power is wasted. Solid friction, though generally objectionable, is sometimes useful; for instance, solid friction may be used between pulleys and belts for driving a lathe.

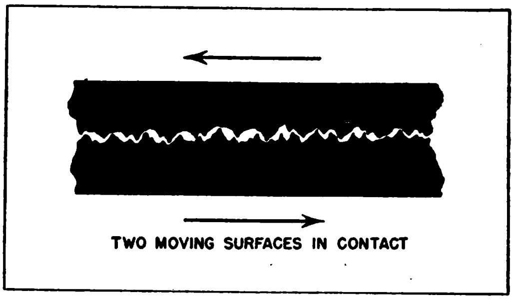


FIGURE 1.—Solid friction; surfaces in contact.

(2) Every substance, whether a gas, liquid, or solid, is composed of small particles called "molecules." Molecular attraction is the tendency of these small particles or molecules to hold together and resist motion; this is fluid friction. If the particles are of similar material, the molecular attraction is called "cohesion." If of dissimilar material, the molecular attraction is called "adhesion."

(*a*) Adhesion in a lubricant is its ability to cling or stick to surfaces and stay between them.

(*b*) Cohesion in a lubricant is its ability to cling together and resist disturbance: the thinner the body of a lubricant, the less the cohesion; the heavier the body, the greater the cohesion. Cohesion of a lubricant is determined by its viscosity (body).

(*c*) Oil between two surfaces is usually considered as being divided into a series of layers, each composed of thousands of small particles or globules. The oil layers nearest the surfaces, because their particles are different from those of the surfaces, adhere to and move with them. The next oil layers, because they are only touching each other, cohere to each other and create fluid friction as they slide or roll along. Internal friction like all other friction creates heat. Figure 2 shows an exaggerated view of some of the thousands of small globules (molecules) that make up the oil layers.

(*d*) Fluid friction is present in a great many familiar substances, but it is not readily recognized—there is fluid friction when a stick is moved through a liquid. The liquid touching the stick is drawn along with it, causing eddies and whirls in the liquid which readily suggests that the molecules (or particles) of the fluid pull each other along.

3. Oil film.—The oil film theory of lubrication assumes that perfect lubrication can be obtained by separating moving surfaces in contact by a film of oil. A thick film of oil is preferable to a thin one. A thin film of lubricant between moving surfaces may rupture or break under thrust and other pressures and permit momentary metal-

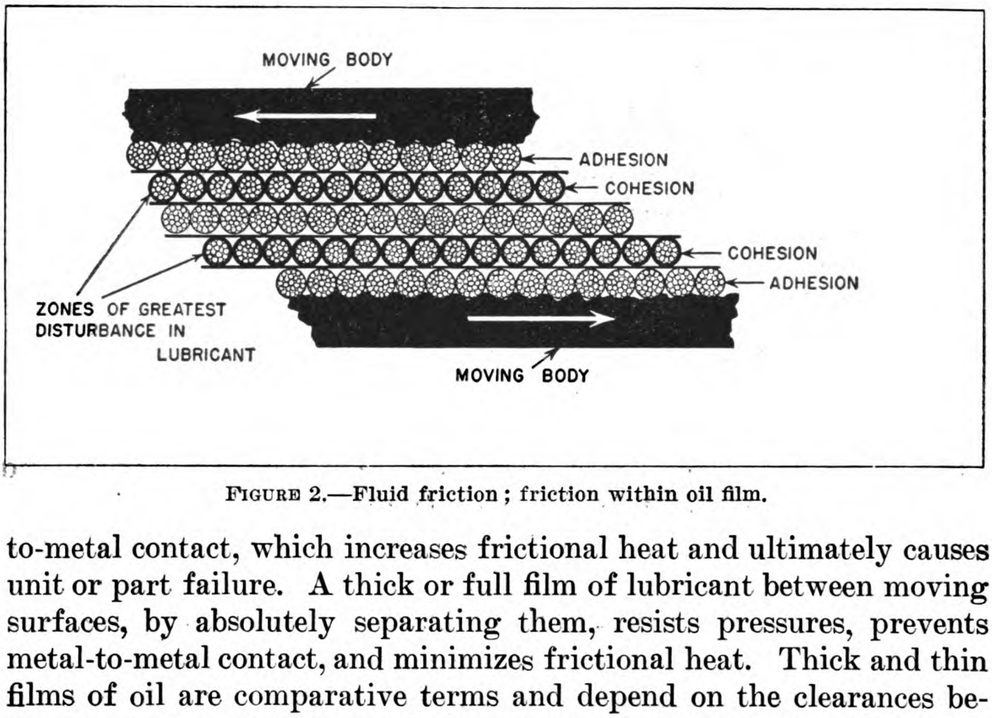


FIGURE 2.—Fluid friction; friction within oil film.

to-metal contact, which increases frictional heat and ultimately causes unit or part failure. A thick or full film of lubricant between moving surfaces, by absolutely separating them, resists pressures, prevents metal-to-metal contact, and minimizes frictional heat. Thick and thin films of oil are comparative terms and depend on the clearances between moving surfaces and the method by which a lubricant is applied. (See fig. 3.)

4. Oil wedge.—*a.* In sleeve or inclosed type bearings, such as an engine main or connecting rod bearing containing a round shaft, lubrication depends primarily upon the oil wedge principle.

b. When a shaft is not in motion, it rests on the bottom of the sleeve or bearing, forcing most of the oil from between the two metal surfaces. As the shaft starts to rotate, the oil follows it as a result of adhesive action. It flows up around the top of the shaft and down underneath it, to some extent simulating the action of a pump. The speed of the moving oil increases with the speed of the rotating shaft. The cohesive action of the oil then causes it to wedge underneath and around the shaft, and the oil gradually lifts it toward the center. As the shaft lifts and centers, more

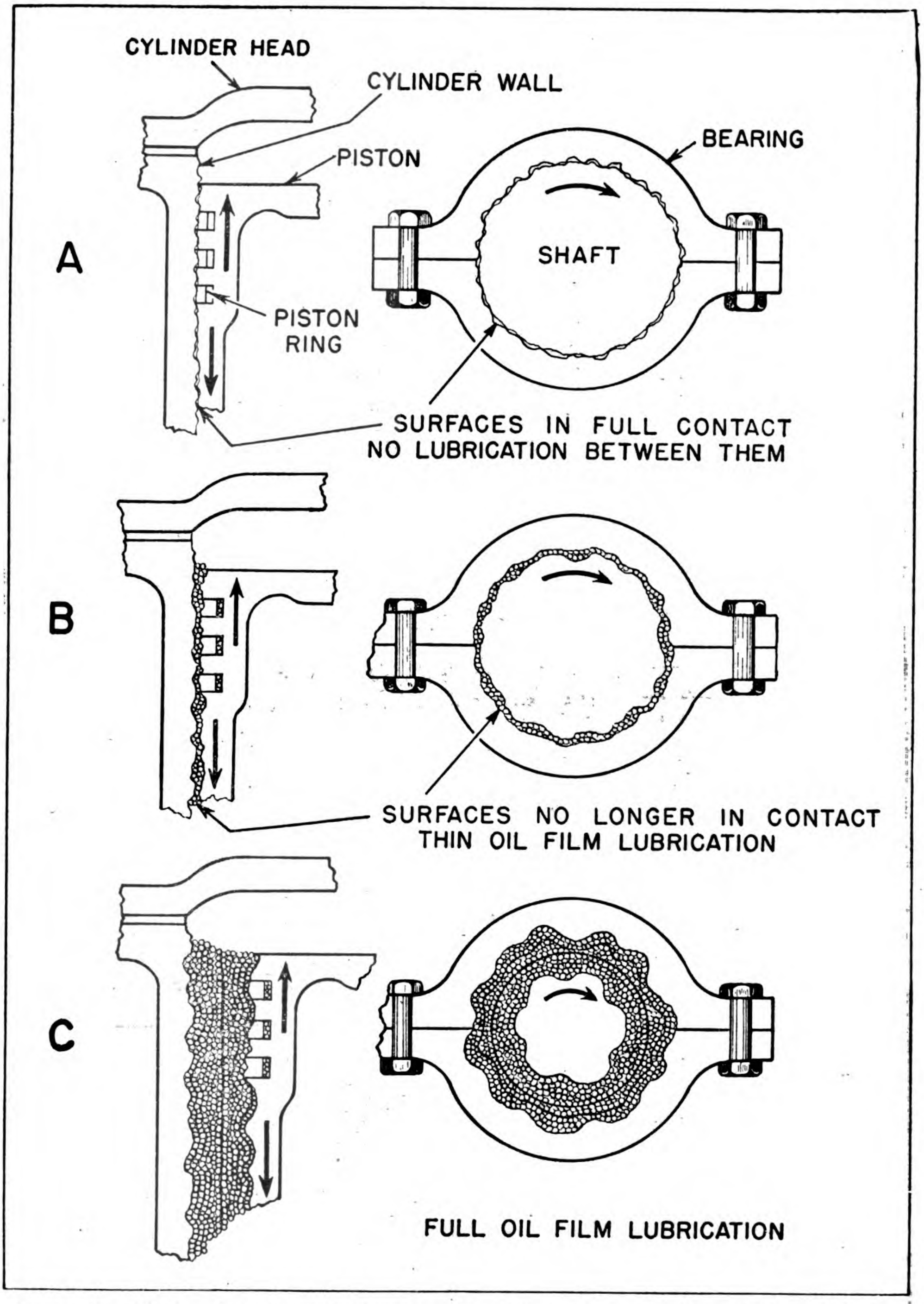


FIGURE 3.—Oil film theory; no lubrication and thin oil film and thick oil film lubrication.

oil wedges under it. This tends to maintain an oil film of equal thickness around the rotating shaft and between it and the sleeve or bearing. The thickness of the oil film depends on the speed of the revolving shaft, the clearances, the load pressures developed, and the lubricant used. (See fig. 4.)

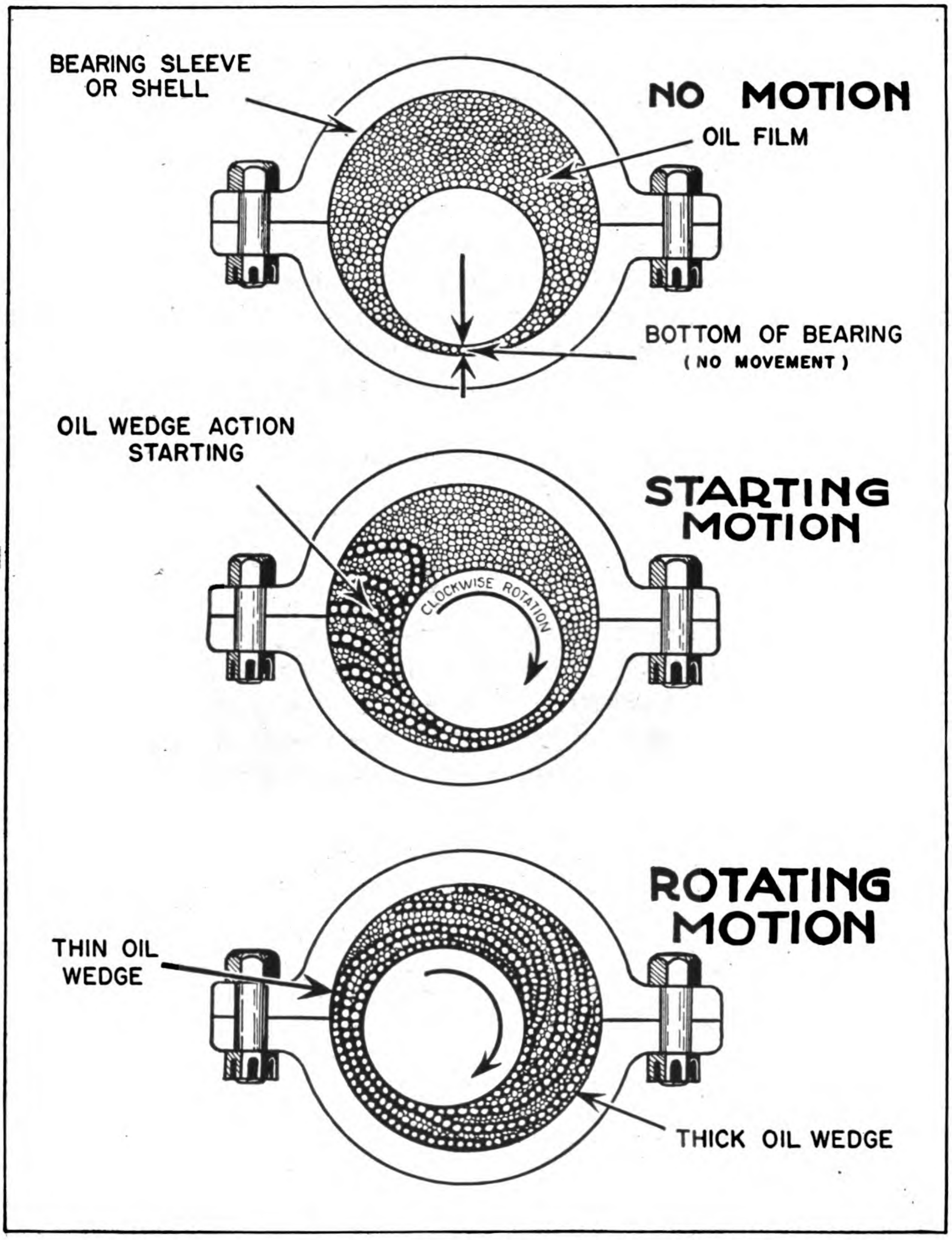


FIGURE 4.—Oil wedge theory.

SECTION II

SOURCES OF LUBRICANTS

5. General.—*a.* Automotive lubricants are obtained from mineral oils (petroleum crudes), fixed oils (animal or vegetable), and solids, or by compounding (combining) these to produce a lubricant of desired quality.

b. Lubricants are commercially known, according to their physical characteristics, as fluid lubricants (oils), semifluid or semisolid lubricants (compounded gear oils or greases), and solid lubricants.

6. Mineral oils (petroleum crudes).—*a.* Mineral oils are obtained from petroleum crude oils. In their natural state they vary in consistency from rather thin to heavy bodied or tarry substances.

b. A petroleum crude oil is usually classified by its basic ingredients: paraffinic, naphthenic, asphaltic, or mixed. (See fig. 5.)

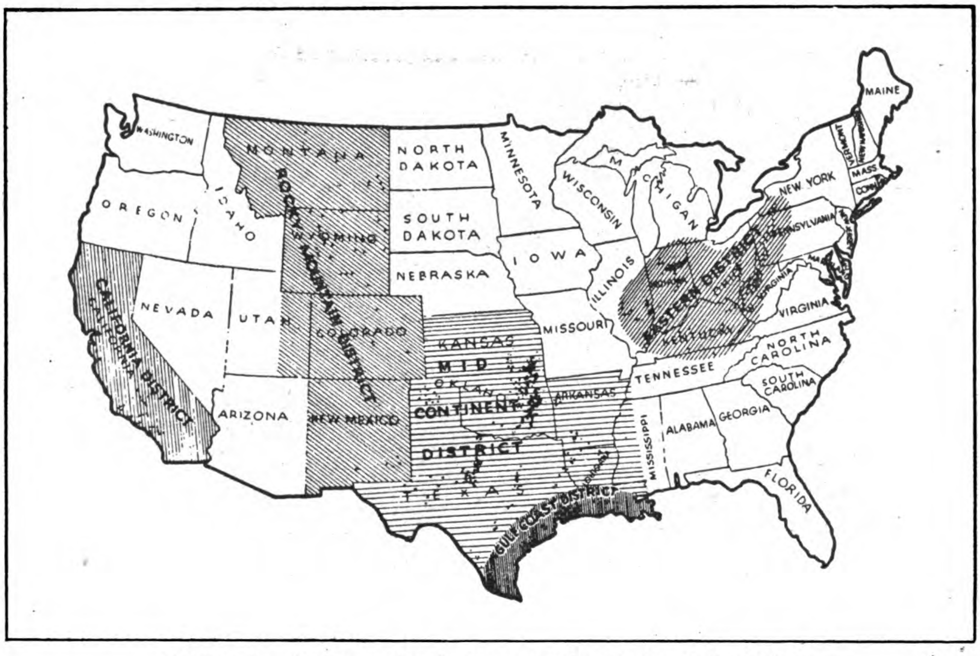


FIGURE 5.—Sources of petroleum crude oils in United States.

(1) Each crude has desirable as well as undesirable properties. However, modern methods have developed processes to obtain highly uniform lubricants by retaining the good properties of crudes and

eliminating or minimizing the bad ones, depending upon the purpose for which the lubricant is intended.

(2) (*a*) In general, paraffinic base lubricants will stand high temperatures without becoming thin in body (losing viscosity). At low temperatures, however, unless the wax they contain is removed, they will thicken and become nonfluid.

(*b*) Lubricants with a naphthenic base will function at low temperatures without thickening.

(*c*) Asphaltic crudes are very viscous, black, and rich in lubricating and fuel oils. They contain complex sulphur compounds which make refining difficult.

(*d*) Mixed crudes, which contain both wax and asphalt, have no uniformity and must be specially treated.

c. In general, the quality of mineral oils depends more upon the refining and manufacturing processes than upon the base crude oil.

d. The methods of processing crude oils vary. The following three, however, are in common use:

(1) The fractional distillation process (fig. 6), which traces the flow of crude oil from the well to the finished product.

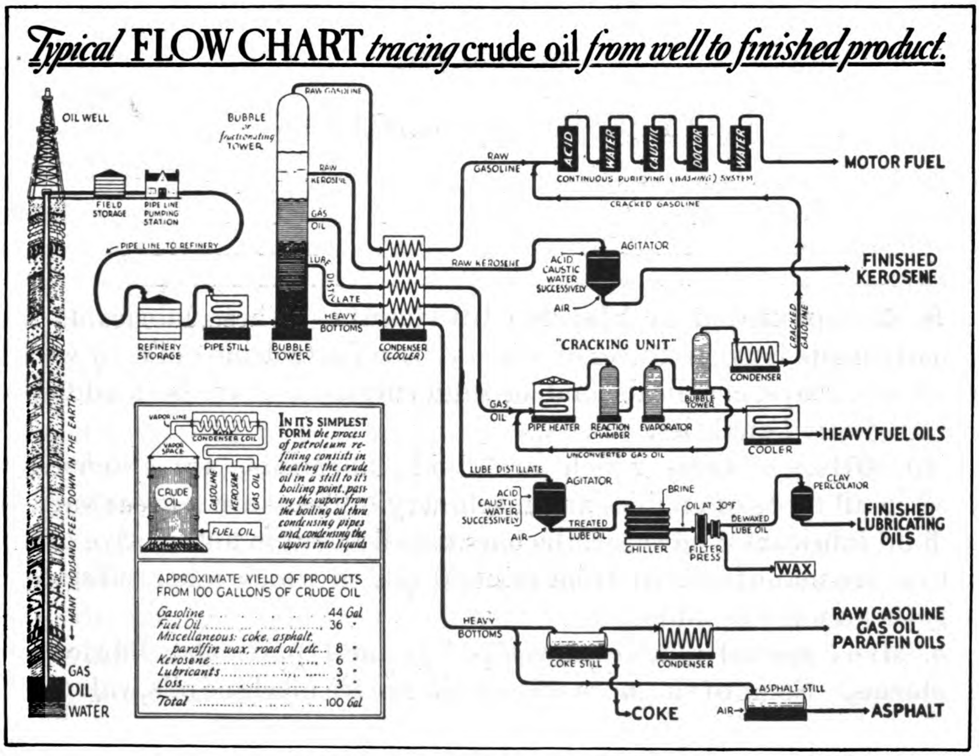


FIGURE 6.—Fractional distillation.

(2) Hydrogenation, another refining process, uses compressed hydrogen gas and heat.

(3) Solvent extraction is a refining process that uses chemicals to refine crude oil.

7. Fixed oils (animal and vegetable).—*a.* Fixed oils are of animal or vegetable origin. They are processed by heating, pressing, or extracting. Animal oils include lard oil, neat's-foot oil, sperm oil, and tallow oil. Vegetable oils include olive oil, cottonseed oil, peanut oil, and castor oil. Castor oil has excellent qualities, but it is expensive, congeals (thickens) easily, and must be changed frequently.

b. Under certain conditions of high temperatures and pressures, a straight petroleum base lubricant does not possess the qualities needed to prevent absolute metal-to-metal contact. For this reason, fixed oils in small amounts are often added to mineral oils. As a rule, this compounded or blended lubricant has greater oiliness and film strength, which permits better adherence and minimizes break-down.

8. Solids.—Solids, such as graphite (graphitic carbon), soapstone, talc, aluminum salts and waxes, usually in ground form, are mixed with a fluid lubricant for special purposes. The very nature of these lubricants makes them suitable, in the solid form, only for slow speed lubrication.

SECTION III

TYPES OF LUBRICANTS

9. Compounded or blended lubricants.—These lubricants are usually made from mixtures of mineral base (petroleum) oils, to which fixed oils, soaps, chemicals, and/or solid substances have been added to obtain desired qualities.

10. Oils.—*a.* Oils, which are fluid lubricants, are extensively used in all types of engines and machinery. There are a great variety of fluid lubricants; however, the ones usually used in automotive lubrication are manufactured from mineral oils to which other substances may or may not be added.

b. Many special oils are developed to meet particular lubrication problems. Some of the more special oils are ice machine oils, valve oils, and engine top oils.

c. (1) From an automotive point of view, the most important of all fluid lubricants are the engine (motor) oils used in lubricating the internal moving parts of engines.

(2) The Society of Automotive Engineers (SAE), while not attempting to fix or establish the quality of any engine oil, has standardized a code of SAE numbers to indicate the viscosity (body) of engine oils and gear lubricants. The code is shown in paragraph 30. In the lower numbers of this code, the SAE number followed by a W indicates a special oil for use during winter or in cold temperatures, for example, 10 W and 20 W. SAE 80, 90, 140, and 250 are used to indicate fluid gear lubricants.

d. Light machine oil is a lubricant, usually processed to eliminate gumming, that is used for small, high speed bearing surfaces where shocks are relatively mild and pressures are even. Oil cups are usually provided at these points on generators, starters, and distributors. If this special type oil is not available, SAE 10 engine oil (Navy symbol 2110) may be used as a temporary substitute.

e. Penetrating oil, or a rust-preventing oil, is often used for lubricating between leaves of flat springs. This oil (or another known as kerosene oil) when applied to nuts, bolts, or other rusty and corroded parts aids in loosening them.

f. (1) Kerosene oil is a nonvolatile, mineral oil, but it cannot normally be considered a lubricating oil. It has special uses as an automotive cleanser and as a fuel oil.

(2) Due to its low volatility, kerosene added to gasoline makes a good cleaning mixture, because it minimizes the explosive nature of vaporized gasoline. Gasoline used alone as a cleaning agent is extremely dangerous, and existing regulations prohibit its use for cleaning purposes in shops and garages. In such instances a noninflammable solvent or chemical compound should be used.

g. A flushing oil is commercially available for removing the residue of contaminated engine oil trapped in various recesses and pockets in the engine crankcase. A light engine oil (SAE 10, Navy symbol 2110) may also be used to clean the crankcase.

h. Other fluid lubricants commercially available include break-in, valve, cylinder head, and top cylinder oils. As a rule, these fluid lubricants are used only where special conditions warrant.

11. Gear lubricants.—*a.* Gear lubricant is a heavy bodied oil usually dark in color. It must have sufficient body to cushion and sustain the sudden, high pressure loads transmitted to the gear teeth surfaces and cling to the teeth to protect them against metal-to-metal contact; and it must also be sufficiently fluid not to channel (gear teeth cutting a channel through the lubricant), nor impose undue drag on the motion of the parts, and must flow in ample supply to the bearings which support the gear shafts.

b. Gear lubricants are used in transmissions, transfer cases, driving axle housings, steering gears, winch and hoist drive mechanism housings, and similar inclosed units. Some gear lubricants for transmission are listed in the viscosity tabulation in paragraph 30. The Navy Department annual contract does not provide for the heavy SAE 250 gear lubricant which is occasionally used in heavy duty units, or where climatic temperatures are exceedingly high; this lubricant should be purchased locally.

c. Changes in gear design and application, particularly the hypoid gear, brought about the development of a compounded oil in order to obtain increased load carrying capacity of the lubricant. This increase is obtained by the addition of chlorine compounds, sulphur compounds, lead soaps, and other additives to a mineral oil. This general class of oils is referred to as extreme pressure (E.P.) lubricants without any distinction as to how much greater their load carrying capacities are than those of a mineral gear lubricant.

(1) Gears, such as the hypoid rear axle, require a lubricant having the highest possible load carrying capacity. Such lubricants are known as powerful E.P. lubricants and because of their application to the hypoid gear are referred to as hypoid lubricants.

(2) Other E.P. lubricants not requiring such high load carrying capacities because of the nature of their application are known as mild E.P. lubricants.

(3) Mild E.P. lubricants are classified as SAE 80, SAE 90, and SAE 140, while the powerful E.P. lubricants are classified as SAE 80 and SAE 90. In the powerful or hypoid type, SAE 90 is recommended by most manufacturers for both summer and winter operation, while some recommend SAE 80 for temperatures below 0° F.

(4) Hypoid type lubricants should always be used in hypoid gears, and one make of hypoid lubricant should never be mixed with that of another because of possible chemical reaction and corrosion. Tentative specifications, No. FS–VV–L–761, for hypoid gear lubricants purchased by the Federal Government have been drawn so as to provide a lubricant which can be mixed with any other hypoid gear lubricant purchased under this specification regardless of the manufacturer of either. Hypoid gear lubricants purchased which do not meet this specification cannot be mixed with another lubricant.

12. Greases.—*a*. Greases are semifluid or semisolid lubricants, usually blended from mineral oils and a metallic soap. Metallic soaps (grease soaps) are chemical compounds produced from soda, lime, aluminum, calcium, potassium, antimony, barium, and other substances.

b. Lime or calcium soap greases are generally limited to use at temperatures less than 175° F. They are less affected by the action of water than other greases. Known as cup greases, they have a tendency to separate at high temperatures into oil and metallic soap.

c. Soda (sodium) soap greases are fibrous and stringy in appearance although they contain no actual fibers. These greases are more adhesive than other types, more resistant to centrifugal "throw-off," and more suitable for high temperatures. However, they are not as water resistant as lime soap greases. Primarily these greases are used in high speed rotating units—wheel bearing, universal joints and the like.

d. Aluminum soap greases are used in making soft lubricants for pressure gun lubrication. They have good adhesive characteristics, but they become fluid under moderately high temperatures.

e. Mixed base greases are usually mixtures of mineral oils and combinations of lime and soda soaps, lime and aluminum soaps, and potassium and lime soaps. In these combinations the dominant characteristic of one soap can be modified by that of the other. For example, the addition of lime soap to soda soap shortens the fibrous structure of the finished grease, thereby slowing up the change in consistency under heat and making the grease more resistant to water. This combination meets requirements for a water pump grease that must be unaffected by water and must have a melting point above the boiling point of water (212° F.). Soda and aluminum soaps combined with lime soap make a grease that resists separation at extremely high temperatures.

f. (1) Greases are used primarily on slow-moving parts and on surfaces that are concealed, not readily accessible, or exposed to outside elements; for example: dead axles, spring shackles, wheel bearings, universal joints, and similar points generally considered under chassis lubrication.

(2) The term "chassis" lubricant might lead to the conclusion that only one type of grease is required to lubricate a chassis. This is not so. Various types of grease that may be used are listed below:

(*a*) Semifluid No. 0 is a very soft (almost fluid) fiber type lubricant. It is intended for steering universal joint drive ends of front wheel drive mechanisms and as a general chassis lubricant for spring shackles, steering knuckle pivots, steering knuckle arm tie rods, steering gear connecting rods (drag arms), pedal shafts, and other similar places where movement is relatively slow. It should be used at temperatures below 0° F.

(*b*) Soft No. 1 is intended for the same uses as semifluid No. 0 lubricant when outside temperatures are between 0° F. and 32° F.

(*c*) Medium No. 2 is a fibrous type lubricant. Its uses as a general chassis lubricant are the same as those of semifluid No. 0 and soft No. 1 greases for general summer lubrication and for wheel bearing service at temperatures lower than 10° F.

(*d*) Hard No. 3 is a lubricant intended primarily for the lubrication of all wheel bearings at all temperatures above approximately 32° F. It may be required as a chassis lubricant under exceptionally high climatic temperatures; however, this should be an exception rather than a rule.

(*e*) Waterproof grease is intended only for the lubrication of water pumps, and should be a special water resistant grease with a minimum melting point of 200° F.

g. In extremely cold weather or under certain conditions imposed by manufacturing design (for example, motorcycle transmission), a more fluid oil than a gear lubricant is necessary. However, lighter lubricants should not be used for gears unless specifically recommended by the manufacturer. Where applicable, these lighter fluids should be selected according to the SAE and Navy symbol numbers shown in the tabulation in paragraph 30 under the heading "For Transmission."

h. Petrolatum is a jelly-like material, commercially known as vaseline, obtained from petroleum. It is compounded for various needs and purposes. It is used on the breaker cam of distributors; and when applied to storage battery posts and cable terminals, it retards corrosion and the formation of the green-white crystal-like substance that tends to increase resistance to the flow of electric current. Petrolatum may be mixed with graphite for lubricating springs.

SECTION IV

PROPERTIES AND CHARACTERISTICS OF LUBRICANTS

Paragraph

13. General.—*a.* Measuring the oiliness of a lubricant is not commercially practicable, but it can be judged on the basis of certain characteristics or properties which indicate its ability to reduce friction. It must be remembered that friction can never be eliminated; it can only be minimized.

b. The petroleum industry uses many different tests to determine the quality of a lubricant, but none of them are readily available to nontechnical laymen, who must rely upon the reputation of the producer for developing and delivering the desired lubricant.

c. Engine oils and gear oils, suitable for military motor vehicles, must comply with the specifications and standards in the annual Navy Department contract. Under normal conditions this contract must be used by the Army in purchasing lubricants.

14. Oiliness.—Oiliness is the characteristic of a lubricant that makes it cling or adhere to surfaces. This characteristic can vary considerably between lubricants having the same viscosity, because oiliness is a chemical property and viscosity is a physical property. Fixed oils possess more oiliness than mineral oils, but mineral oils stand up better under heat and pressures than fixed oils. A blend of fixed and mineral oils will produce an oily lubricant that will withstand heat and pressures.

15. Film strength.—Film strength is the characteristic of a lubricant that makes it hold together or cohere at the surface under extreme pressure. Mineral oils do not have great film strength, so other substances, such as sulphur, lead, and aluminum, are added to form a compounded lubricant where the use of the oil requires a greater film strength. When other substances are added, corrosive ingredients that would be harmful to lubricated surfaces must be eliminated or neutralized.

16. Viscosity.—*a.* Viscosity is the internal resistance of a lubricant to being disturbed. Stated in a simpler way, viscosity is the body of a lubricant. Viscosity is necessary and important, because mechanical failure will result if a lubricant squeezes out under heavy loads or thins out at high operating temperatures. (See fig. 7.)

b. (1) Viscosity of an engine (motor) oil has a quieting effect upon the operation of an internal combustion engine, especially when clearances in moving parts have become enlarged or worn out-of-round. It also aids in maintaining the seal between piston rings and cylinder wall that is so essential to good engine performance.

(2) An oil must flow freely and with a minimum of fluid friction (internal resistance) to circulate easily and spread completely over moving surfaces. For this reason, especially during the break-in

period and early life of an engine, the lowest viscosity oil consistent with proper lubrication should be used. Stated in another way, the general rule for engine lubrication is to use an oil with the lowest possible viscosity that will maintain a proper film on the moving surfaces involved. Bearing design and metals have been improved materially in modern engines so that much lighter engine oils than those previously used are now necessary to insure good engine performance and to prevent excessive frictional wear.

c. An oil whose body changes the least over a wide temperature range is said to have a high viscosity index. Such an oil is particularly desir-

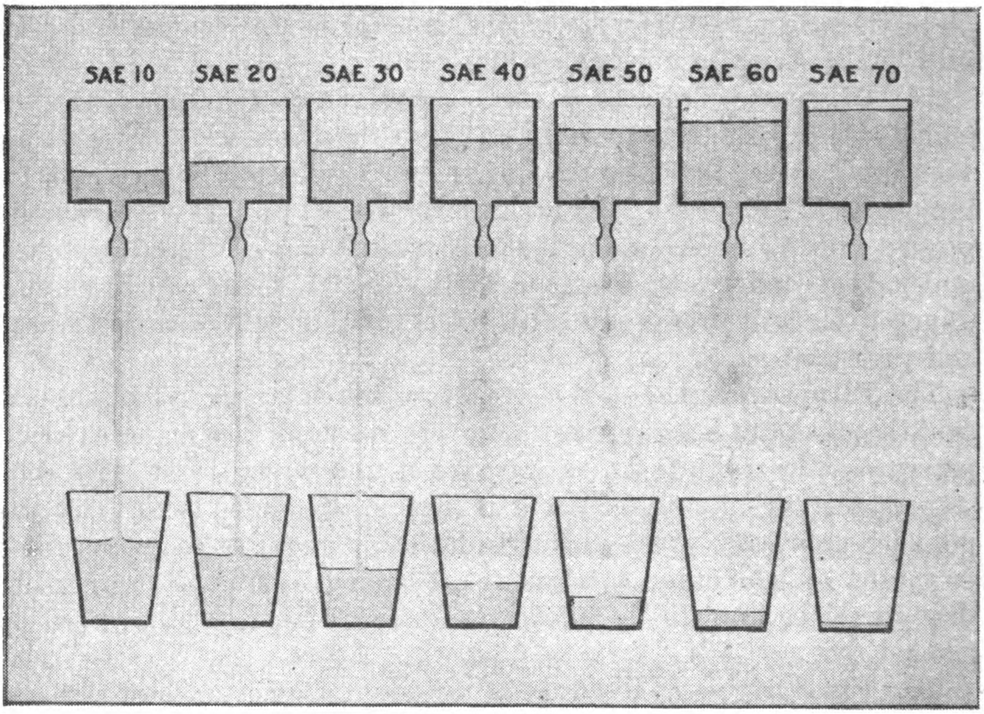


FIGURE 7.—Effect of viscosity on flow of light and heavy oils.

NOTE.—The spout in each container is of the same size, and each grade of oil has flowed for the same time.

able for winter or cold weather use when the changes in engine temperature are greatest, ranging from extremely low temperatures (below freezing) in a cold engine to high operating temperatures of 160° to more than 200° F.

d. The table in paragraph 30 shows the SAE and Navy symbol viscosity ratings.

17. Pour and cold points.—Fluid lubricants (oils) subjected to low temperatures change in character from a freely flowing liquid to a thick fluid that barely flows (pour point) or ceases to flow (cold point). The pour point temperature is approximately 5° higher than that of the cold point. This characteristic, as determined by these two points, is an important consideration in the selection of an oil for low temperature lubrication.

18. Flash and fire points.—These indicate the volatile characteristic of an oil that permits it to vaporize and burn. A burned oil leaves a hard, gritty residue known as carbon. The fire point is usually 60° to 65° higher in temperature than the flash point.

19. Color.—The natural color of a lubricant largely indicates its origin. The use of other substances in compounding lubricants eliminates color as an important indication of origin or quality. A lubricant may be clear, or dark and hard to see through; it may be red, yellow, green, blue, brown, or black without affecting its quality.

20. Specific gravity.—The specific gravity of a lubricant has no direct bearing on its performance. Considered with viscosity and flash point, it merely indicates the origin of the petroleum crude used. A gravity hydrometer is used to measure the specific gravity of an oil.

21. Volatility.—This characteristic indicates the tendency of a lubricant, especially an engine oil, to evaporate. A grease having a volatile oil as an ingredient might be extremely soft when first manufactured, but after exposure to air or heat it would soon become hard and unsatisfactory as a lubricant.

22. Impurities.—Acids, alkalies, oxides, and other impurities must be eliminated by the manufacturer. Acidity and alkalinity are characteristics that may cause corrosion. Oxidation takes place in the engine crankcase. The churning action of high speed engines operated for long periods of time forms an oxide binder that collects and holds together dust, carbon, and metal particles, and other foreign matter. These impurities clog oil passages and cause a break-down in the oil supply system. Suspended matter in the form of tar or other insoluble substances are also undesirable in an engine oil. Adulterants in a gear lubricant may cause foaming.

23. Desirable properties in lubricant.—A good lubricant should possess the following desirable qualities:

a. Good viscosity.—The body or viscosity of a lubricant should be natural and not dependent upon a filler, such as talc, mica, pulp, cork, or similar substances. A lubricant should have good cohesive and adhesive properties.

b. Purity.—This implies the use of high grade materials, as well as proper manufacturing methods, to eliminate or minimize such harmful or undesirable elements as acid, gum, water, tar, wax, and other impurities.

c. High stability.—A lubricant should have the ability to retain its normal consistency and structure under the varying and extreme conditions of load and temperature imposed by the modern high power, high speed motor vehicle engine.

SECTION V

PROBLEMS IN LUBRICATION

24. General.—*a.* A small, finely built machine presents an entirely different lubricating problem from a heavy, loosely built machine. Similarly, a small, lightly built internal combustion engine with a splash circulating lubricating system presents a distinctly different problem from a large, heavy duty internal combustion engine with a full force feed lubricating system. The Diesel engine with its greater pressures, higher compression temperatures, and closer precision fits presents still another lubricating problem.

b. No general rule will solve all lubricating problems. It is generally conceded that in an emergency any good lubricant will reduce friction and can be safely used. In purchasing lubricants other than those on the Navy contract, it is advisable to deal with a reputable dealer and use only established and well-known brands. To purchase and use unknown products is dangerous and often results in mechanical failures and serious damage.

25. Contamination.—Lubricants are subject to contamination from different sources:

a. Road dust.—Road dust, enters a crankcase either through the carburetor, the breather pipe, or some other opening. When new engine oil is poured into a dirty crankcase or out of a container that is either dirty or that has been opened to dust and dirt, the value of changing oil has been lost. Dust usually acts as an abrasive and speeds up the wear of parts. Circulating oil carries dust and dirt and deposits it in drilled holes, recesses and other parts of the lubricating system. Enough dust can accumulate to restrict or stop the circulation of oil, especially in small engines. Air filters on carburetor air passages and oil filters in the oil circulating system minimize the effects of road dust and dirt.

b. Particles of metal.—Particles of metal worn off moving parts, or foreign matter resulting from corrosive chemical reactions, ultimately go into the crankcase. These add to the problem of contamination and excessive abrasion.

c. Carbon.—Carbon or the residue of burned lubricants creates the same problem as any other hard foreign substance carried by circulating oil.

d. Sludge.—(1) Dirt and water present in any marked amount in the bottom of the engine crankcase mix with the oil and form a thick, viscous, buttery mass known as "sludge." Contaminated oil may render satisfactory service at slow speeds for short trips, but under more severe operating conditions it will cause damaged bearings, scored cylinders, and other mechanical difficulties.

(2) Most of the water in engine crankcases is formed by the condensation of water vapors. Water, before changing into sludge, can impair oil circulation by freezing.

e. Dilution.—In winter more than at any other time, unburned gasoline is likely to wash past the piston rings and piston, down the cylinder walls and into the crankcase, where it mixes with the engine oil, dilutes it, and changes its viscosity. The same is true when, in starting an engine, the choke is used excessively. Most engine designs provide a crankcase ventilating system to minimize dilution and to aid in carrying off gasoline and water vapor. As a rule, the viscosity of oil recommended by vehicle manufacturers and furnished by reputable refiners is such that average dilutions do not make the oil too thin for safe operation. However, as little as 5 percent dilution reduces the viscosity of SAE 30 oil about one-third, and 10 percent reduces it two-thirds. Crankcase dilution is most common in cold weather or when operation is intermittent, as in city driving with its frequent starts and short runs.

26. Cold weather.—*a.* All lubricants are thickened by cold weather; very often the normal viscosity is increased several times. This creates a resistance which makes the engine hard to start. There are various methods of overcoming the effect of cold weather. Changing to a lubricant having a lower viscosity to provide a lighter bodied oil is usually the easiest solution.

b. In zero and subzero weather it may even be necessary to drain the engine oil after a day's run while the engine is warm. Before starting the engine again, the oil should be warmed and, while still warm and fluid, poured back into the engine to assure easy cranking and early oil circulation. It is not generally realized, after an engine has been started in cold weather, that the oil circulates poorly until it has been warmed and thinned out.

c. Engines started cold should not be raced (operated at high speeds). Cold oil does not circulate, so the racing and lack of lubrication will damage the engine.

d. Gear lubricants have a tendency to "channel" and not move freely in cold weather.

e. Greases are difficult to apply during cold weather, especially with hand grease guns; so the softest grease available for general chassis lubrication should be used.

f. Units should, if possible, be lubricated indoors and in heated places during extremely cold weather.

27. Time.—Beside the daily routine lubrication, motor vehicles should be lubricated (serviced) or have lubricant added, if needed, every 1,000 miles or once a month. Under severe operating conditions, lubrication every 500 miles is desirable. Wheel bearings, transmissions, driving axles, and similar units and subassemblies should usually have their lubricant changed seasonally, that is, spring and fall of each year. Every 6,000 miles (or 6 months) the lubrication of the entire vehicle should be technically checked in detail and necessary action taken.

28. Responsibility.—*a. General.*—Lubrication should be systematic and constantly supervised because the life and service of a motor vehicle essentially depend upon lubrication. Supervision should be exercised by noncommissioned officers or other persons with sufficient mechanical knowledge to detect false or improper practices and maladjustment in vehicle units and assemblies. During field service operation, a system of decentralized lubrication is used, while in posts, camps, and stations where permanent facilities are available a system of centralized lubrication should be used.

b. Decentralized lubrication.—(1) This system of lubrication is used in field service operations where the responsibility of lubrication falls upon the driver. He should wash his vehicle before lubricating it. In addition to his daily responsibility of adding to or changing engine oil, he should lubricate such parts as spring and spring shackle bolts, steering knuckle pivots, steering knuckle tie rod ends, steering gear connecting rod ends, clutch and brake pedal and lever pivots and linkage, accelerator linkage, door hinges, and other points that are lubricated by the oil can and hand grease gun with which he is equipped.

(2) Mechanics should lubricate gear cases, wheel bearings, clutch release bearings, water pumps, or other units requiring a special lubricant or special care to prevent overlubrication.

c. Centralized lubrication.—When permanent lubrication facilities are available, all lubrication functions are performed by personnel trained in lubrication work with the exception of replenishment of crankcase oil. This responsibility remains the driver's. Drivers should accompany the vehicle to the central lubrication point with all of his first echelon responsibilities completed. The driver's services should be utilized in the lubrication of his vehicle in order to expedite the work and to give him training in lubrication as the responsibility of complete lubrication will be his should the vehicle be detached or used in field service operations away from other units.

29. Method.—*a. System.*—Vehicle manufacturers and refiners indicate how vehicles are to be lubricated by charts or manuals covering specific types and models of vehicles. An improvised form, listing parts to be lubricated and other data taken from these charts and manuals, can be used as a detailed reminder or check list. As each part is lubricated, it can be checked off on this form. A procedure which insures complete and systematic lubrication of each vehicle should be adopted. General guides of this nature are given in appendixes I and II.

b. Procedure.—The following is a step by step method that can be used when completely lubricating a vehicle. It should be modified to meet local or special conditions.

(1) Remove drain plugs of engine crankcase, transmission and transfer mechanism case, winch gear case, driving axle housings, and similar units to be drained. Hoist oil chambers, except when use is constant and frequent, seldom require oil replacement, but linkage surfaces should be lubricated monthly. All units should be drained while at operating temperatures and flushed with flushing or SAE 10 oil.

(2) While the above units are draining, lubricate with grease gun all those parts that require use of chassis grease, starting with left rear shackle and moving toward left front, continuing around vehicle to right front, and then completing chassis from right front to pintle (or cross member) in rear.

(3) Lubricate wheel bearings with wheel bearing greasing (or packing) equipment after all old grease has been removed and bearing thoroughly cleaned. Remove wheels individually and pack each bearing. As a rule, fibrous type grease is used.

(4) Lubricate universal joints of propeller shafts, generally using universal joint grease gun. If the universal joints are self-lubricated, no lubrication is necessary until they are repaired. Some universal joints may require a special lubricant, usually a viscous, semifluid gear lubricant.

(5) After replacing crankcase drain plug, pour new engine oil in engine crankcase. Drain plugs should be replaced in transmission

case driving axle housing and similar parts before a new gear lubricant is added.

(6) When inspection indicates that a hypoid lubricant must be added to the original lubricant in the housing, the same kind of lubricant *must* be used. If the only lubricant available is of a different kind, make, or type, the old hypoid lubricant must be completely drained out of the housing before the new and different hypoid lubricant is added.

(7) In lubricating springs it is often necessary to pry the leaves apart, pack the spring covers with a soft or semifluid lubricant, or take the springs completely apart. Usually a fluid penetrating oil, a soft or semifluid lubricant, or a graphite mixed grease is used.

(8) When a nongumming light machine oil is not commercially available, lubricate starting motor, generator, distributor, and similar units with SAE 10 W oil after the engine crankcase is filled.

(9) The water pump is usually lubricated with a water pump grease. In lubricating the water pump, care must be taken not to force grease into cooling system through water pump fittings. The grease may clog the small spaces in the radiator core and affect the water hose.

(10) While lubricating a vehicle, it may be desirable to check battery for corrosion, loose connections, and need for adding water. At the same time it may be desirable to inspect tires for inflation pressures.

(11) Lubrication of parts not outlined above should be accomplished in accordance with the manufacturer's instructions.

Section VI

SELECTION AND USE OF LUBRICANTS

30. SAE and Navy symbol classification.—To assist in the selection of lubricants, the following tabulation has been made, which compares SAE numbers with Navy symbol numbers:

Type of lubricant	Navy symbol numbers	SAE numbers[1]	
		For engine	For transmission
Force feed oils (also general light oil for gravity feed).	2110	10 (10 W)	
Force feed oils (automotive and general).	3050	20 (20 W)	
	3065	30	80 (medium).
	3080	40	90 (low).
	3100	50	90 (high).
	3120	60	140.
Aviation oils (also recommended for heavy duty engine use and some gear cases).	1080	40	80 (high).
	1100	50	90 (medium).
	1120	60	140.
	1150	70	140 (medium).
Mineral marine-engine and cylinder oil (suitable gear lubricant).	5190	----------	140.

[1] Except when extreme pressure gear oils are specified by vehicle manufacturer.

a. "Low" indicates the lower side of the viscosity range, while "high" indicates the higher side.

b. An oil having one Navy symbol number often has two different SAE viscosity ratings as shown in the above table. However, in both ratings the oil is identical in all characteristics except that its viscosity is determined by a different standard, depending on whether it is to be used as an engine or a gear lubricant. For example, Navy symbol 1100 oil has two SAE numbers—the SAE 50 viscosity rating for use as an engine oil, and the SAE 90 (medium) rating for use as a gear oil in transmissions, transfer mechanism, power take-offs, live axles, and similar units. An oil with one Navy symbol number can be safely used as either an engine lubricant or as a gear lubricant as long as it meets the manufacturer's recommendation as to SAE number. Figure 7 shows the comparative flow of light and heavy viscosity oils.

c. All lubricants shown in the above tabulation and included in the annual Navy Department contract made under the direction of the Bureau of Engineers, Navy Department, Washington, D. C., should be purchased under that contract whenever they meet actual lubricating requirements.

31. Lubricating equipment.—Figure 8 shows various types of fittings used in automotive lubrication and a gear oil pump.

a. Oil cups.—The oil cups generally found on starters, distributors, and generators are designed to admit a limited quantity of light oil, usually a few drops. They sometimes use cloth wicking to act as a feed so the oil will be applied over a greater period of time.

b. Grease cups.—Grease cups are usually the screw cap type. The cap is removed, filled with a soft grease, replaced, and screwed down until the grease comes through. After this, these caps should be screwed down approximately one turn at every scheduled lubricating period.

c. Grease fittings.—Grease fittings are generally used in pressure gun lubrication of chassis and other vehicle units and parts. These

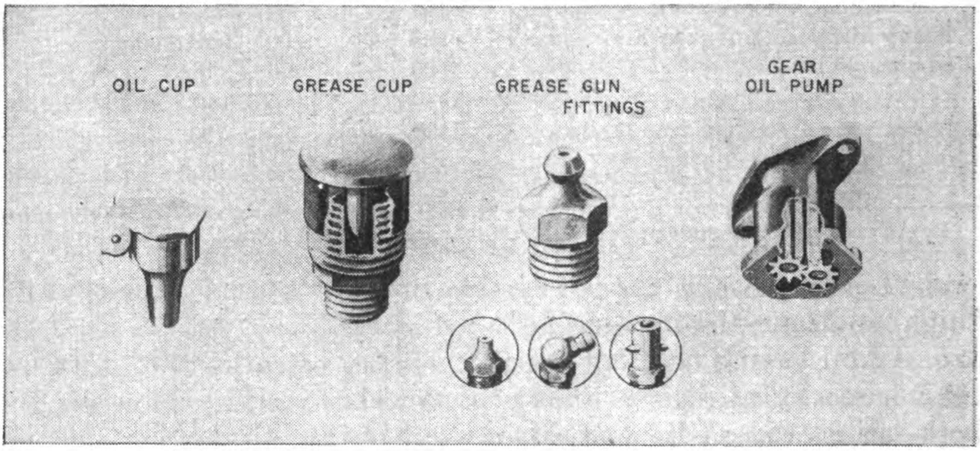


FIGURE 8.—Various means for applying lubricants.

are fitted with a spring and ball check valve and have pointed, ball, or other shaped ends to fit the various types of pressure guns. They are made with different length bodies and set at various angles to make them accessible when installed in close places. Some special types, including automatic or limited feed fittings, will sometimes be found.

d. Grease guns.—Grease guns are designed according to the type of lubricant they are to handle. Extension hose and nozzles vary in length, diameter, and in material, depending upon the pressures involved and the units to be lubricated. The types of grease guns commonly used are as follows:

(1) *Hand operated.*—All military motor vehicles are equipped with this type. It is used by the driver as part of his first echelon responsibility in the field.

(2) *Hand auxiliary lever pressure.*

(3) *Power pressure* (air or electric ram).

(4) *Bucket.*—This type is not a grease gun in a true sense. It is a bucket equipped with a pressure pump device and long supply lines designed to reach parts of the vehicle, especially transmissions, live axle housings, and similar units.

e. Oil cans and guns.—It is a general practice to use oil cans for fluid lubricants. The types available are many. One type, designed to be airtight, is equipped with a hand plunger air pump to develop pressures; the operation of a release valve will force the oil out of the can and squirt it into relatively inaccessible places. Another type is the oil (or spray) gun designed for use in connection with lines bringing air pressure from a compressor; this type with the addition of a suction feed line is often used to carry kerosene or other mixtures for cleaning the outside of parts heavily coated with dirt and grease.

f. Oil filters.—Figures 9, 10, and 11 show the interior construction of various types of oil filters. The primary function of an oil filter is to strain the engine oil of some of the contaminating substances it contains by passing it through a filtering element, either a cloth bag, a screen, or a metal strainer. As a rule, all oil filters are designed with a by-pass valve which permits free circulation of the lubricating oil when the filter elements become clogged and retard oil movement. Normally, a filter element should be replaced or cleaned (when nonreplaceable), approximately every 8,000 to 10,000 miles; however, this should be specially considered every 6 months. This is particularly true in the case of new engines where metal particles, core, sand, and similar foreign material can be expected in the oil. Oil from the bayonet gage should always be rubbed between the thumb and finger to detect any grit or cuttings that may be in the oil. An oil filter should be checked monthly, especially for tight connections or for broken oil lines that may not be noted during daily operating inspections.

g. Oil gages.—(1) *Pressure gage.*—Many different types of oil gages have been in use in the past. However, because recent trends have been toward force feed lubricating systems, the instrument panel type of oil pressure gage is now in almost universal use. It will usually show broken or clogged lines because it indicates the resistance of the oil to being circulated. This resistance is generally measured in pounds of pressure exerted; some gages show a numerical reading without relation to pounds. Pressure gages used with

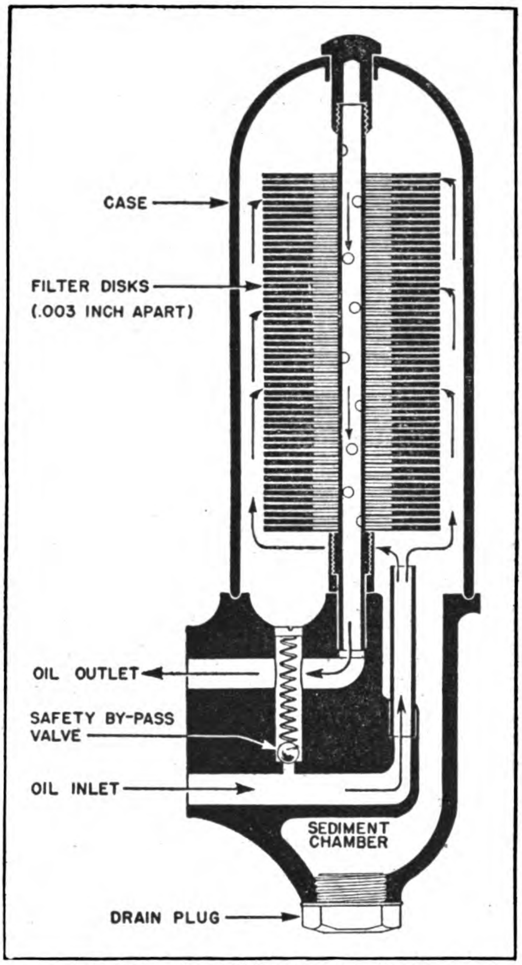


FIGURE 9.—Disk type oil filter.

NOTE.—Oil is filtered as it passes between closely spaced metal disks.

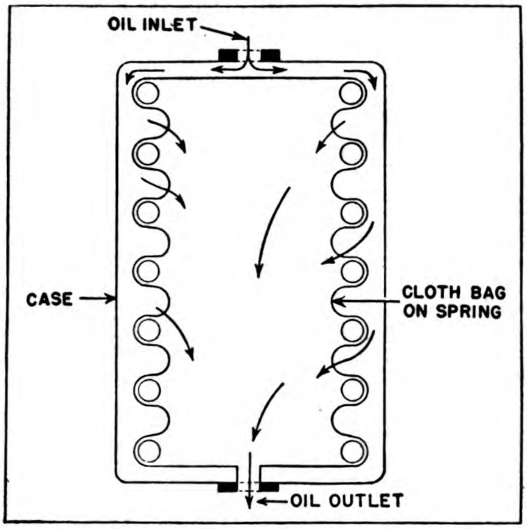


FIGURE 10.—Cloth bag type oil filter.

NOTE.—Cloth bag through which oil must flow is supported by a spring.

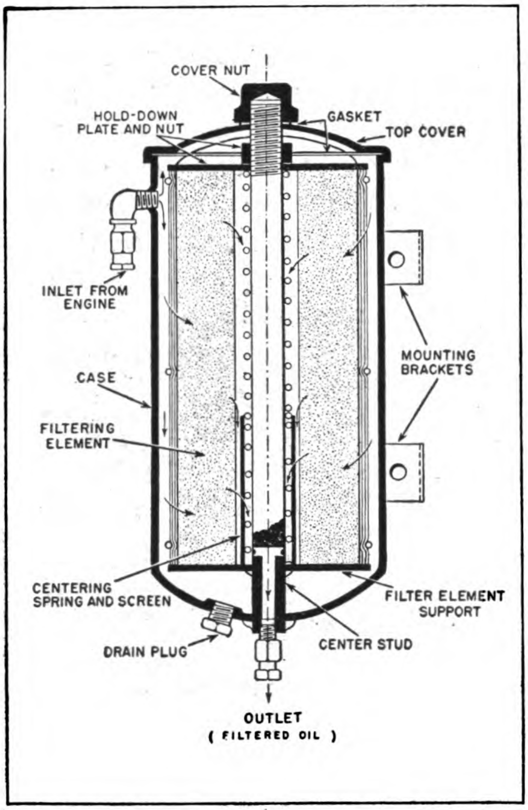


FIGURE 11.—Depth type (absorbent) oil filter.
NOTE.—Oil is filtered as it passes through a replaceable filter element.

the circulating splash system are of the low pressure type; with the full force and force feed lubricating systems, they are of the high pressure type. *Pressure gages do not show actually how much oil is in the crankcase.* They merely show that oil is moving sufficiently to create indicated pressure. Figure 12 shows an inside view of an oil-pressure gage. The oil, forced up the Bourdon tube, compresses the air in the flexible tube and makes it straighten out. This action pulls the connecting link and makes the geared sector move its indicator needle.

(*a*) An abnormal change in dial readings noted on pressure gages indicates one or more of the following conditions:

1. Loose main or connecting rod bearing.
2. Oil thinned out by excessive heat or crankcase dilution.
3. Oil too low in viscosity or of poor quality.
4. Oil filter element partially or wholly clogged. (Especially in full flow type filters. By-pass line filters will not affect gage readings.)
5. Pressure relief valve out of adjustment.

(*b*) A sudden change in oil pressure, especially a decrease, must be immediately investigated to determine the cause in order to avoid serious damage to engine parts from lack of lubrication. The defect, if serious, should be corrected before continuing operation of the engine.

(2) *Bayonet gages.*—These are usually located in the side of the engine crankcase and indicate the oil level when withdrawn from the crankcase. They are marked "low," "half," and "full" or by some other similar method.

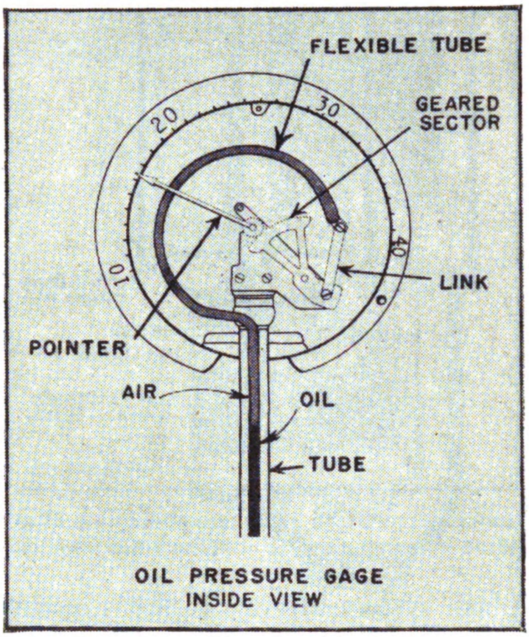


FIGURE 12.—Oil pressure gage of bourdon tube type.

NOTE.—As pressure increases, flexible tube tends to straighten out causing link to act on geared sector and swing pointer.

32. Engine lubrication.—*a. Functions of engine oil.*—(1) If correct lubrication is to be attained in an engine, the oil must at all times—

(*a*) Prevent metal-to-metal contact.

(*b*) Provide for sealing the very small spaces between piston ring, piston groove, and cylinder wall.

(*c*) Absorb heat from piston and transmit it to cylinder walls.

(2) If a lubricant completely fails to do these, the result is instantaneous damage to an engine. On the other hand, if the lubricant partly performs its functions, the destructive effect may be gradual and not readily noticed, but the damage that will ultimately result is no less certain. The fact that an engine oil appears to be satisfactory is no guarantee that it is fully performing its functions.

(3) (*a*) Figure 13, an engine cross section, shows how oil flows to the various moving parts.

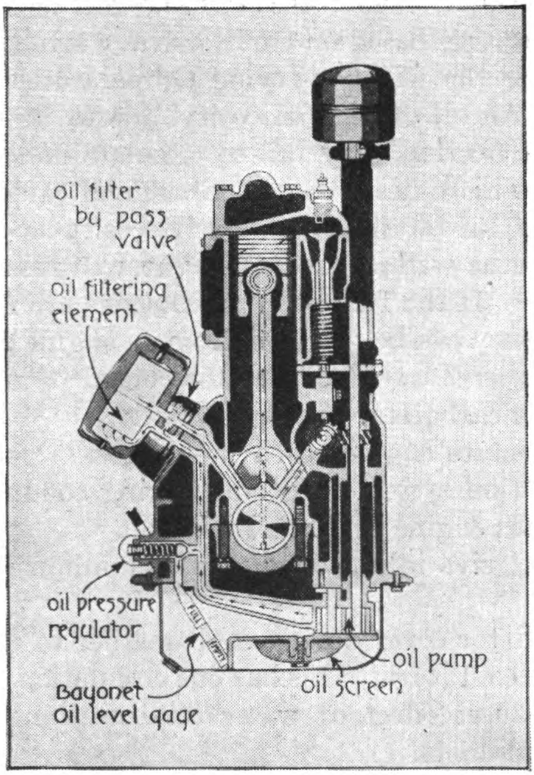


FIGURE 13.—Cross-sectional view of engine showing flow of oil (direction shown by arrows).

(*b*) Figure 14, a piston within an engine cylinder, shows how oil acts as a lubricant, as a seal, and as a heat carrying agent (from piston to cylinder wall to water in cooling system) between the moving piston assembly and the stationary cylinder wall.

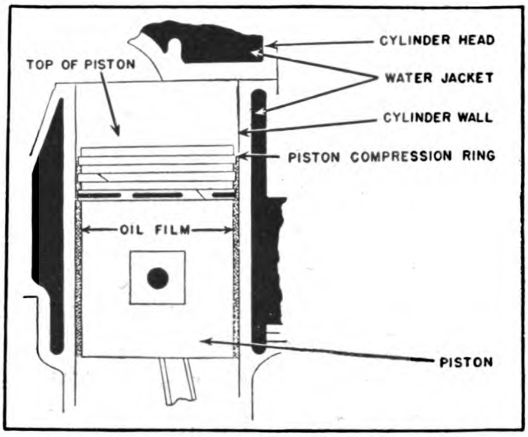


FIGURE 14.—Exaggerated sectional view showing oil seal between piston assembly and cylinder wall.

b. Grades of oil.—The correct engine oil is the one having the viscosity rating which best suits all the various requirements of the engine under all conditions of operation. Sometimes different grades (according to viscosity based on SAE or Navy symbol numbers) will be required under the widely varying temperatures of summer and winter service. An oil of high viscosity, due to its heavy body and its fluid internal friction, may fail to circulate under certain conditions; it develops more heat, wastes power, and causes excessive fuel consumption. If an oil with too low viscosity is used, "blow-by" and loss of power as well as excessive wear will result.

c. Precautions.—If the following precautions are followed, greater lubricating efficiency can be obtained from an engine oil:

(1) Avoid excessive use of carburetor choke.

(2) Avoid rich carburetor mixtures.

(3) Do not operate engine when it misfires.

(4) Keep ignition system in good working condition; when it is inefficient it causes engine crankcase dilution.

(5) Avoid excessive idling of engine to minimize crankcase dilution.

(6) Use a radiator cover during cold weather to quicken warming of engine after a cold start. This hastens circulation of lubricant and eliminates or reduces effect of water condensation by speeding up evaporation of dilutents.

(7) When oil purifying or filtering devices are installed, keep them clean and keep circulating passages open.

(8) Clean oil screen which is usually installed near circulating pump intake.

(9) When using a bayonet gage to check oil level in a crankcase, note condition of oil. If it is too thick or too thin, or if it feels gritty when rubbed between the fingers, drain it and replace it with clean oil.

d. Troubles and remedies.—Possible sources of trouble are indicated below and general corrective measures are suggested:

(1) *Lack of oil.*—Check engine crankcase frequently (at least daily) for correct oil level, using bayonet gage. Note if oil pressure gage is registering correctly; repair or replace it if unsatisfactory. Replenish oil supply when needed.

(2) *Water leaks.*—Water in the crankcase may be caused by leaks from the water cooling system through cylinder head gaskets, by cracks in the cylinder block, or by moisture which condenses during cold weather operation. Necessary repairs should be made to eliminate leaks. Crankcase ventilation, if aided by use of a radiator cover, should minimize condensation.

(3) *Low pressures.*—A low pressure reading on a pressure gage indicates insufficient oil, badly diluted oil, or excessive clearances and loose connections. To remedy: add oil, or drain and replace old oil with new, or make needed mechanical adjustments or repairs.

(4) *High pressures.*—Abnormally high pressures on a pressure gage indicate either cold or thick oil or clogged passages. When the oil is cold, the engine should be run slowly until the heat thins out the lubricant. If the oil is too thick (high viscosity), it should be replaced. When clogged oil passages are indicated, the entire lubricating system from the intake screening through the pump and through all lines or passages must be checked, section by section, until the cause has been removed.

(5) *Loose connections.*—Loose connections are usually indicated externally by signs of oil leakage. Tighten loose connections to eliminate all leaks.

(6) *Oil pumping.*—(*a*) When excessive oil consumption is still noted after the sources of the troubles listed above have been eliminated, it is safe to assume that the cylinder piston ring clearances are excessive. This condition, called "oil pumping," is caused by oil passing the piston rings at every stroke of the piston into the combustion chamber where it is burned and exhausted through the muffler in the form of a gas. Although only a minute quantity of oil passes by the rings at each piston stroke, the total amount of oil pumped over a long period of time becomes large. For example, in an ordinary 6-cylinder car driven 100 miles there would be approximately 1,612,800 piston strokes. If one drop of oil passed into the combustion chamber at each piston stroke and was burned or otherwise lost, the oil consumption for the trip would amount to approximately 7 gallons.

(*b*) To eliminate oil pumping, piston and piston ring expanders may be used as an emergency repair. To eliminate this trouble permanently the engine must be rebuilt, which involves the reboring of cylinders, the replacement of pistons and rings with oversized units, and the general tightening or replacement of other related parts.

e. Methods.—There are many methods of lubricating an engine. The splash and circulating splash methods are seldom used in modern engine design. The force feed system, which pumps lubricants under pressure to all connecting rod and main bearings and provides an excess of oil for dispersion in the form of a mist, is used in some engines. A commonly used method of lubricating an automotive internal combustion engine is the "full force feed" system (fig. 16). Oil is pumped through passages to main and connecting rod bearings, up through the drilled connecting rod (or an externally attached oil

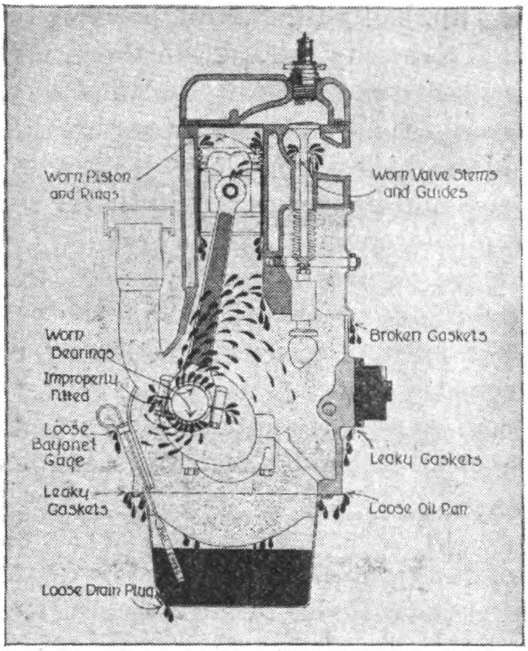


FIGURE 15.—Common causes of excessive oil consumption and oil losses in an engine.

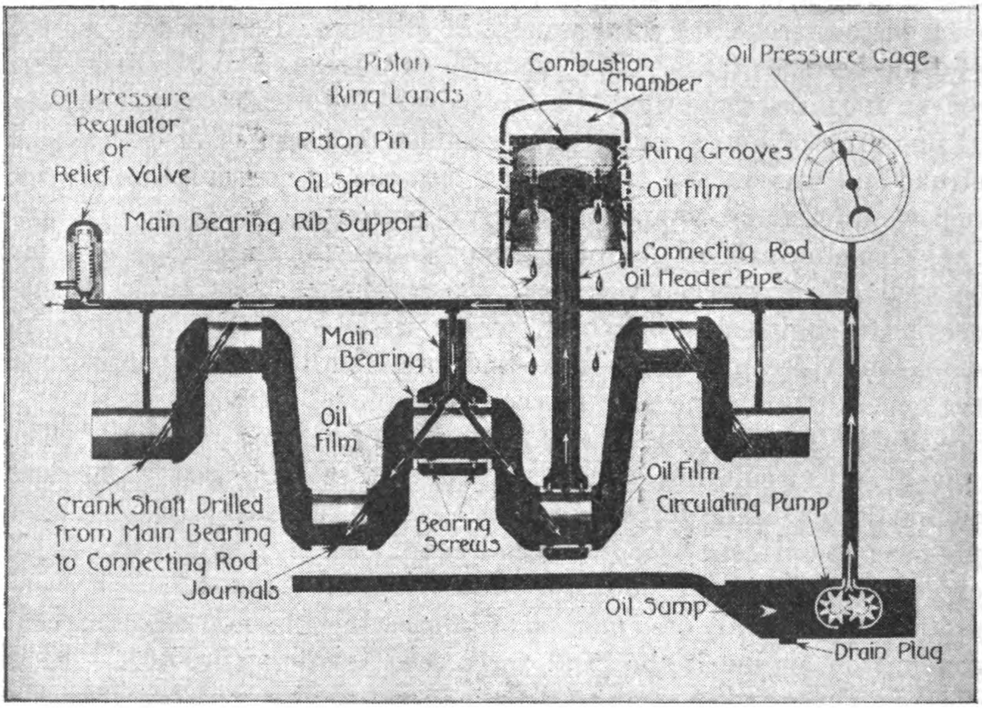


FIGURE 16.—Full force feed lubricating system.

line) to the piston pins, out through the ends of the piston pins and onto the cylinder walls from where it drains back into the crankcase. Figure 17 illustrates various features of the engine showing oil film and lubricated moving surfaces.

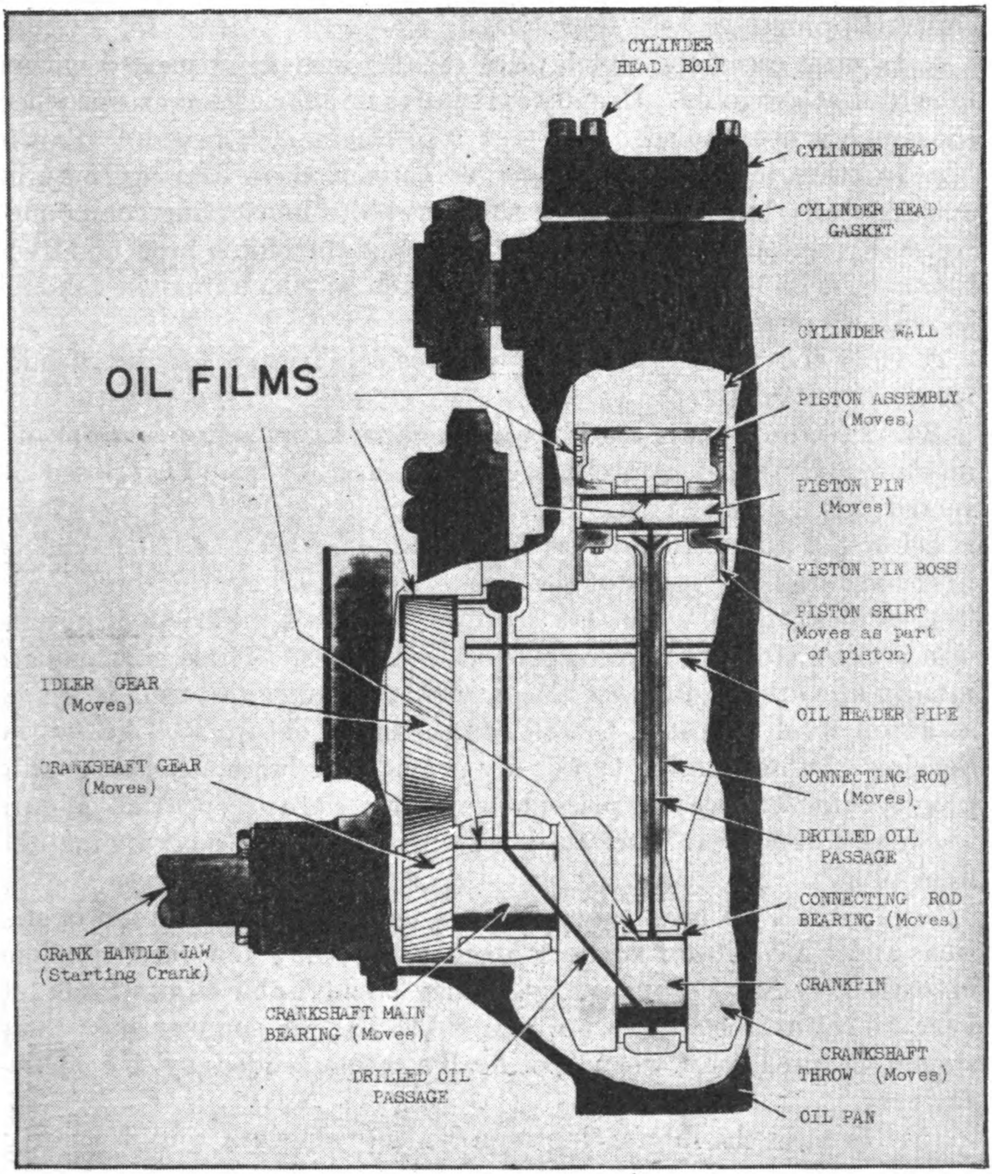


FIGURE 17.—Engine lubrication; oil films (moving parts indicated by word "moves").

33. Clutch lubrication.—Differences in the lubrication of the many and varied types of clutches must be anticipated. Various types and grades of lubricants are specified by vehicle manufacturers, together with widely different methods and periods of lubrication.

a. In greasing a vehicle, the clutch release (throw-out) bearing is usually the one vital part commonly overlooked. The clutch release bearing is subject to constant use and in most instances must be regularly lubricated with chassis grease. However, overlubricating a clutch release bearing results in greasy clutch plate linings and causes clutch slipping.

b. In most cases, the clutch pilot (shaft) bearing is packed with a lubricant at assembly. Usually it requires no lubrication except when the clutch is overhauled.

c. In other instances, either one or both of these bearings may be automatically lubricated with a solid graphite lubricating compound. Normally, automatically lubricated parts of the clutch need no attention until it is necessary to rebuild the clutch, at which time they should be replaced or repacked.

d. Only the "wet" type clutch requires a lubricant, usually a fluid, for the clutch plates.

34. Transmission and tranfer case lubrication.—*a.* Transmission and transfer mechanism parts are invariably inclosed in vented oil-tight housings. In transmissions where the countershaft is below the main (direct drive) shaft, the gear lubricant should at least touch the under side of the countershaft. Excessively high levels in these tend to make the seals leak, which causes inefficient transmission brake action due to oil-soaked brake linings. These housings are usually filled through an oil plug at the side which also usually serves as an oil level indicator, the oil level being about ½ inch below the opening. Other housing types may provide for lubrication through a plug opening in the cover plate; however, these are exceptional. Figure 18 shows correct gear lubricant level with relation to the gears and the filler plug.

b. (1) SAE 90 gear lubricant is usually used for winter operations and SAE 140 for summer operations. On a few rare occasions on extremely heavy duty trucks, it may be advisable to use SAE 140 gear lubricant for winter use and SAE 250 for summer use; these should be used only when specifically recommended by the manufacturer.

(2) To meet the lubricating requirements of gears, a high quality, heavy-bodied semifluid gear lubricant is usually required. In some instances, a lighter fluid lubricant may be necessary to assure distribution over and around the gears and to facilitate gear shifting at very low temperatures. Heavier types of these units may require a heavier bodied lubricant to minimize lubrication break-downs. These units should be checked at least every 1,000 miles, and a lubricant

should be added when necessary. Usually they should be drained and refilled periodically, preferably in the spring and the autumn of each year.

35. Propeller shaft and universal joint lubrication.—*a.* (1) A propeller shaft with the spline entirely inclosed and sealed, and with a lubricating fitting in the housing around the spline, only requires greasing with a chassis lubricant about every 1,000 miles.

(2) A propeller shaft spline inclosed within a torque tube is usually lubricated automatically from an adjacent unit or assembly and requires no attention. This type shaft is sometimes equipped

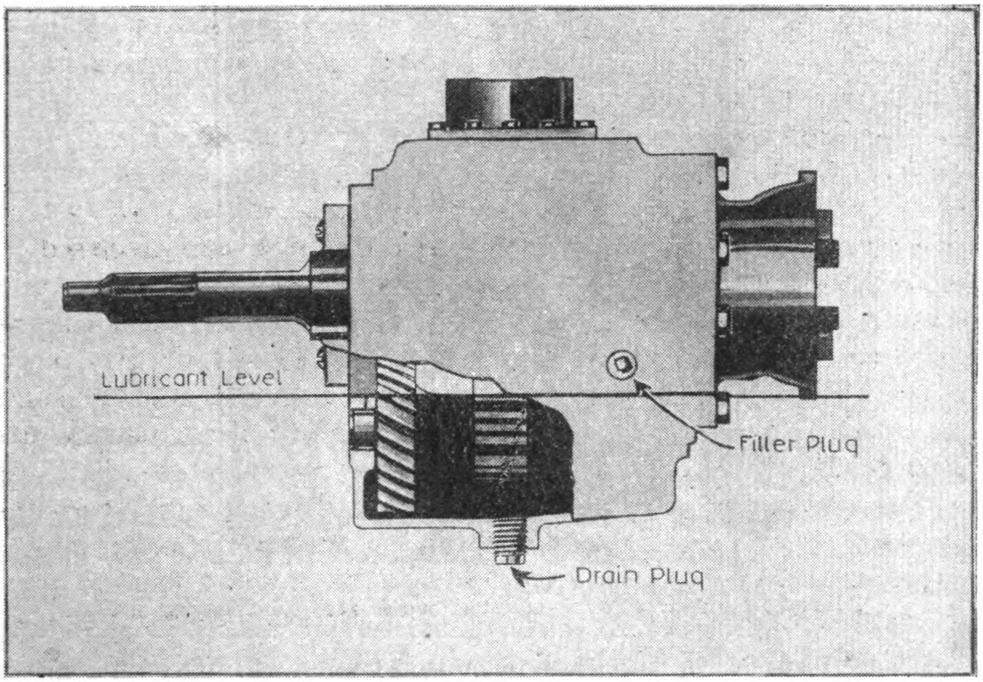


FIGURE 18.—Oil level in transmission gear case (proper level, about ½ inch below filler plug, indicated by black line).

with a center bearing which is lubricated from a fitting on the side of the torque tube.

(3) A propeller shaft having a partially exposed spline (for example, the drive (propeller) shaft of the 1940 winches) must be kept free of rust and lubricated with a heavy-bodied fluid. In addition to adding grease through the grease fitting, it should be inspected every 1,000 miles or monthly to avoid "freezing" the spline lands and grooves from rust and corrosion, which would result in shaft failure.

b. (1) As a rule, the lubricant used on universal joints should be fibrous and fairly viscous, so that it will not separate under the high speed rotating action of the joint and "throw-off." Figure 19 illustrates a normal method of lubricating the universal joints with a hand lever pressure gun. These joints frequently operate at high rotating speed and under heavy pressures. Depending upon whether the universal joint casing is an open type, a needle bearing type, or an inclosed type, the lubricant required may be a fluid or a semifluid.

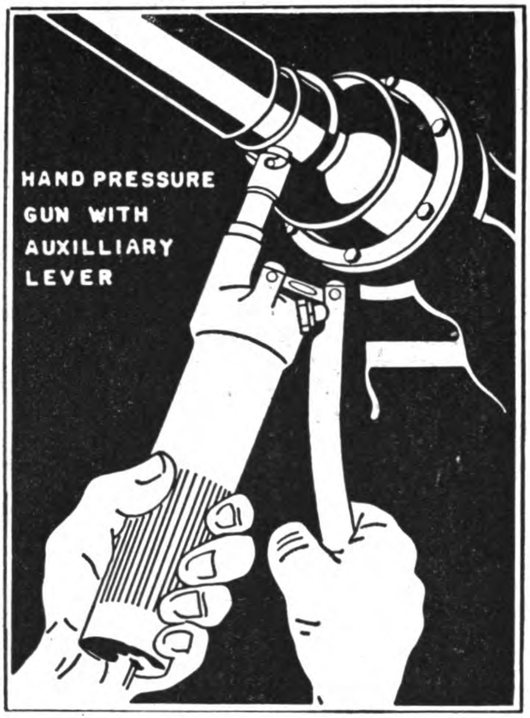


FIGURE 19.—Lubrication of universal joints with hand-pressure gun.

(2) Figures 20, 21, and 22 show types of universal joints in common use and indicate the lubricant required.

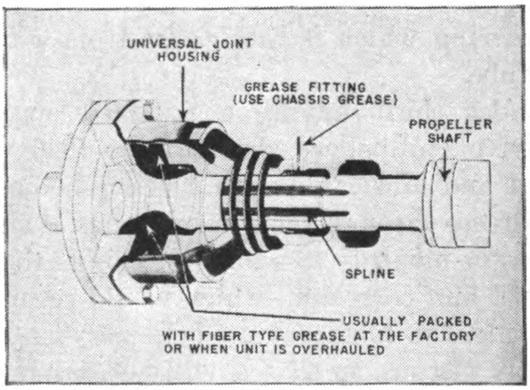


FIGURE 20.—Lubrication of inclosed universal joint.

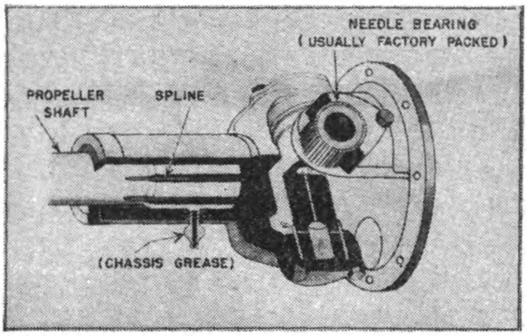


FIGURE 21.—Needle bearing type universal joint packed with fibrous grease.

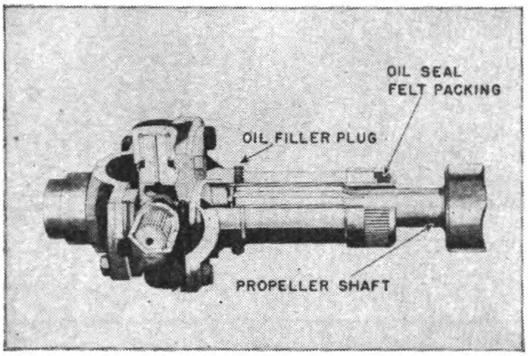


FIGURE 22.—Oil sealed type universal joint using heavy-bodied fluid lubricant.

36. Steering gear lubrication.—Steering gears require a pressure resistant lubricant because the heavy pressures and the slow sliding motion of the surfaces in contact tend to scrape off any film of lubricant and cause metal-to-metal contact. The usual method of lubricating the working parts is to fill the inclosed oil-tight steering gear housing so that the teeth and spirals are coated at all times with a gear lubricant (fig. 23).

37. Axle lubrication.—*a. Dead axle.*—The dead axle, that is, the I-beam or tubular type without any final drive mechanism, is an important part requiring lubrication. As a rule, grease fittings are installed at the various points requiring lubrication, including the steering gear connecting rod (drag link), ball joint connections, and steering knuckle pivots (king pins). These grease fittings or nipples should be lubricated approximately every 1,000 miles. A pressure grease gun is normally used for forcing the grease—either semifluid No. 0, soft No. 1, or medium No. 2, according to climatic temperature—into the various fittings. Figure 24 illustrates lubrication of a typical front, dead, nondriving axle.

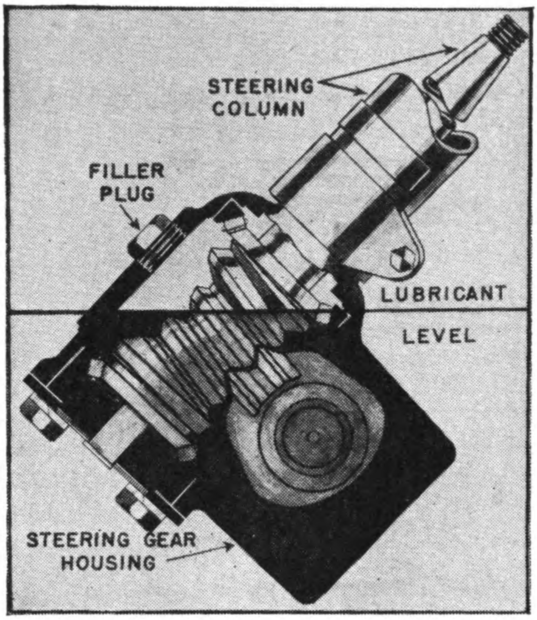


FIGURE 23.—Steering gear lubrication.

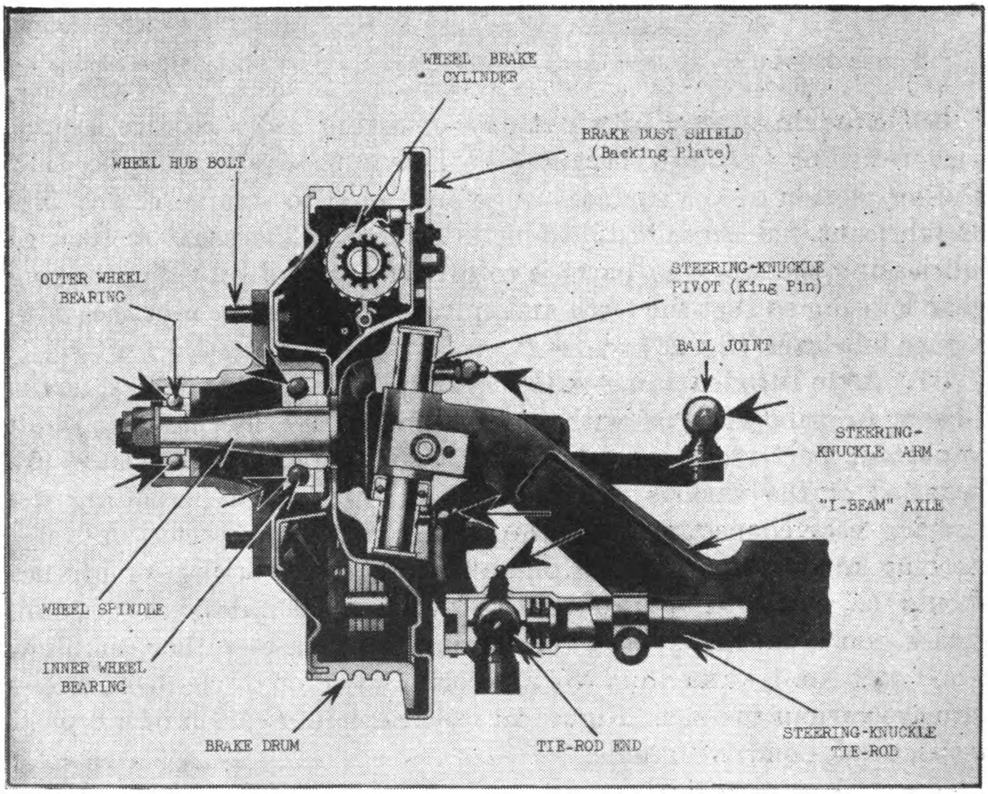


FIGURE 24.—Lubrication of dead axle (heavy arrow heads show points requiring lubrication).

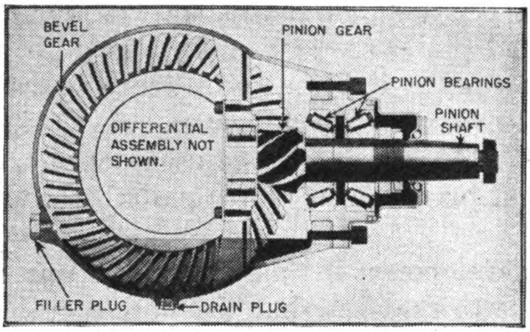
b. Live axle.—(1) A live or driving axle usually consists of an oil-tight axle housing designed to hold the final drive mechanism (driving and differential gears, axle shafts, and bearings) in position. In the ordinary bevel pinion, worm, or spur gear driven type of live axle, it is common practice to use an ordinary gear lubricant having an SAE 90 or 140 viscosity for winter and SAE 140 or 250 for summer. However, the exact grade to be used depends essentially upon the clearances and pressures involved and whether the unit is light or heavy duty.

(2) A recent development in final drive mechanisms is the "hypoid gear drive." Due to the fact that the pinion gear in this drive is below the centers of the axle shaft and the differential gear assembly, the forces and pressures between the teeth surfaces during contact are much higher than in the ordinary final drive. This necessitates a specially compounded lubricant known as a hypoid gear or powerful E.P. (extreme pressure) lubricant. (See pars. 11*b* and 29*b* (6).) For winter use either SAE 80 or SAE 90 hypoid lubricant may be desirable, but only SAE 90 hypoid lubricant should be used for extremely warm temperatures. Whether a mild or powerful type E.P. lubricant should be used depends on the manufacturer's recommendations.

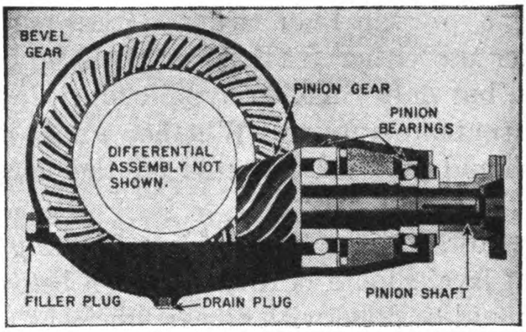
(3) Figure 25 shows various types of live (driving) axles. In each type the lubricant level should be about ½ inch below the filler plug. Axle housings should be filled with a gear lubricant to within ½ inch of the filler plug opening, which depth is sufficient for the moving gears to dip into the lubricant and still prevent it from overflowing due to heat expansion. Live axle housings should not be filled to too high a level, because the lubricant when expanded by frictional heat tends to break through the seals at the outer end of the axles and leak or seep onto brake linings.

c. Wheel bearings.—Wheel bearings, because of general design and installation practices, are not lubricated from the axle housing by the lubricant used in live axles. (See par. 38.)

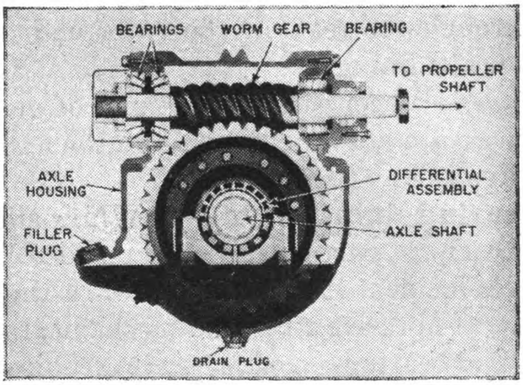
38. Wheel bearing lubrication.—*a.* While sliding friction is present in wheel bearings, particularly in tapered roller bearings, the forces and pressures incident to rotating and thrusting actions require lubrication to prevent abrasive wear and mechanical failures in races, cones, cages, balls and bearings. Surfaces also require protection from moisture and dirt. The high speed of wheel bearings tends to create great heat. The method of lubrication employed depends entirely upon the particular design of the unit in which the bearings are used. Wheel bearings are practically always hand or machine packed with a



① Bevel and pinion gear type.



② Hypoid gear type.



③ Overslung worm gear type.

FIGURE 25.—Live (driving) axles.

fibrous type grease, usually Medium No. 2 and Hard No. 3, because the adhesive qualities of this type of grease enable it to withstand rotary speeds. Figure 26 shows wheel bearing points requiring lubrication.

b. Great care must be exercised in lubricating wheel bearings to avoid forcing the seals and pushing excess grease through the axle hub end onto the brake linings. Grease on brake linings usually results in braking troubles. For this reason, pressure guns should not be used.

c. Universal joints (Rzeppa or Bendix Weiss front steering joints) in live front axles are usually lubricated through a filler plug in the upper steering knuckle pivot or near it in the universal joint housing. The level of the lubricant can be checked by removing another plug in the side of the housing near or below its center.

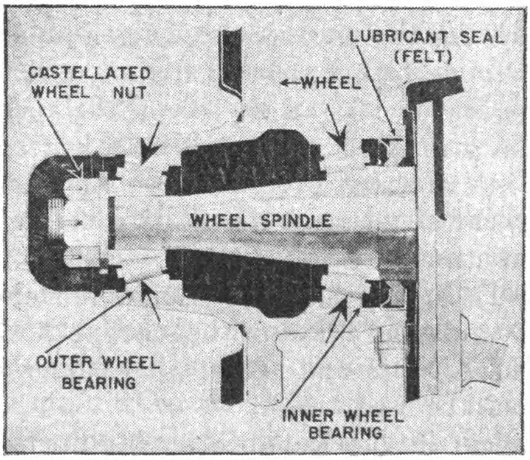


FIGURE 26.—Wheel bearing lubrication (points of lubrication shown by heavy arrows).

(1) A No. 0 grease should be used for temperatures of 0° F. or below; No. 1 for temperatures from 0° to 32° F., and No. 2 for temperatures above 32° F.

(2) Some models of the Rzeppa joint are lubricated through a rifle-drilled hole in the axle stem, and SAE No. 140 gear oil should be used in summer and SAE No. 90 gear oil in winter.

d. Wheel bearings should be cleaned thoroughly and the lubricant replaced seasonally, that is, every 6 months (usually spring and fall of each year).

39. Spring, shackle, and shock absorber lubrication.—*a. Springs.*—(1) *Coil.*—As a rule, the coil spring used in some "knee action" or independent springing devices requires no lubrication. However, if a coil spring is inclosed in a housing, the housing should usually be filled with an oil recommended by the manufacturer. This is usually a shock absorber oil. The inclosed type coil spring, however, is being replaced by the exposed or open coil type. The linkages of this latter type, as a rule, are lubricated with chassis grease.

(2) *Multiple leaf.*—(*a*) These springs, which are lubricated at the factory, present no particular problems in lubrication, especially if they are covered with a metal or canvas cover. They should be inspected for lubrication approximately every 6,000 miles or periodically, usually in the spring and fall of each year. Metal covers are sometimes equipped with grease gun fittings for lubrication.

(*b*) Uncovered leaf springs are lubricated during manufacture with a graphite compound or a similar substance that lasts for approximately 10,000 miles. Various methods of lubricating uncovered flat springs are used. One involves the use of a fluid graphited lubricant that will flow between the surfaces of the spring leaves. Another method of lubricating the uncovered spring is to remove the entire spring from the vehicle, take it apart, and apply a mineral oil graphite paste between the leaves. As an expedient, the spring leaves can be pried apart and a graphited grease lubricant spread between them; however, as this is a laborious procedure and tends to change the "set" or curve of the springs and make them "hard riding", this procedure should not be a routine practice.

b. Shackles.—(1) Spring shackles should be lubricated approximately every 1,000 miles, as a part of the scheduled chassis lubrication. Usually, No. 0, No. 1, No. 2, and perhaps in extremely warm climates, No. 3 greases should be used.

(2) Shackle pivots are lubricated through a fitting on one end. If the lubricant cannot be forced through, the shackles are either rusty or clogged with dirt, hardened grease, or foreign matter. In this case it will be necessary to "rock" the vehicle by using a pry bar or some other tool to break up the obstruction. In extreme cases where the lubricant cannot be forced through in spite of all such efforts, it is necessary to dismantle the shackle completely and clean the shackle pin and its housing.

(3) Rubber shackles should not be lubricated with oil because it will rot the rubber. Should rubber squeaks develop, the shackles should be painted with hydraulic brake fluid.

c. Shock absorbers.—Shock absorbers are frequently neglected in lubrication. Greases used in the outside fittings or on outside surfaces of shock absorbers should be the same grade as those applied to shackles. However, when rubber insulators are used on shock absorber arms (no grease fittings in place), it is best to spray the contact places with brake fluid to eliminate squeaks and avoid deterioration of the rubber. The hydraulic type shock absorber which depends upon the action of a fluid in its cylinder or cylinders usually requires a special shock absorber liquid. Due to low viscosity index, the use of a regular lubricating oil is inadvisable. The shock absorber should be thoroughly cleaned around the filler hole before refilling.

40. Brake lubrication.—As a rule, brakes require no lubrication. However, the type of brake in which the brake shoes are pivoted on fixed anchor pins or movable cam levers must be lubricated to prevent rust from forming and hindering the movements involving brake shoe slots, anchor pins, and cam levers. This type of brake should be lubricated with a light engine oil. Sometimes, however, a thin film of semifluid or medium graphited grease, as used between spring leaves, may be required for cam levers and brake shoe location points. Care must always be exercised to prevent the lubricant from coming in contact with brake shoe linings, as brakes become ineffective and fail to function properly when greasy or oily. Brakes requiring lubrication should be included in the regular chassis lubrication scheduled for every 1,000 miles. All brake pedal and lever pivots should be lubricated as fittings indicate. Brake cables operating in conduits should be removed, cleaned, and relubricated seasonally to prevent sticking. Some brake cable conduits are equipped with fittings for pressure lubrication.

41. Generator, starter, and distributor lubrication.—In regularly scheduled lubrication, 2 or 3 and not more than 8 or 10 drops of a light nongumming machine oil or engine oil should be sufficient in these electrical units when they are fitted with oil cups. When a light machine oil is not available, use SAE 10 W to SAE 30 engine oil as recommended by the manufacturer. Occasionally, especially on a distributor driving shaft, a screw down type grease cup may be found. Grease of either grade soft No. 1 or medium No. 2 should be used in this fitting, and the filler cap should be screwed down one-half to one turn about once each week.

42. Water pump lubrication.—Water pumps present no particular difficulties in lubrication. In the packless types using oilless bearings, no lubrication is required. When there is a water leak in the water pump, the entire bearing and sealing unit must be replaced. In the comparatively rare type of water pump where oil cups are installed on the water pump shaft housing, a fluid lubricant will be found satisfactory as a lubricant does not normally make contact with the water. In the type of water pump where screw down cups or other types of grease fittings are used, a water resistant lubricant having a melting point of 200° F. (minimum) should be used. This is especially true of designs where the bearings are placed so that the lubricant comes in contact with the water pump seal, where it might enter the cooling system. Water pumps should be lubricated approximately every thousand miles or during the regularly scheduled chassis lubrication.

43. Hoist and winch lubrication.—*a.* In the most modern power-driven winches, it is common practice to use a heavy motor oil or a gear lubricant in the gear case. These units should be checked for lubrication through the side filling plug opening for transmission and transfer cases (par. 34). The universal joints of the drive shaft in these units should be lubricated in the same manner as any other similar propeller shaft and universal joints (par. 35). Lubrication fittings installed on the outside bearings of winches and hoists should be lubricated with grease at the same time the other chassis parts are lubricated. The lubrication of other parts of the hoist mechanism should be included as a part of the regular chassis lubrication.

b. It is advisable to consult the manufacturer's handbook for the specific details of lubricating this equipment.

44. Hardware and lock lubrication.—Door handles, door hinges, window regulators, locks, and similar hardware usually require little lubrication. A stick of solid lubricating tallow wax should be used for rubber door stops and striker plates. However, in the absence of such a special lubricant, door hinges and other hardware, except cylinders of locks, may be lubricated with a light, nongumming oil approximately once every 6 months, or oftener if necessary. Powdered graphite should be blown into lock cylinders. Lock cylinders that are gummed usually can be freed by squirting carbon tetrachloride (fire extinguisher chemical) into the key hole. After they are clean, they should be lubricated with powdered graphite. Window regulator mechanisms should be cleaned and lubricated with a nonhardening grease and graphite compound, if they are difficult to operate.

45. Other units requiring lubrication.—*a. Special equipment.*—Detailed lubrication of a vehicle will depend upon its equipment and accessories. Operating linkages and controls of special equipment have numerous points of friction which require a lubricant.

b. Vacuum operated units.—The vacuum cylinders used in booster systems for brake and clutch operation are usually fitted with pistons having a leather seal. Most manufacturers recommend that about an ounce of shock absorber fluid be added to these units every 15,000 miles to keep the seal soft and pliable.

c. Air compressors.—Air compressors on motor vehicles may be driven from a belt, a gear, or a shaft from the engine or transmission.

Some compressors have a self-contained lubrication system while others, which are oiled from the engine lubricating system or the transmission, require no special attention. Compressors having self-contained lubricating systems should be checked monthly or every 1,000 miles and lubricant added if needed, or drained every 6 months (or 6,000 miles) and refilled with a good summer or winter grade engine oil depending on the season.

d. Slack adjusters.—Brake slack adjusters on air brake systems should be taken apart once a year, thoroughly cleaned, and filled with a soft No. 2 grease.

e. Small electric motors.—Heater motors should be serviced at the beginning of each winter season. Four or five drops of a light, non-gumming oil on each armature bearing are usually sufficient. Other small accessory unit motors should be checked and serviced monthly.

f. Windshield wipers.—(1) These are usually self-contained units. If motor driven, the gear case is packed with a soft grease and only requires lubrication when repaired.

(2) All windshield wiper linkages require 2 or 3 drops of light oil each season or oftener during frequent use. The shaft, where it leaves the housing, should be checked frequently for indication of rust, and cleaned and oiled if necessary.

g. Window glass channels.—Glass channel felts often become hardened or glazed on the surface and cause squeaks, or the glass sticks as it is raised or lowered. This can be overcome by rubbing the surfaces of the channel felt with a thin block of paraffin wax.

h. Cowl ventilator.—Adjustments and linkages of cowl ventilators often become hard to operate, and squeak. Points of wear should be coated with a soft grease.

i. Operating linkages and control lever pivots.—(1) All clevis pins or lever pivots which have movement between two or more interconnected or adjacent parts should be lubricated with a few drops of oil each time the vehicle is given a 1,000-mile lubrication.

(2) Carburetor linkage of the ball and socket type should be lubricated each 6,000 miles or every 6 months, using a small amount of No. 0 or No. 1 chassis grease. All excess oil and grease should be removed to prevent the accumulation of dust and dirt.

SECTION VII

LUBRICATION SCHEDULES AND CHARTS

46. General.—*a.* No specific rules for lubrication can be given that are universal in their application. For this reason, only general rules can be given. These general rules, however, will serve as safe guides in the absence of definite information or data from the manufacturer.

b. To assist in establishing lubrication schedules and in selecting types of lubricants for various points of lubrication, a lubrication schedule and guide chart are given in appendixes I and II. The chart, in the absence of other instructions, can be used in an emergency; however, correct lubrication information should be promptly obtained from authoritative sources such as the manufacturer, a local dealer of known repute, or others.

47. Lubrication schedule.—Lubrication may be considered on two different bases: time and mileage. However, based on the Army maintenance system, time is so interwoven with mileage that choosing between the two depends on whether the time basis or mileage basis is reached first. For convenience, the following subdivisions are made:

a. Time lubrication.—(1) *Daily.*—This must always be a first echelon maintenance duty, that is, the responsibility of the driver. Essentially, this anticipates a frequent (at least once every day while operating) check of the oil in the engine crankcase for quantity, quality, and condition. The driver should be required to check the quantity of the engine crankcase oil (bayonet gage level) before he starts to operate the vehicle, after the completion of the day's run, and at various halts on long trips or march convoys. In addition to engine lubrication, he should be required to make daily reports of squeaks, unusual noises, or any other conditions that indicate a lack of lubrication. The driver's performance of this responsibility should be frequently checked by a noncommissioned officer specifically charged with this duty in his capacity as squad or section leader, truck master, chief mechanic, or motor sergeant.

(2) *Periodic.*—Periodic lubrication is required primarily for such units as wheel bearings, driving axle housings, transmission and transfer case mechanism, and winch gear housings. It is good practice to perform this lubricating work just before placing vehicles in storage, or every 6 months, or just prior to any maneuver or exercise period.

b. Mileage lubrication.—(1) The mileage basis, usually 1,000 miles of ordinary operation, provides for all checking and lubrication when necessary at intervals longer than the daily routine. A chart system for follow-up on a basis of miles operated is generally used. During field service operations, the usual rule is to have this lubrication done by the driver of the vehicle as part of his first echelon responsibilities. Under severe operating conditions, the mileage basis should be reduced to 500 miles or even daily in some instances.

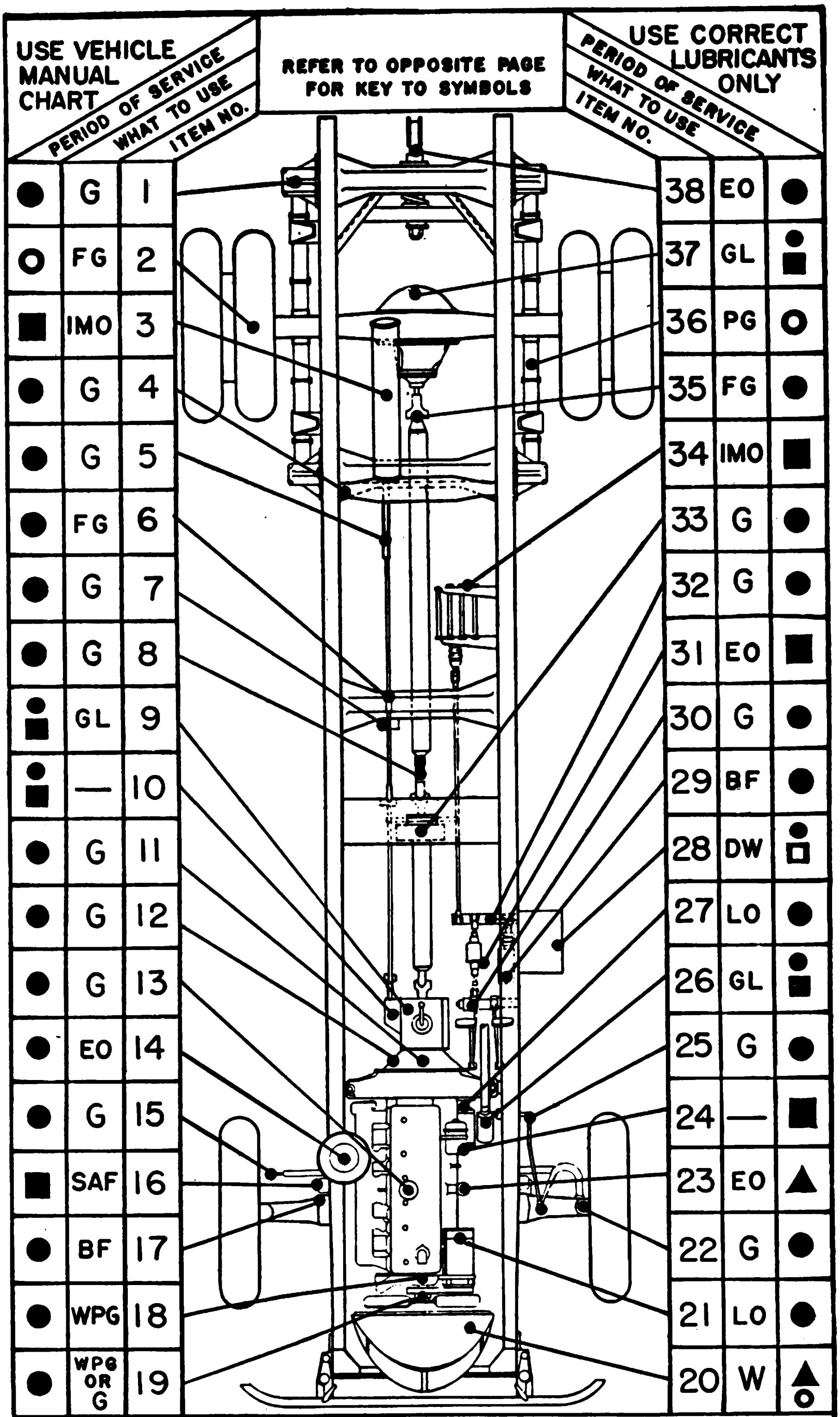
(2) (*a*) Vehicles subjected to stream crossings or operation in flood areas should be inspected as soon as possible after submersion to determine whether or not water has entered the rear axle, gear cases, or engine. All units having water in them should be thoroughly drained and new lubricant added.

(*b*) Vehicles stored in damp areas for any length of time with the vehicle weight on the wheels, or shipped by carrier for any great distance, should have the wheel bearings inspected for rust formation along the line of roller contact or for rough creases in the bearing cups.

(3) In some cases, especially in garages at permanent posts, camps, and stations, this lubrication work may be made the responsibility of mechanics or noncommissioned officers; the use of detailed personnel to perform mileage lubrication may be advisable. The date of completion and the unit or part lubricated should be noted as a matter of record.

Appendix I

GENERAL LUBRICATION AND SERVICE CHART



GENERAL LUBRICATION AND SERVICE CHART

A GENERAL LUBRICATION AND SERVICE CHART

THIS "LUBRICATION AND SERVICE CHART" DOES NOT APPLY TO ANY SPECIFIC MAKE OR MODEL OF VEHICLE AND SHOULD BE USED ONLY AS A GENERAL GUIDE FOR THE LUBRICATION OF VEHICLES OPERATING UNDER NORMAL CONDITIONS.

KEY TO SYMBOLS

PERIOD OF SERVICE

▲ --- DAILY

□ --- TWO WEEKS

● --- MONTHLY OR 1000 MILES

■ --- EVERY 6 MONTHS OR 6000 MILES

○ --- SEASONAL SPRING AND FALL

NOTE: OFTENER DURING PERIODS OF UNUSUAL SERVICE

WHAT TO USE

"BF" HYDRAULIC BRAKE FLUID	"IMO" ICE MACHINE OIL
"DW" DISTILLED WATER	"LMO" LIGHT MACHINE OIL
"EO" ENGINE OIL	"LO" LIGHT OIL (NON GUMMING)
"FG" FIBER TYPE GREASE	"P" PETROLATUM (VASELINE)
"G" CHASSIS GREASE (OR LUBE)	"SAF" SHOCK ABSORBER FLUID
"GL" GEAR LUBRICANT	"W" WATER (OR ANTIFREEZE)
"—" NOTHING	"WPG" WATER PUMP GREASE

"PG" VASELINE-GRAPHITE OR GRAPHITED GREASE

FOR DETAILS OF EACH ITEM REFER TO APPENDIX II

Appendix II

GENERAL SERVICING AND LUBRICATION CHECK SHEET

1. The tabulation following, which is to be used only under normal operating conditions, is based essentially on the vehicle chart shown in appendix I. It is general in nature and cannot be applied in detail to any specific make or model of vehicle. It can be used for developing a systematic procedure and a method of recording all servicing and lubrication.

2. *a.* Column (1), Item number, shows the number used on the vehicle chart in appendix I. Where no number is shown in this column, the described item is not shown on the vehicle chart.

b. Column (2), Description of item, shows details of various items and special notations to cover the unusual. All possible combinations cannot be covered, so in case of doubt always consult the manufacturer's manual.

c. Column (3), What to use, is intended as a general guide only. Again, it is advisable to consult the manufacturer's manual with regard to a specific vehicle.

d. Column (4), U. S. A. Reg. No., can be used for recording the service and lubrication performed by having the responsible individual check opposite each item and under the vehicle number as the work is finished.

3. This form can be altered and developed to provide a schedule and check sheet for either an individual vehicle or a group of them and to cover the different items under the various periods (2 weeks, monthly, 6 months, and seasonal). The daily items should be a responsibility of the drivers as a part of their first echelon maintenance.

▲ DAILY

(1) Item number (see appendix I)	(2) Description of items	(3) What to use	(4) U. S. A. Reg. No. W-0	W-00	W-000
20	*Radiator (cooling system)*— Check and fill as needed to about 1 inch from top. If alcohol is used as antifreeze, check specific gravity daily.	Ordinary water from faucet or stream. Use antifreeze when weather demands.	----	------	------
23	*Engine crankcase*— Check oil level by means of bayonet gage and add oil if needed.	Engine oil----------	----	------	------
	Vehicle fuel tank— Check quantity of fuel and add, if necessary.	Gasoline------------	----	------	------

☐ EVERY 2 WEEKS

(1) Item number (see appendix I)	(2) Description of items	(3) What to use	(4) U. S. A. Reg. No. W-0	W-00	W-000
28	*Battery*— Check water level and add if needed to keep water ½ inch above top of plates.	Distilled water------	----	------	------

● MONTHLY OR EVERY 1,000 MILES

(1) Item number (see appendix I)	(2) Description of items	(3) What to use	(4) U. S. A. Reg. No. W-0	W-00	W-000
1	*Spring shackles (all)*— Right and left, front and rear. If rubber type use brake fluid to eliminate squeaks.	Grease-------------	----	------	------
	Coil springs— Inclosed (independent wheel springing or knee action). Check and add engine oil if needed.	Engine oil----------	----	------	------

● MONTHLY OR EVERY 1,000 MILES—Continued

(1) Item number (see appendix I)	(2) Description of items	(3) What to use	(4) U. S. A. Reg. No. W-0	W-00	W-000
	Independent wheel; springing linkage— (Use engine oil at surface contact points if no fittings are installed.)	Grease	----	------	------
	Brake anchors and cam pivots— If no fittings are provided use engine oil.	do	----	------	------
4	*Hoist cylinder trunnion*	do	----	------	------
	Winch worm gear case— Check and add lubricant as required.	Gear lubricant	----	------	------
	Winch parts— Where grease fittings are installed.	Grease	----	------	------
5	*Splines, hoist, or winch propeller shaft.*	do	----	------	------
6	*Universal joints, hoist, or winch propeller shaft.*	Fiber type grease	----	------	------
7	*Center or other bearings, hoist or winch propeller shaft.*	Grease	----	------	------
8	*Spline, propeller shaft*	do	----	- -	------
9	*Transmission (and transfer case)*— Check and add lubricant to ½-inch of filler plug level.	Gear lubricant	----	------	------
10	*Power take-off*— Usually lubricated by overflow from transmission to which it is attached. If a separated unit, check and add lubricant to ½ inch of filler plug level.	do	----	------	------
	Clutch pilot bearing— Usually prepacked at factory; no lubricant required until clutch is overhauled. Grease if lubricant fitting is provided.	Grease	----	------	------

● MONTHLY OR EVERY 1,000 MILES—Continued

(1) Item number (see appendix I)	(2) Description of items	(3) What to use	(4) U. S. A. Reg. No. W–0	W–00	W–000
11	*Clutch release (throw-out) bearing*— If packed at factory and no lubricant fittings are provided, it should be lubricated only when overhauled.	do			
12	*Clutch release (throw-out) shaft*— If no lubricant fittings are provided, this shaft is fitted with oilless bearings and requires no lubrication.	do			
13	*Ignition distributor*— If oil cups are provided, use light, nongumming oil as lubricant.	do			
14	*Air cleaner*— Remove filter element and clean, then saturate with oil.	Engine oil			
	Oil bath air cleaner— Remove, clean, and refill. See instruction on cleaners.	do			
15	*Steering gear tie rod ends, right and left.*	Grease			
17	*Shock absorber linkage*— If rubber cushioned, grease or oil should not be used.	Brake fluid			
18	*Water pump*	Water pump grease			
19	*Fan assembly*— If part of water pump assembly, use water pump grease.	Grease			
21	*Generator*	Light, nongumming oil or SAE 10W engine oil.			
22	*Steering knuckle pivots (king pins), right and left.*	Grease			
25	*Steering gear, connecting rod*	do			

● MONTHLY OR EVERY 1,000 MILES—Continued

(1) Item number (see appendix I)	(2) Description of items	(3) What to use	(4) U. S. A. Reg. No.		
			W-0	W-00	W-000
	Steering gear column top bearing— Usually packed at factory and requires lubrication only when overhauled.	do			
26	*Steering gear case*— Check and add necessary lubricant.	Gear lubricant			
27	*Starting motor*	Light, nongumming oil.			
28	*Battery*— Clean terminals, when necessary, using a solution of baking soda and water to remove corrosion. Coat terminals with petrolatum (vaseline) and tighten. Add distilled water if necessary.	Solution of baking soda and water; petrolatum (vaseline).			
29	*Brake (hydraulic); master cylinder*— Check and add needed brake fluid. Level in cylinder must not drop below halfway mark.	Brake fluid			
30	*Brake and clutch pedal linkage, rods, shafts, and cams*— If lubricant fittings are not provided, use engine oil.	Grease			
32	*Master cylinder cross shaft*	do			
33	*Center bearing, propeller shaft*	do			
35	*Universal joints, propeller shaft.*	Fiber type grease			
37	*Live (driving) axle, differential*— Check and add necessary lubricant to ½ inch of filler plug level.	Gear lubricant			
38	*Pintle hook*	Engine oil			

■ EVERY 6 MONTHS OR 6,000 MILES

(1) Item number (see appendix I)	(2) Description of items	(3) What to use	(4) U. S. A. Reg. No. W-0	W-00	W-000
3	*Hoist cylinder*— Check oil in cylinder. Add more if needed. If oil is too thin or dirty, drain and replace.	Ice machine oil			
	Winch worm gear case— Drain lubricant and refill	Gear lubricant			
9	*Transmission (and transfer case)*— Drain lubricant and refill. Fill to ½ inch of filler plug level.	do			
10	*Power take-off unit*— Usually attached to and lubricated from transmission. If separate unit, drain old lubricant and fill with new to ½ inch of filler plug level.	do			
16	*Shock absorbers (all), right and left, front and rear.*	Shock absorber fluid			
24	*Oil filter*— If nonreplaceable filter element; clean thoroughly. If filter element is replaceable type, install new one on 8,000-mile basis.	None			
26	*Steering gear case*— Drain and refill	Gear lubricant			
31	*Booster external air valve filter*— Clean and wash. Saturate filter element with oil.	Engine oil			
34	*Vacuum booster cylinder*— Remove plug and pour in 2 ounces of oil.	Ice machine oil			
37	*Live (driving) axle, differential*— Drain and refill. Fill to ½ inch of filler plug level.	Gear lubricant			

● SEASONAL (spring and fall)

(1) Item number (see appendix I)	(2) Description of items	(3) What to use	(4) U. S. A. Reg. No. W–0	W–00	W–000
20	*Radiator—* Drain, flush, and refill. Chemical cleaners may be necessary to remove excessive rust and scale deposits. Only noncorrosive cleaners should be used in aluminum core radiators.	None	----	------	------
2	*Wheel bearings (all), right and left, front and rear—* Remove each individual wheel; clean hub bearing cones and other items. Pack and replace assembly.	Fiber type grease	----	------	------
36	*Multiple leaf springs (all), right and left, front and rear—* Check and, if necessary, remove each spring, separate leaves, clean off rust, and coat with lubricant. Reassemble spring and reinstall on vehicle.	Vaseline-graphite, or graphited grease.	----	------	------

Appendix III

LIST OF REFERENCES

T. C. Thomsen, "The Practice of Lubrication"—Third Edition, New York, N. Y.: McGraw-Hill Book Company, 1937.

"Lubrication"—New York, N. Y.: The Texas Company.

J. Howard Pile, "Service Man's Guide to Automotive Lubrication"—Fifth Edition, Chicago, Ill.: The Chek-Chart Corporation, 1938.

J. F. Winchester, "Automotive Money-Saving Facts"—New York, N. Y.: Traffic Publishing Company, 1936.

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By order of the Secretary of War:

G. C. MARSHALL,
Chief of Staff.

Official:
E. S. ADAMS,
Major General,
The Adjutant General.

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