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DEPARTMENT OF THE ARMY TECHNICAL MANUAL

LUBRICATION OF ORDNANCE MATERIAL

HEADQUARTERS, DEPARTMENT OF THE ARMY

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No. 9-273

HEADQUARTERS,
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LUBRICATION OF ORDNANCE MATERIEL

***This manual supersedes TM 9-2835, 11 May 1949; TB 9-2835-1, 18 December 1951, including Changes No. 1, 20 August 1952; and TB 9-2835-13, 17 July 1952.**

CHAPTER 1
INTRODUCTION

1. Purpose

This manual is published to give information on lubrication to Ordnance personnel. Since lubrication is basic to the Department of the Army Preventive Maintenance program, essential concepts are given to show the necessity for proper lubrication of Ordnance materiel.

2. Scope

a. Chapters 2 through 4 discuss the elements of friction, lubrication, bearing surfaces, and the manufacture and properties of lubricants. Chapter 5 deals with the equipment used to lubricate, while chapters 6 through 12 discuss the lubrication of typical Ordnance materiel. Pertinent technical manuals and lubrication orders should be consulted for specific materiel. In chapters 13 through 15, the effect of weather on lubrication, extended uses of lubrication materials, and Department of the Army publications, pertinent to lubrication, are presented.

b. The appendix contains a list of current references, including supply manuals, technical manuals, forms, and other available publications applicable to lubrication.

c. This manual differs from TM 9–2835, 11 May 1949, as follows:

(1) New ideas on friction and lubrication theories have been added.
(2) Additions on the materials, construction, and lubrication of bearings have been made.
(3) Lubricants, used by Ordnance, have been tabulated.
(4) The manufacture of lubricants has been added.
(5) The properties of lubricants are discussed.
(6) The reasons for additives to lubricants are shown.
(7) Nonpetroleum lubricants are disclosed.
(8) Material on the specialized lubrication of new equipment such as radar, missiles, and instruments has been added.
(9) Lubrication information on small arms and artillery has been expanded.
(10) New material, in keeping with the advances of automotive equipment, has been added.
(11) New forms of lubrication orders are shown and discussed.
(12) Additional references are made.
(13) Several subjects, appearing in TM 9–2835, not relative to lubrication, have been omitted.
(14) Some references, because of obsolescence, have been eliminated.
(15) Materials, no longer used, are not discussed.

d. Any errors or omissions will be forwarded on DA Form 2028 direct to the Commanding Officer, Raritan Arsenal, ATTN: ORDJR–OPRA, Metuchen, N. J.

Note. Specifications and standards used by the Department of the Army are listed in the Department of Defense Index of Specifications and Standards, which is comprised of three separate parts: Part I, Straight Alphabetical Listing; Part II, Numerical Listing; and Part III, Federal Supply Classification Listing. Copies of specifications and standards may be requisitioned in accordance with this Index.

CHAPTER 2
FUNDAMENTALS OF FRICTION AND LUBRICATION

Section I. FRICTION

3. General

Lubrication is the act of applying lubricants and lubrication substances which are capable of reducing friction between moving mechanical parts. Since modern materials are designed to utilize lubrication for obtaining proper functioning, it is a most vital type of preventive maintenance.

4. Nature of Friction

Natural laws say that bodies will remain at rest or in motion unless acted upon by forces large enough to change these conditions. Consider a block of steel at rest on a concrete floor. It will not move until forces greater than those which hold it at rest influence it. Natural forces acting on the block are gravity and friction. Gravity is measured by the weight or mass of the block acting downward. Friction is a force acting between the contacting surfaces of the block and the floor. It is a direct result of the surface conditions of the block and the floor. If these surfaces are smooth or rough, hard or soft, wet or dry, the amount of friction will change.

5. Definition of Friction

a. All surfaces, no matter how smooth they may appear to the unaided eye, when sufficiently magnified are rough and uneven (fig. 1). Friction is the resistance to relative motion between two bodies in contact. This resistance or drag between the surfaces of bodies in contact retards or prevents them from moving in relation to one another. When vehicle 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 axle housings, retards movement of the wheels. When a clutch is engaged, the frictional drag existing between the driving surface and the driven surface prevents these surfaces from slipping and makes them move together as a unit. Friction absorbs power and generates heat in proportion to the amount of effort required to overcome it. When a sled is drawn over a dry pavement, friction occurs between the runners and the ground. The drag is apparent. The sled runners will be warm, indicating that heat has been generated.

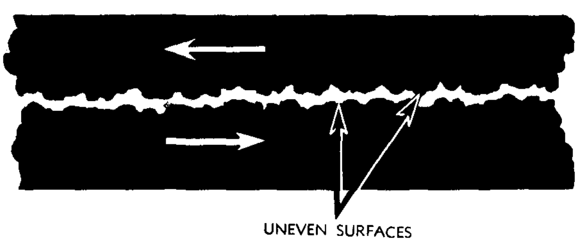


Figure 1. Magnified view of two surfaces in contact.

b. Coefficients or factors of friction between surfaces have been determined for many materials. The larger these coefficients are, the larger is the force of friction between surfaces that must be overcome. Some typical values are shown in table I.

Table I. Coefficients of Friction (Sliding)

Materials	Dry	Greasy
Hard steel on hard steel	0.42	0.09
Hard steel on babbit	0.35	0.07
Mild steel on mild steel	0.57	0.12
Mild steel on phosphor bronze	0.34	0.17
Brass on mild steel	0.53	0.12
Glass on glass	0.40	0.09
Cast iron on cast iron	0.35	0.07
Bronze on cast iron	0.22	0.07
Laminated plastic on steel	0.35	0.05

6. Types of Friction

a. Friction of Rest and Friction of Motion. Before any body at rest can be moved, sufficient force must be applied to overcome its inertia and the friction between it and the surface with which it is in contact. This is static friction or friction of rest. After the body is once in motion it can be kept in motion by expending sufficient energy to overcome the friction between it and the surface with which it is in contact. This is kinetic friction or friction of motion. Static friction which must be overcome to put any body in motion, is greater than knietic friction, which must be overcome to keep the body in motion after it is started. This fact is illustrated in figure 2 which shows a man exerting himself to start a body in motion, but another man pushing it easily after it is once in motion. The force of friction always acts in the opposite direction to the motion and always reduces the effectiveness of the force moving the body. Its magnitude is dependent upon the weight of the body and the coefficient of friction for the two surfaces in contact. Frictional force is not influenced by area dimensions. A brick building block sliding on its small flat end will require the same force to move it as if it were sliding on its large flat side.

b. Sliding Friction. Sliding friction (fig. 3) results when the surface of one solid body is moved on the surface of another solid body.

c. Rolling Friction. Rolling friction (fig. 4) results when a curved body such as a cylinder or sphere rolls upon a flat or curved surface. In his early existence, man discovered that if rollers or wheels were used, a considerable part of the force necessary to move objects against sliding friction was eliminated; thus rolling friction was utilized to save labor.

d. Fluid Friction. Man also discovered in his early existence that the force required to overcome fluid friction (fig. 5) was less than the force required to move the same body if either sliding or rolling friction had to be

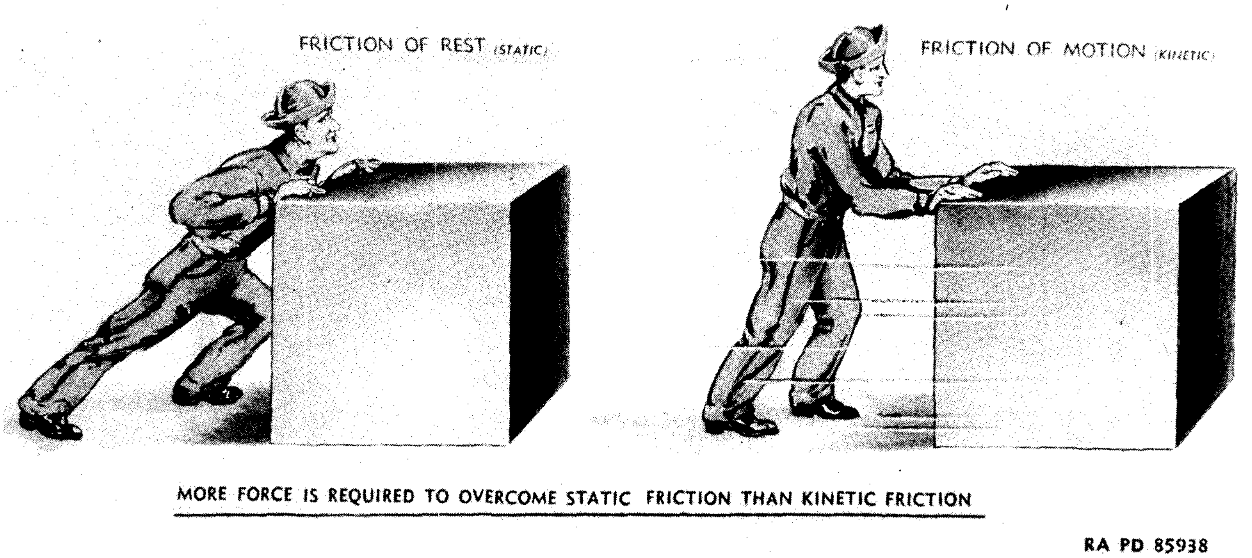


Figure 2. Friction of rest and friction of motion.

overcome. Fluid friction is the resistance to motion set up by the (*cohesive*) action between particles of a fluid and the (*adhesive*) action of those particles to the medium which is tending to move the fluid. For example, if a paddle is used to stir a fluid, the cohesive force between the molecules of the fluid will tend to hold the molecules together and thus prevent the motion of the fluid. At the same time, the adhesive force of the molecules of the fluid will cause the fluid to adhere or stick to the paddle and thus create friction between the paddle and the fluid.

7. Cohesion and Adhesion

a. Cohesion and Adhesion Defined. Cohesion is the molecular attraction between like particles throughout a body or the force that holds any substance or body together. Adhesion is the molecular attraction existing between surfaces of bodies in contact or the force which causes unlike materials to stick together. From the standpoint of lubricants, adhesion is the property of a lubricant that causes it to stick or adhere to the parts lubricated, while

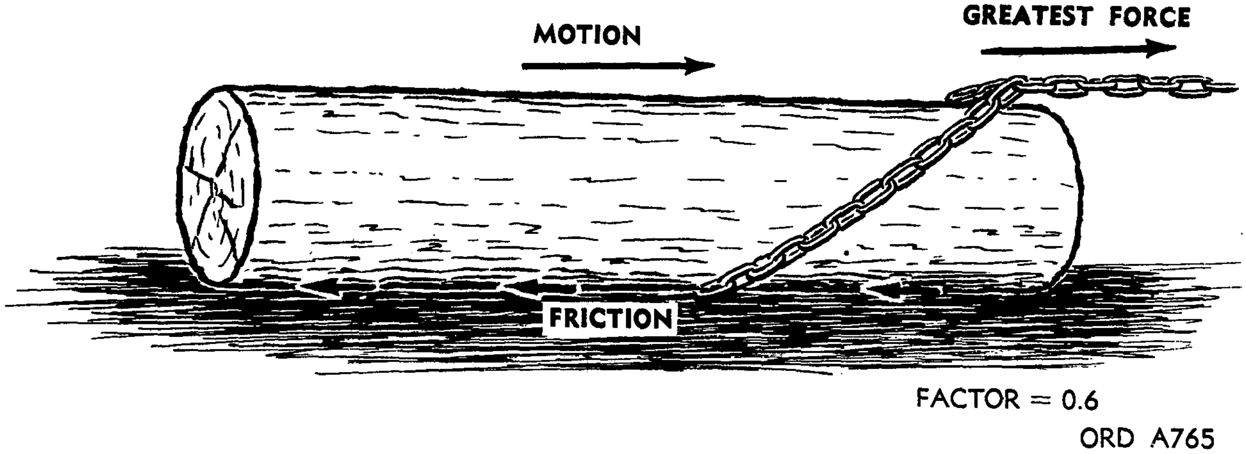


Figure 3. Sliding friction.

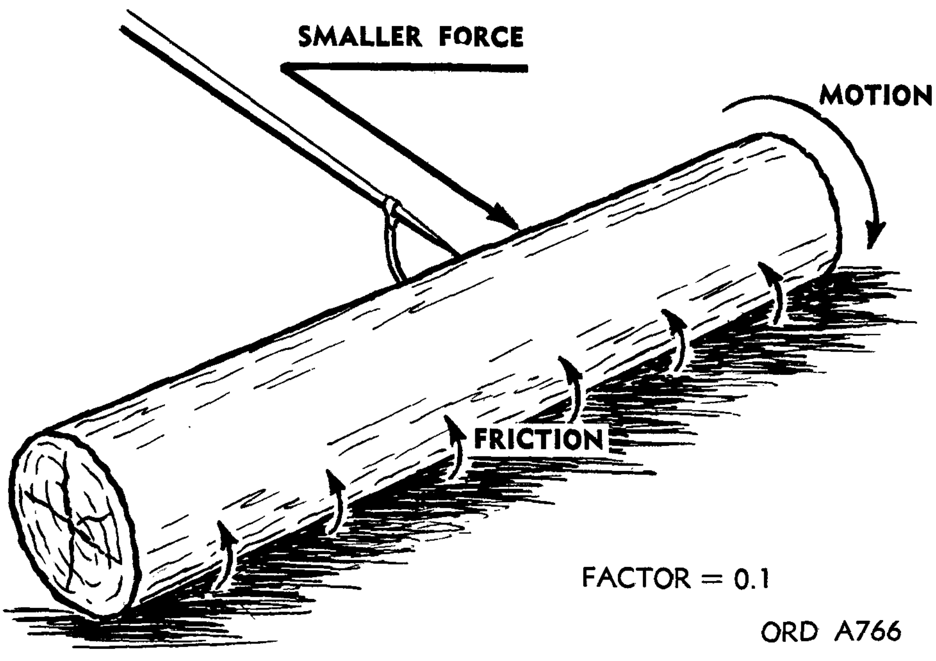


Figure 4. Rolling friction.

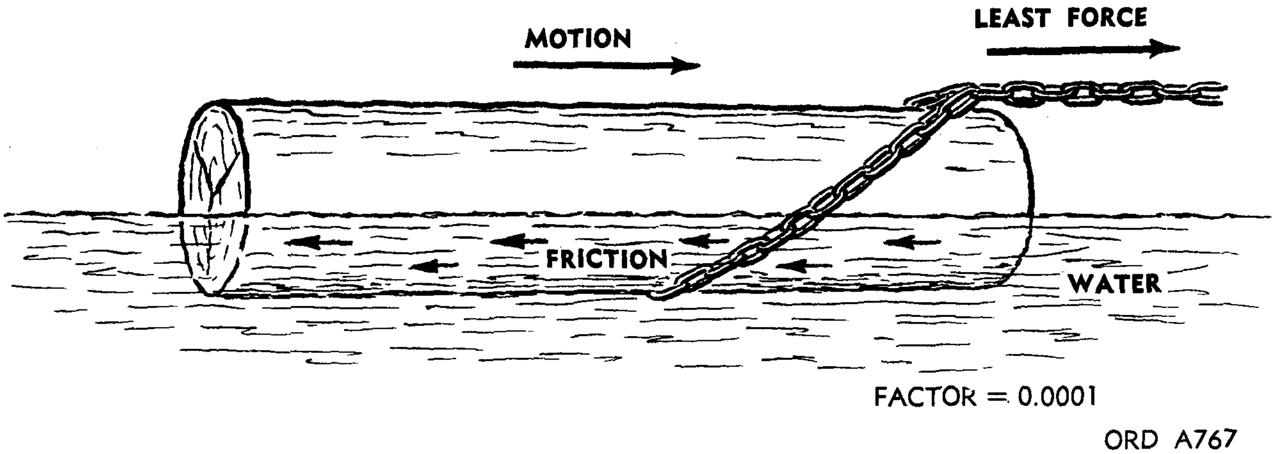


Figure 5. Fluid friction.

cohesion is the property which holds a lubricant together and resists a breakdown of the lubricant under pressure.

b. Varying Degrees of Cohesion and Adhesion. Cohesion and adhesion are possessed by different materials in widely varying degree. In general, solid bodies are highly cohesive but only slightly adhesive. Fluids, on the other hand, are quite highly adhesive but only slightly cohesive. Generally a material having one of these properties to a high degree will possess the other property to a relatively low degree. The adhesive property of fluids varies greatly (fig. 6). If mercury, which is highly cohesive and slightly adhesive, is poured over a sloping iron plate, it will run off in drops without adhering to the plate. Water, which has relatively low cohesive and adhesive properties, will not spread out over or adhere to the plate to any great extent and will run off rapidly. Oil, which has higher cohesive and adhesive properties than water, will adhere to the plate, spread out over it to a considerable extent, and will run off slowly.

8. Relation of Friction, Cohesion, Adhesion, and Lubrication

a. Friction always consumes power and produces heat. The amount of power consumed and heat produced varies with the conditions under which the friction is produced or occurs. Sliding friction consumes the greatest amount of power and produces the greatest amount of heat. Rolling friction consumes a lesser amount of power and produces a lesser amount of heat. Fluid friction consumes the least amount of power and produces the least amount of heat.

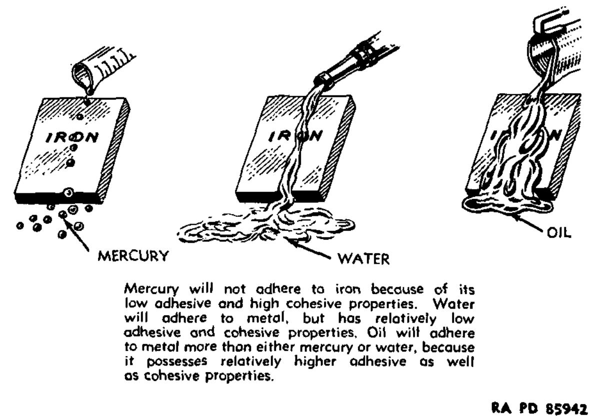


Figure 6. Adhesive properties of fluids vary greatly.

b. Any fluid when placed between two surfaces tends to keep the two surfaces apart and to change any sliding friction between them into fluid friction. This is because all liquids are noncompressible. The liquids will fill all of the cavities of the rubbing surfaces (fig. 1) and will not be reduced in volume by the forces holding the surfaces together. When two such surfaces are kept apart by such a fluid film, they are said to be lubricated.

c. The extent to which lubrication reduces the friction between two surfaces is governed by two factors: first, the selection of the fluid which has the best proportion of cohesive and adhesive properties for the particular application; and second, the amount of pressure between the two surfaces. To insure lubrication, the layer of fluid must be kept intact, and the greater the pressure the more difficult this becomes.

Section II. LUBRICATION THEORY

9. Langmuir Theory of Lubrication

a. It is agreed generally that the Langmuir theory offers the best and simplest explanation concerning the possible behavior of a lubricating oil film. According to this theory, a film of oil capable of maintaining a full fluid film between two surfaces in motion is composed of many layers of oil molecules (fig. 7).

b. When two surfaces separated by an oil film are set in motion, the oil film "splits up" into layers of these molecules. One layer slides across the surface of another and in so doing sets the next layer in motion. The layers closest to the surfaces adhere to them, while the intermediate layers cohere to each other (fig. 8).

c. The Langmuir theory also offers an excellent explanation of the varying degrees of lubrication that may appear between two surfaces in motion. Engineers usually recognize three degrees of lubrication. The condition illustrated in figure 9, where there is metal contact and practically no lubrication present, usually is considered to be "insufficient lubrication." A very thin film of lubricant usually is considered "partial lubrication" (fig. 9) (sometimes called "boundary lubrication") although many bearings operate satisfactorily in this region under certain conditions. "Sufficient lubrication" (fig. 9) or "full fluid film lubrication" denotes that enough oil is present to establish and maintain a full fluid film between the two moving surfaces. These three degrees of lubrication can be likened to the layers of molecules present; for example, full fluid film can be visualized as five or more layers; partial film as three layers; and the insufficient film as less than three layers (fig. 9).

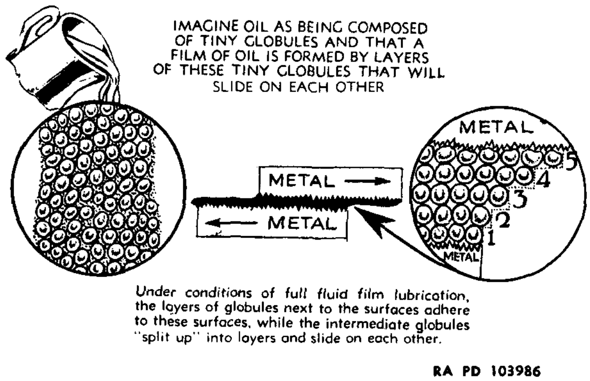


Figure 7. Theory of an oil film.

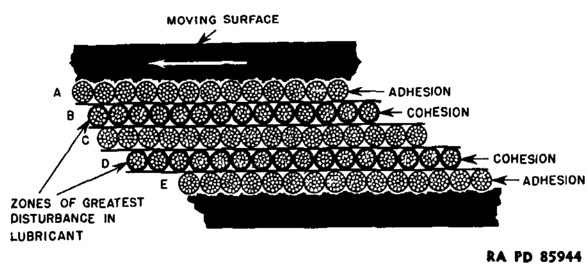


Figure 8. Action of an oil film between two moving surfaces.

10. Oil Film and Wedge Theory

a. We have considered flat surfaces only up to this point. When we apply the same principles to shafts and bearings, we see a different type of action taking place.

b. The oil film and wedge theory explains the action of an oil film between a shaft and its bearing. According to this theory, oil molecules adhering to the surface of a rotating shaft are carried along by the motion of the shaft. These molecules drag along the adjacent layer of molecules by the force of cohesion. At the same time, the weight of the load

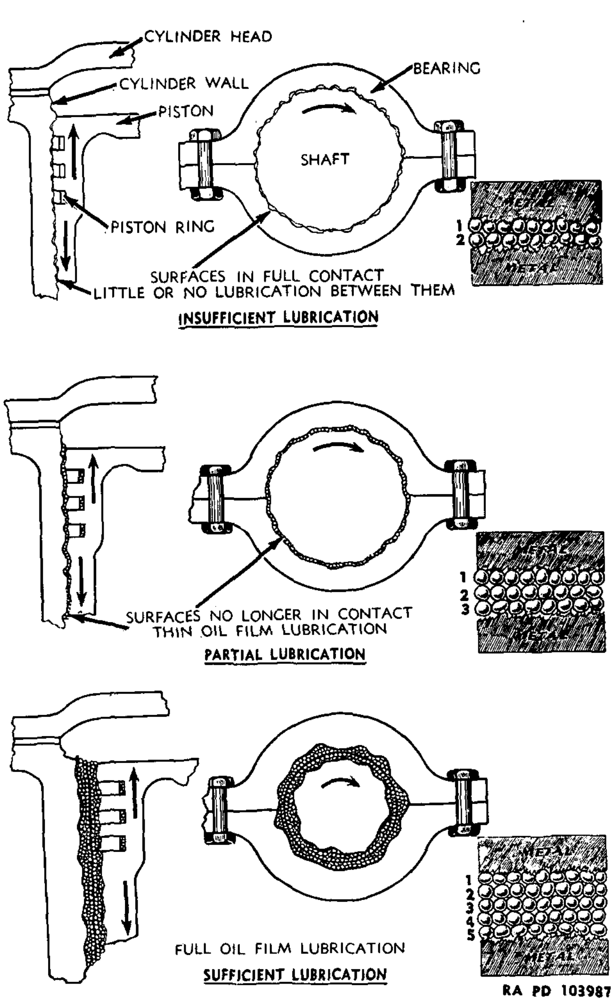


Figure 9. Insufficient, partial, and sufficient lubrication.

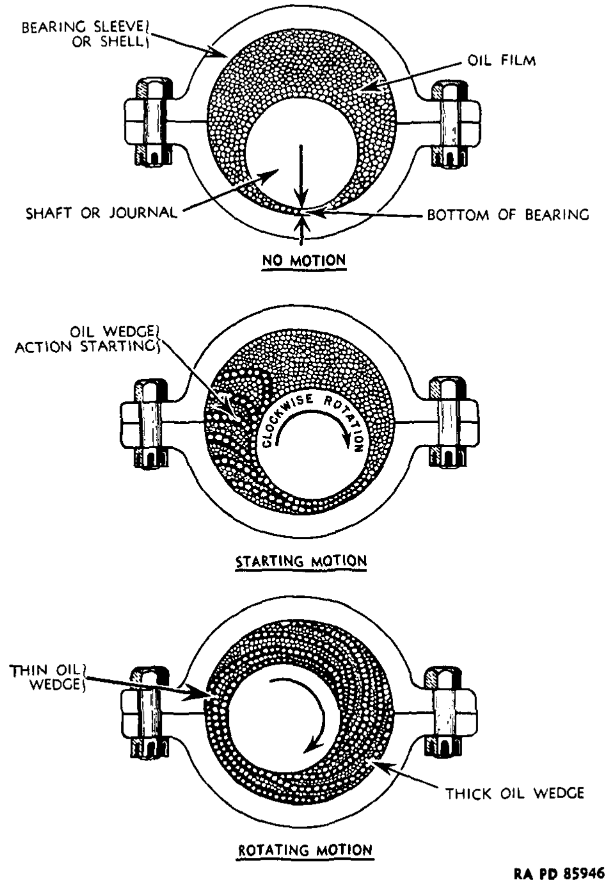


Figure 10. Oil film and wedge theory.

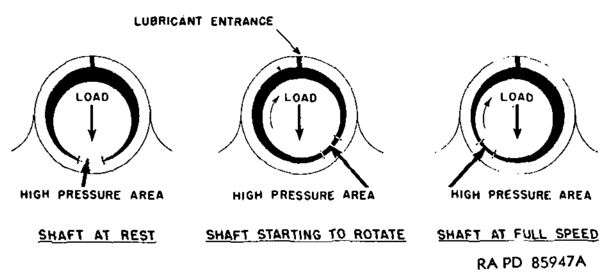


Figure 11. Speed of rotation determines the high- and low-pressure areas.

on the shaft forces the shaft down into the oil film near the bottom of the bearing. This pressure action narrows the clearance at the lower side of the bearing, causing some of the layers of molecules to be "squeezed" or "wedged" into this space. This wedging action lifts the shaft from the bearing and thus establishes the full fluid lubricating film (fig. 10). The wedging action of the oil film in a bearing creates high- and low-pressure areas, the oil supply being introduced at the low-pressure area (fig. 11). The positions of the low- and high-pressure areas vary somewhat with the speed of rotation.

11. Viscosity

The degree of cohesion betwen the molecules of an oil determines its grade or viscosity. The molecules of the more viscous or heavy oils are bound together more firmly than the molecules of the less viscous, lighter oils. The behavoir of oils of different viscosities in a simple shaft and bearing can be illustrated by the following: Too heavy an oil may be visualized as an oil in which the molecules are so large that they cannot wedge themselves between the rotating journal and bearing surface. Too light an oil may be visualized as an oil in which the molecules are either so small that they cannot individually sustain the loads imposed on them, or the force of cohesion between the molecules is not strong enough to hold them together in great enough masses to collectively support the load. The correct oil is that oil which is made up of molecules of the right size and cohesiveness to prevent the shaft, in its rotary motion, from breaking through the molecular layers of the oil film (fig. 12).

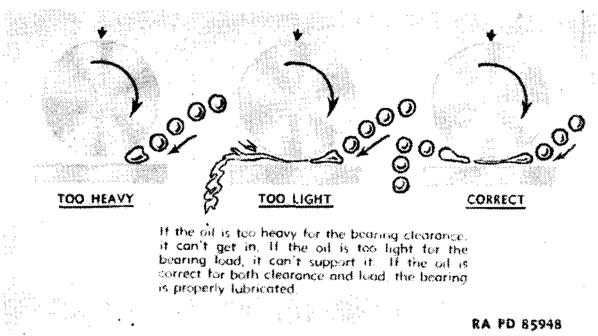


Figure 12. Effect of viscosity.

12. Fundamental Factors Influencing Selection of Proper Grade of Lubricant

There are factors which influence the selection of the proper grade of lubricant for any normal bearing operated under normal conditions: rubbing speed (generally in linear feet per minute); the clearance between bearing surfaces; the load in terms of pressure per unit of bearing area (generally pounds per square inch). Obviously there may be innumerable variations or combinations of these conditions; depending upon factors of outside origin; for instance, high or low temperatures from outside the bearing, heat generated within the bearing, presence of moisture or abrasive dust, presence of contaminating substances, etc. All these conditions are taken into consideration in selecting the grade of lubricant.

a. Rubbing Speed. The properties of a lubricant must be such that it will stick to the bearing surfaces and support the load at operating speeds. More adhesiveness is required to make the lubricant adhere to bearing surfaces at high rubbing speeds than at low speeds. At low rubbing speeds less adhesion is required but, due to the decrease in wedging action, greater cohesion is necessary to prevent the lubricating film from being squeezed out from between the bearing surfaces.

b. Clearance Between Bearing Surfaces. Other conditions being the same, greater clearance between bearing surfaces requires higher viscosity and cohesiveness in the lubricant to insure maintenance of the lubricating film. The greater the clearance the greater must be the resistance of the lubricant against being pounded out with the resultant destruction of the lubricating film.

c. Bearing Load. Other conditions being the same, the greater the unit load on a bearing the higher the viscosity of the lubricant should be to maintain the lubricating film. The cohesion must be sufficient to prevent a breakdown of the lubricating film. A lubricant which initially is too viscous (cohesive) for a given condition of load and speed will absorb more power, convert the power to heat, and thereby automatically reduce its own viscosity to a lower value. Such reduction is at the expense of higher operating temperature and shorter lubricant life. The load in terms of pressure per square inch of bearing area is calculated by a rather simple formula. Actually the projected bearing area can be visualized as the shadow which the shaft would cast if a light were held directly above it. The importance of the calculation of unit pressures may be illustrated by visualizing a heavy flywheel mounted on a shaft and the shaft in turn mounted upon sharp knife-edge bearings at each end. It is obvious that the force of weight and motion in such a shaft would cut either the shaft or the bearings, depending upon which was the softer.

d. Clearance of Shafts. The amount of clearance between a shaft and bearing surface is primarily governed by the operating speed of the shaft. Here are three general rules covering this point—

(1) High shaft speed demands closer clearances and close bearing clearances require lower viscosity lubricants.
(2) Medium shaft speeds allow moderate clearances and moderate clearances warrant medium viscosity lubricants.
(3) Low shaft speeds permit large clearances and large clearances call for higher viscosity lubricants.

13. Summary

a. Friction is a force which counteracts a driving force. It is present in all mechanisms. It can be greatly reduced by lubrication. Lubrication reduces the amount of wear by providing a fluid barrier between rubbing surfaces. Lubrication is the means of changing "dry friction" to "fluid friction."

b. Lubricants must have the qualities to—
(1) Remain fluid under heat and cold.
(2) Remain stable under loads.
(3) Be noninflammable.
(4) Leave no residues.
(5) Transfer heat.

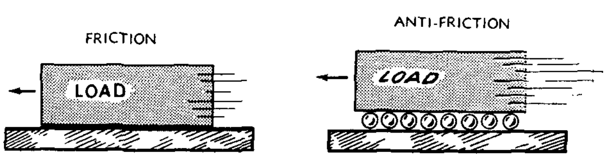
Modern lubricants will have these qualities. Intelligent use of these qualities will prevent wear of equipment and keep equipment combat ready.

CHAPTER 3
BEARINGS AND LUBRICATION

Section I. TYPES OF BEARINGS

14. General

a. Machine Bearings. Strictly speaking, the word "bearing" has many applications and, from the standpoint of mechanics, may be applied to anything that supports a load. However, this text will be concerned only with those bearings which support or confine the motion of sliding, rotating, and oscillating parts in those mechanisms known as machines. Machine bearings generally are referred to or may be classified in two major groups, namely: friction-type bearings and antifriction-type bearings.



In friction type bearings, one body slides over the surface of another, and if unlubricated, sliding friction is developed. In anti-friction bearings, the surfaces are separated by balls or rollers, and rolling friction is developed.

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Figure 13. Friction- and antifriction-type bearings.

b. Friction-type Bearings. Friction-type bearings (fig. 13) may be defined broadly as those bearings which have sliding contact between their surfaces. In these bearings, one body slides or moves on the surface of another and sliding friction is developed if the rubbing surfaces are not lubricated.

c. Antifriction-type Bearings. Antifriction-type bearings (fig. 13) are so-called because their design takes advantage of the fact that less energy is required to overcome rolling friction than is required to overcome sliding friction. They may be defined broadly as bearings which have rolling contact between their surfaces.

15. Friction-type Bearings

a. General. Friction-type bearings (those which have sliding contact between their surfaces) may be broadly grouped into three classifications: first, journal bearings, which support and confine a rotating or oscillating shaft; second, guide bearings, which guide the longitudinal motion of a shaft or other part; and third, thrust bearings, which restrict the motion of or support a rotating shaft or other part longitudinally.

b. Journal Bearings. Journal bearings, in turn, may be subdivided into different styles or types, the most common of which are solid bearings, half bearings, two-part or split bearings, and multipart bearings.

(1) *Solid bearings.* A typical solid style journal bearing (A, fig. 14) application is the piston pin bearing, more commonly called a bushing, in the small end of an engine connecting rod. Solid bearings can be used only where it is possible to slip them over the end of the shaft with which they operate. Solid bearings frequently are pressed into the part to which they are applied. Solid bearings due to their construction, offer a smooth internal surface not to be found in a multipart bearing and this smooth inner surface minimizes the danger of interrupting the oil film. Solid bearings also can be made quite rigid, due to the absence of either bolts or

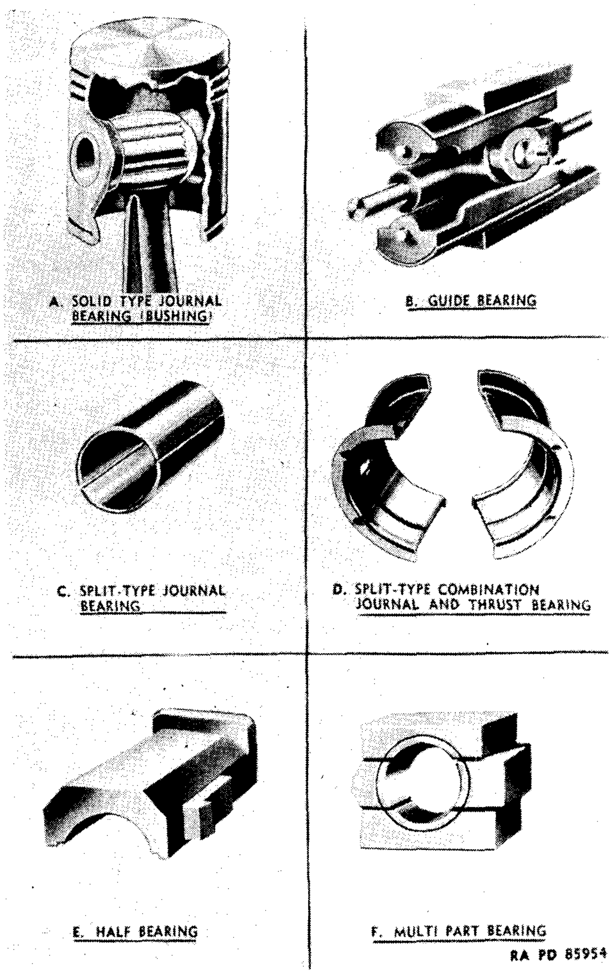


Figure 14. Various friction-type bearings.

clamps which may either work loose or permit flexing.

(2) *Half bearings.* Perhaps the most common application of the half bearing (E, fig. 14) in equipment is on the journal or axle of a railroad car. These bearings are easy to install and replace. Where the load is exerted only in one direction, they obviously are less costly than a full bearing of any type.

(3) *Split bearings.* Split-type journal bearings (C, fig. 14) are used more frequently than any other friction-type bearing. A good example is the connecting rod crankpin bearing. The split bearing can be made adjustable in order to compensate for wear. If the construction of the machine to which a split bearing is applied calls for fairly frequent adjustment during its service life, shims may be provided to reduce the clearance of the bearing. Modern automotive bearings are precision-built and when they are worn, they are replaced rather than adjusted.

(4) *Multipart bearings* Multipart bearings (F, fig. 14) of the friction type are used chiefly in heavy industrial machinery. Their application is largely where the loads are either too great to be carried economically by a split bearing, or where the direction of the load would place its burden upon the parting line of a split bearing. The parting lines of multipart bearings can be so arranged around the circumference of a journal as to cause the least possible interference with oil film and wedge formation. This means that the parting lines will be kept away from the high-pressure point of the oil film and wedge.

(5) *Guide bearings.* Guide bearings (B, fig. 14), as the name implies, are used for guiding the longitudinal motion of a shaft or other part. Perhaps the best illustrations of a guide bearing are the valve guides and the cylinders in the internal combustion engine. The crosshead of a locomotive or the slides controlling the recoil of a gun are other common forms of guide bearings.

(6) *Thrust bearings.* Thrust bearings are bearings which are used to limit motion of, or support a shaft or other rotating part longitudinally. Thrust bearings sometimes are combined functionally with journal bearings (D, fig. 14). That is to say, a journal bearing often is flanged at one or both ends, and these flanges bearing against the end of the box absorb the thrust and prevent end motion of

the journal; an example is the bearing on the crankshaft of an automobile engine. Another example is a shaft with a collar bearing against the end of a bearing to prevent end motion.

16. Materials of Bearings

a. General. The complete subject of bearing materials involves metallurgy and machine design problems. These subjects are broad enough to warrant extensive study. This manual will be concerned only with the simple fundamentals. In general, however, it is well established that good bearing lubrication practice must take into consideration the kind of material used.

b. Babbitt. Babbitt, as originally made, was composed of fixed proportions of copper, tin, and antimony. However, many changes in the original proportions have been made. In fact, any soft metal lining containing lead, tin, or antimony is called "Babbitt." The importance of a babbitt-lined bearing lies in the fact that a shaft will run with less friction and less power loss if the bearing is lined with a metal softer than the shaft itself. Compare the first two items listed in table I. A soft metal of this description is sometimes called an antifriction metal. In general, the tin in the babbitt formula gives the metal its stability and ability to resist corrosion and oxidation. The lead makes it more ductile and smooth. Antimony and copper provide a rigidity which gives the alloy mechanical strength.

c. Bronze. An older form of a bearing alloy is bronze. The term bronze should be applied only to those alloys of copper in which tin is the predominating quantity. Bronze bearings were used to support the moving parts of crude machinery long before the industrial era. It was used as a bearing material because of primary requirements that a bearing should be softer than the shaft it supports. Bronze does not have the high antifriction value of babbitt. Although it is prepared in many forms of alloys, the best known type is called phosphor bronze. Phosphor bronze has very high tensile strength and toughness. These properties are required in applications where the bearing must stand heavy loads and resist wear. Bronze bushings are use to support piston pins, water pump shafts, and distributor shafts.

d. Copper-lead and Cadmium-Silver. Copper-lead and cadmium-silver alloys were developed as bearing material for automobile connecting rod bearings. Both of these alloys are capable of withstanding high load pressures. They are susceptible to oxidation by the corrosive elements in crankcase oils. For this reason special oils are specified for use with these alloys. Some engine bearings, operating at high speeds, will be subject to 2,000 pounds per square inch load and at 300° F. Thin linings of the above alloys wear very well under these conditions.

e. Synthetic Bearing Materials. Fiber or synthetic bearings are made by impregnating a cloth or paper base with a resinous compound under high temperature and pressure. Bearings made of these fibrous materials are adaptable to a wide variety of speed and load conditions. These bearings wear well, require little lubrication, have high antifriction characteristics and are not generally corroded. Where it is important to have good electrical insulation, such as electric motors, synthetic bearings are commonly used.

f. Bearing Finishes. The finish and surface of a bearing has considerable influence on the characteristics of the bearing. To have high antifriction qualities, the bearing surface should be as smooth as possible. It is always desirable to have a mirror-finish. The finish of the bearing has a definite fundamental effect upon: first, the unlubricated friction factor of the bearing; and second, the formation and maintenance of the proper film and wedge.

g. Oilless Bearings. Oilless or self-lubricating bearings are used in inaccessible places or where the presence of oil is undesirable. A number of types have been developed, some of the more common being bronze with grapite inserts, graphite impregnated with some bearing metal such as white alloy or bronze, wood impregnated with oil, wax, paraffin, or some such substance, and hard wood reinforced with babbitt metal, the wood shell being impregnated with lubricant. The various types are manufactured under different trade names.

17. Antifriction-type Bearings

a. General. Antifriction-type bearings are those which have rolling contact between their surfaces. They may be classified as roller bearings or ball bearings according to shape of the rolling elements. Both roller and ball bearings are made in different types, some being arranged to carry both radial and thrust loads. In these bearings, the balls or rollers generally are assembled between two rings or races, the contacting faces of which are shaped to fit the balls or rollers. The basic difference between ball- and roller-type bearings is that a ball at any given instant carries the load on two tiny spots diametrically opposite while a roller carries the load on two narrow lines (fig. 15). For high-speed, small, light loads, ball bearings are generally most suitable. For low-speed, large, heavy loads, roller bearings are usually the only satisfactory choice. Theoretically, the area of the spot or line of contact is infinitesimal. Practically, the area of contact depends on how much the material, out of which the bearing parts are made, will distort under the applied load. Obviously, bearings must be made of hard materials because if the distortion under load is appreciable, the resulting friction will defeat the purpose of the bearings. Bearings, with small highly loaded contact areas, must be lubricated carefully if they are to have the antifriction properties they are designed to provide. If improperly lubricated, the highly polished surfaces of the balls and rollers soon will crack, check, or pit, and failure of the complete bearing follows.

b. Roller Bearings. Rollers, which may be cylindrical, tapered, shaped (as hour glass), and needle are the general types of roller bearings. All are used in different applications of radial loads. The shaped and tapered rollers may also be used as end thrust bearings. Needle bearings are used for supporting slow speed shafts.

c. Ball Bearings. This type of antifriction bearing has universal use. It is used to support end thrust as well as radial loads. Shaft speeds of slow motion to very high revolutions per minute can be accommodated.

d. Materials and Contruction. Antifriction bearings are made of hardened steel. The rollers and balls are generally separated from each other. They roll on hardened steel races. Because they are manufactured to close tolerances, dirt and grit will damage the polished surfaces of the bearings, causing severe damage. Seals, both mechanical and those formed by grease, help to keep these elements from the internal parts of the bearing. Figure 16 shows some typical antifriction bearings.

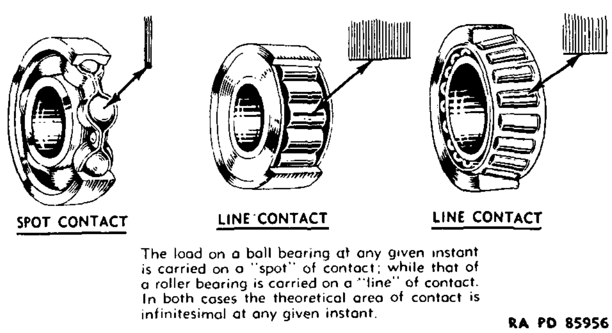
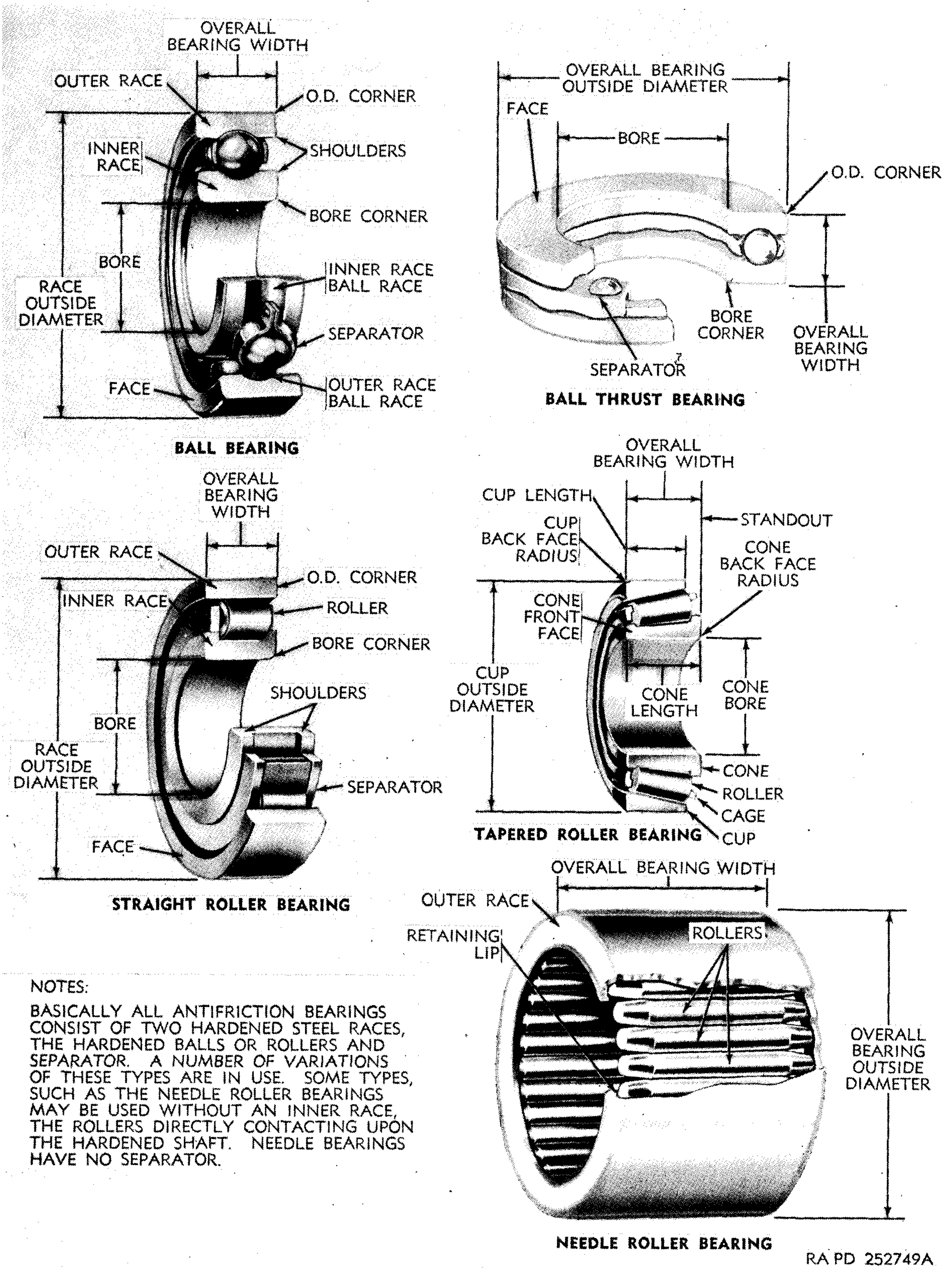


Figure 15. Load carrying areas of ball and roller bearings.



NOTES:
BASICALLY ALL ANTIFRICTION BEARINGS CONSIST OF TWO HARDENED STEEL RACES, THE HARDENED BALLS OR ROLLERS AND SEPARATOR. A NUMBER OF VARIATIONS OF THESE TYPES ARE IN USE. SOME TYPES, SUCH AS THE NEEDLE ROLLER BEARINGS MAY BE USED WITHOUT AN INNER RACE, THE ROLLERS DIRECTLY CONTACTING UPON THE HARDENED SHAFT. NEEDLE BEARINGS HAVE NO SEPARATOR.

Figure 16. Types of antifriction bearings.

Section II. LUBRICATION OF BEARINGS

18. Friction Bearings

a. General. There are three important points to consider in the distribution of oil in friction bearings: first, the point of lubricant introduction; second, the design and location of the oil grooves; and third, the proper chamfering of the corners or edges of any grooves in the surface of the bearing lining.

b. Point of Lubricant Introduction. The point at which the lubricant should be introduced is usually in the low-pressure area. This point will depend upon the position of the bearing, the direction of rotation, the speed of rotation, and other factors. If an attempt is made to introduce the oil into a bearing at the high-pressure point, the pressure of the oil film wedge may force the oil back out of the bearing and may result in a failure of the lubricating film. The correct location of the point of lubricant introduction must be considered carefully and circumferentially placed in a low-pressure area. In the case of horizontal bearings, the point of introduction is normally at the top of the bearing circumferentially and in the center of the bearing longitudinally. Thus, the force of gravity, is used as an aid in carrying the oil down onto the rotating journal.

c. Oil grooves. Oil grooves (fig. 17) are simply reservoirs which trap some of the oil supplied to the bearings. They keep a portion of the oil supply available for the starting and stopping periods when the main supply system may not be operating or for a period when, due to low temperature conditions, the viscosity of the oil may be so high as to prevent its immediate flow from the supply stream. Oil grooves also aid in offsetting the tendency of the loaded journal to squeeze most of the oil film out of the clearance space. This squeezing out of the oil is greater in slow-speed than in high-speed operation, because the greater wedging action of the oil film occurring at higher journal speed tends to maintain an adequate oil film. The location of oil grooves in the high-pressure area of a bearing usually is avoided or held to a minimum. Oil grooves never should be cut large or deep, or left with sharp or ragged eges. Even when grooves are placed advantageously and are of the correct size, grooves with sharp corners facing the direction of rotation will tend to scrape the oil off the journal and destroy the oil film. An oil groove cannot perform its function of more evenly distributing the oil film in the bearing, unless the corner of the groove facing the rotation of the journal is chamfered properly. If the journal reverses its direction of rotation, the grooves must be chamfered on both edges.

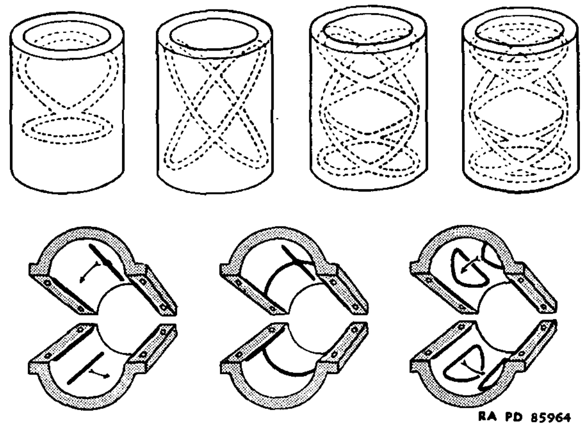


Figure 17. Oil-groove patterns in friction-type bearings.

19. Antifriction Bearings

a. The continued proper functioning of an antifriction bearing depends largely upon lubrication. Proper lubrication with the correct materials will prevent most bearing failures.

b. Correct lubrication provides for—

(1) Protection of polished surfaces from rust and corrosion.

(2) Reduction of friction.

(3) Removal of heat.

(4) Sealing against dirt, water, dust, etc.

c. Unit contact pressure in excess of 300,000 pounds per square inch are quite common in antifriction bearings. Under such pressures the fine line of contact in the case of roller bearings, or the small spot of contact in the case of ball bearings, tends to make impractical the formation and maintenance of an unbroken oil film. The very limited area of contact in the antifriction-type bearing punctures the film and the load is directly supported by the balls and races which are theoretically in a state of metal-to-metal rolling contact. Because a continuous lubricating film does not exist between the areas of contact of the balls or rollers and their adjacent races, the ability of such balls or rollers to carry heavy loads is believed to be due in a large measure to the deformation which takes place in balls, rollers, or races. Heat is generated by this continual deformation or distortion and, therefore, the action of the lubricant in this type of bearing is more of a cooling than of a lubricating nature.

d. Choice of lubricants for antifriction bearings is between oil or grease. Free flowing oils are used in bearings where continuous or easily serviced lubrication can be made. Oils give better cooling conditions than greases and are preferred lubrication in high speed bearings. Greases are used where service is infrequent and where speeds are low with heavy loads. Greases also act as better seals against dirt, water, dust, etc. Whichever type of lubricant is used, the following conditions are necessary:

(1) Good chemical stability.
(2) Correct viscosity for operating speeds and temperatures.
(3) High film strength.
(4) Good adhesive qualities.
(5) Cleanliness (from grit).

It is never recommended to use any lubricant having a graphite base on antifriction bearings. Formation of sludge from such material will clog the bearing and cause early damage. See TM 9-214 for information on care and maintenance of antifriction bearings.

e. Oil or grease seals are used to prevent the entrance of dirt, water, etc., the lubricant from seeping out, and the accumulation of dirt and dust on the outside surfaces of bearing. Seals are made in different styles, depending upon the operating characteristics of the parts to be protected. The plain felt seal generally is installed in a counterbore in the end of the bearing and held in place by a snapring. The leather seal is pressed into a counterbore in the end of the bearing. The felt prevents the passage of oil or dirt by being compressed slightly, while the leather seal incorporates a spring which keeps the leather in contact with the moving part. In both cases the lubricant provided for the bearing also lubricates the seals, but new seals must be soaked in engine oil before installation. When pressure lubricators are to be used on bearings equipped with seals, relief fittings generally are installed on the bearings to prevent the seals being blown out if too much lubricant is injected. TB 9-255 contains more details on oil and grease seals.

CHAPTER 4
LUBRICANTS

Section I. MANUFACTURE OF LUBRICANTS AND PROPERTIES

20. General

Most of the lubricants used by the Army are derivatives of crude petroleums. It is important that the readers of this manual on lubrication learn about the manufacture of oils and greases. The properties and the qualities of the products will be more easily understood.

21. Refining

a. Distillation of Crude. During the distillation of petroleum, many hydrocarbon products are "boiled off." These are recovered and refined to become fuels, solvents, and other valuable chemicals. The bottoms or residue of the still provide the source for lubricating oils and greases. These bottoms are treated in a lubricating oil plant through several processes:

(1) Deasphalting.
(2) Dewaxing.
(3) Solvent extraction.
(4) Redistillation.
(5) Filtration.

b. Deasphalting. The undesirable tars, pitches, mineral solids, and slag present in the bottoms must be removed. When these bottoms are mixed with quantities of liquid solvent, a thinning out (dilution) takes place. The thinner mixture, having less "body," cannot hold the undesirable solids in suspension and they settle to the bottom of the mixing tank and are removed.

c. Dewaxing. Further additions of propane are made to the desirable material in the mixing tank. This mixture is pumped into a cooling tower where undersirable waxes crystallize or "freeze out" at 40° below zero. The solid waxes are then filtered from the liquid. It is noteworthy that here we see elimination of elements, which if not removed, would freeze out in equipment in the field and would greatly contribute to operating difficulties.

d. Solvent Extraction. The deasphalted and dewaxed liquid now undergoes a selective solvent treatment. The solvent used in this process dissolves the unwanted elements but does not take out the valuable components. At the end of the process there are two distinct liquid layers. The top and lighter layer is propane containing the desirable lubricant elements. The lower and heavier layer is the selective solvent containing the undersirable materials. The top layer is siphoned into a device by which the propane is removed.

e. Redistillation. The liquid, now containing all the lubricant elements, is very heavy and viscous. Lighter fractions must be derived from the bulk. This is done by simple distillation methods. The end result is a dozen or so separate liquids each having a particular viscosity.

f. Filtration. Certain undissolved particles still remain in the liquids. By excellent filtering methods clear, nongritty lubricants are finally produced and stored.

22. Properties

a. Blending. Viscosities of oils have been standardized by the Society of Automotive Engineering. Specifications and references are more easily interpreted by means of this standardization. An SAE number (in multiples of 10, as 10, 20, 30, etc.,) demotes the viscosity of an oil. The lower the number, the lighter the oil. The viscosity of an oil is a very important property. Viscosity will grade an oil concerning its applicability for specific conditions. Heavy oils cannot be used on bearings having tight clearances. Light oil cannot be used on gears subject to high loading pressure. The measure of the viscosity of an oil is a good indication of one of its properties.

Note. Commerical oil manufactures who supply oil for the automotive trade have used 10W, 20W, 30W, etc., as designations. These mean that the oils have been winterized to allow easier starting of vehicles in cold weather.

The blending of oils is the process of mixing oils of various viscosities to make oils of definite viscosities in conformance to SAE standards. Sometimes at the blending process additives are put into oils to make additional or special, desired properties.

b. Additives. Under certain operating conditions, lubricants have tendencies to lose their lubricating qualities. Substances are put into lubricants to offset these changes. Definite substances are used for each specific condition. Some of the conditions encountered in lubrication and the additives used to reduce these effects are mentioned below. Lubricants, used by the Army, contain certain additives by specification and no other additives must be used by operating or maintenance personnel.

(1) Viscosities of lubricants vary with temperature. Too high a temperature makes them too thin to be effective. Too low a temperature makes them difficult to apply and too "set" to be effective. Chemicals, which have no harmful effects on machinery, are added to maintain a constant viscosity of the oils over wide temperature ranges. Alcohols, glycols, and esters are the groups used. These same groups are used to extend the temperature range of hydraulic and cooling fluids.

(2) Some conditions of heat and high speed reduce lubrication to the point where seizing or binding of metals takes place. Finely ground soft metals such as zinc, lead, copper, and aluminum are added to retard this effect. Other antiseize agents are talc, mica, and graphite.

(3) Oxidation of bearings takes place at high tempertures. Some lubricants contain inhibitors to prevent this. These inhibitors are sulfur, chlorine, and complex compounds of ammonia in many cases. Prevention of oxidation of the bearings is necessary to prolong the life of the bearing itself; also to prevent any oxidized metal which would form, from oxidizing the lubricant. Oxidation of the lubricant leads to breakdown and forms harmful acids. These acids would attack the metals and cause a result known as galling.

(4) Rust or corrosion products, not only have bad effects on bearings, but they plug the valves and controls of hydraulic and cooling systems. For this reason most of the fluids used in hydraulic and cooling systems contain rust inhibitors.

(5) Some engine oils contain solvents which dissolve "tars and varnishes" that are formed when fuel is burned in the engine. This solvent action prevents valve mechanisms from sticking and reduces the possibilities of the "tars and varnishes" from burning to harmful crystalline carbon.

(6) Certain oils are supplied containing a compound which tends to expel and settle impurities. These impurities gather at the bottom of the crankcase where they stay out of circulation.

c. Other Properties.

(1) The specific gravity of an oil has little significance to the user. It has no relationship to the viscosity. It does not indicate whether an oil is light or heavy. Its basic use is to determine the total weight of a volume of oil.

(2) Oil, when new, will be clear. If an oil is not clear, it indicates use and the darkening is due to oxidiation of the oil or metal, or dirt in suspension.

(3) The manufacturers of lubricating oils determine and control other properties that would interfere with the

proper lubrication of equipment. Soaping or foaming tendencies are controlled. High acid content is reduced. Gums and resins are eliminated. When the lubricants are packaged for use, all harmful factors have been reduced to the limits of latest knowledge.

23. Greases

Soaps, in which oils have been suspended, are known as greases. In effect, the soap acts as a sponge to keep the oil in supply to a shaft, a slide, or a rope. Like oils, soaps are chosen for certain qualities. Some are soft and water soluble. These make good greases for close fitting internal mechanisms where water cannot reach. Some soaps are hard and waterproof. These are used to make greases for heavy, external use.

24. Nonpetroleum Products

a. General. Synthetic lubricants represent about 20 percent of the total amount of lubricants presently consumed. Although there is little probability of their taking the entire place of petroleum lubricants, certain areas of U. S. Army lubrication require their use. Synthetics are generally more expensive than conventional lubricants, and, while some characteristics are highly needed, others are limiting factors in their use.

b. Silicones. This group of synthetics has the desired property of near uniform viscosity throughout a wide temperature range. Silicones have generally high flash-points and very low pour-points. They are used where there are moderate loads. Their lubricating qualities breakdown under high loads and therefore petroleum products are superior under these conditions. Silicones are also used as antifoam agents in lubricants.

c. Glycols. A great variety of lubricants is made from different combinations of glycols. They have the properties of good viscosity ranges and low pour-points. In addition, when they are destroyed by heat (500° F.), they decompose to gaseous products. There is little or no carbon residue formed. These products are used extensively in hydraulic systems because of their ability to remain fluid at low temperatures and their resistance to ignite.

d. Esters. This group has low pour-point and constant viscosity qualities. The lubricating quality is limited by their being too thin; so their use is in instruments, hydraulics, and precision bearings.

e. Sulfur. This product appears in many compounds finding special use in space vehicles and missiles. When sulfur is compounded with various organic lubricants, products are formed which are resistant to breakdown by oxidation. Molybdenum disulfide is directed as a lubricant in several parts of missile mechanisms.

Section II. CARE AND USE OF LUBRICANTS

25. Standardization of Materials

The present lubrication program of the United States Army has been set up for the preservation of the life of materiel. Several all-purpose lubricants have been developed to reduce the number of products necessary. The approved lubricants are limited to those grades and types essential to provide proper lubrication under all anticipated operation conditions. Definite names and symbols result in unformity of products, containers, and markings, when material is supplied by different manufacturers. All branches of the Army are now using these standardized lubricants.

26. Instructions

Proper application of lubricants and servicing materials is just as important as their quality and availability. Therefore, published instructions are revised and supplemented as advances are made through field experience in development of better lubrication and servicing methods. It is important that operating and maintenance personnel obtain and always use the latest instructions issued.

27. Containers

a. Standard Sizes. Standard sizes for oil containers are as follows: 5-cc bottle, 2-ounce, 4-ounce, 1-pint, 1-quart, 1-gallon, and 5-gallon cans; and 55-gallon drums. The standard size for grease containers are as follows: plastic container to fit rifle butt, 8-ounce tube; 1-pound and 5-pound cans; 25-pound pail; and 100-pound and 400-pound drums.

b. Storage. Whenever possible, containers should be stored where they will not be exposed to the weather. If, however, they are stored in the open, they should be covered with tarpaulins and all precautions made to keep sand, dirt, etc., from entering the containers. The markings on the cans properly identify the contents when shipped. If containers and contents are interchanged, great care should be given to see that the identities are not mixed or lost. Oversights in this area could lead to making equipment inoperable if the wrong lubricant happened to be used.

28. Cleanliness

Cleanliness of lubricant at the point of use is dependent upon cleanliness in storage and handling. When dispensing lubricant, wipe all dirt, moisture, and dust from around the openings or fittings. All containers must be closed tight when not in use. Some oils and greases will absorb water to such an extent that their usefulness is reduced. Dirt and dust will cause severe wear and damage to bearings and surfaces. Oil lines and valves will plug and become useless with an accumulation of dirt. Unclean oil will cause a filter to become clogged long before its normal replacement time. Lubricating guns, crankcase plugs, filter caps, gages, dipsticks, etc., should never be placed on the ground.

29. Moisture

a. It is important that no water be introduced into a mechanism that uses oil as the water greatly increases the rate of corrosion. Such corrosion will interfere with the functions of the mechanism and reduce its normal serviceable life.

b. In spite of the care taken in the preparation and shipping of oils, water is often found to be present. Exposure in an open can, even if the top is covered with a cloth, will result in the accumulation of moisture from the air. Condenstion in a container partly filled with oil, or pouring from one container to another which has moisture on its inner walls, results in moisture being carried into the mechanisms.

c. It is advisable that organization commanders test oils on hand for water content. If a clean bottle (1-pint size) is filled with agitated oil and allowed to settle, any water will collect at the bottom. If oil does show water, the oil should not be used. It should be turned back for reclaiming and new oil used.

30. Types and Uses

a. General. There are many types of lubricants available to users of equipment. Some types have been designed to withstand unusual temperatures, climate, and field conditions. Other types have been developed for heavy loads. Further, there are types for cleaning and preserving. Practically any lubricant will lubricate anywhere. Conditions and experience however, have directed the best possible lubricants for specific applications.

b. Automotive and Artillery Grease (GAA). Automotive and artillery grease (GAA) has been added to the supply system for lubrication of all automotive and artillery materiel under all conditions of service where ambient temperatures range from -65° F. to +125° F. This grease is to be used in all automotive and artillery applications requiring lubricating grease, including chassis points, wheel bearings, and universal joints. It is capable of providing a high degree of rust prevention and should be used as a storage corrosion-preventive for all classes of antifriction bearings, except sealed and shielded bearings, and those used in fire control instruments for which aircraft and instruments lubricating grease (GL) is prescribed for all temperatures. Automotive and industrial lubricating grease (WP) (QMC issue) will be used for lubricating water pump bearings; ball and roller bearing lubricant (BR) (QMC issue) will be used for rotating, sliding, or roller bearing surfaces, such as clutch pilot bearings, where constant or intermittent extremely high temperatures are developed in operation.

c. Replacement of Greases. Automotive and artillery grease (GAA) replaces the following greases which were used by the Department of the Army:

General purpose lubricating grease No. 2 (WB) (QMC issue).

General purpose lubricating grease No. 1 (CG–1) (Automotive and industrial lubricating grease) (QMC issue).

General purpose lubricating grease No. 0 (CG–O) (QMC issue).

Ordnance Corps lubricating grease No. 0 (OG–O) (QMC issue).

Ordnance Corps lubricating grease No. 00 (OG–OO) (QMC issue).

d. Lubricating with Automotive and Artillery Grease (GAA). It is extremely important that all components, particularly antifriction bearings, be cleaned and washed thoroughly to remove all traces of previously used lubricants prior to lubricating with automotive and artillery grease (GAA) for operation in extreme cold and/or heat. Disassembly of all components is justified in order to assure that they are properly cleaned before initial application of automotive and artillery grease (GAA). Components may be cleaned by use of volatile mineral spirits or dry-cleaning solvent or by production cleaning methods in rebuild shops, as required.

e. Requisitioning Automotive and Artillery Grease (GAA).

(1) Any existing stocks of the superseded greases (*c* above) are to be expended for use in the Zone of Interior before the automotive and artillery grease (GAA) is issued. However, equipment being processed for shipment to, or operated in, arctic areas and/or FECOM is to be lubricated with GAA grease. Automotive and artillery grease (GAA) is available through normal quartermaster supply channels.

(2) Requisitions submitted for automotive and artillery grease (GAA) for use in the Zone of Interior will contain a notation as to the intended application so that if the grease is not available, the Quartermaster General will supply a proper alternate grease without undue delay.

(3) Typical lubricant materials are listed in table II. For the complete list of lubricants, refer to Department of the Army Supply Manual 10–1–C4–1, which is the Army designation of Department of Defense Section C4–1 of the Federal Supply Catalog. In any conflict between table II and Department of the Army Supply Manual 10–1–C4–1, the latter will govern.

Table II. Typical Lubricants

Material	Symbol	Characteristic	Usual Application
Greases:			
Aircraft	CSG	Good viscosity range	High speed machinery.
Aircraft and instrument		Temperatures –65°F. to 200°F.	All bearing surfaces. Headscrews, worn gears ball and roller bearings. Limited at high unit loads.
Automotive and artillery	GAA	Temperatures –65°F. to 125°F.	Automotive and artillery equipment.
Ball and roller bearing	BR	High temperatures and loads.	Antifriction bearings. Rotating shafts. Sliding surfaces.

Table II. Typical Lubricants—Continued

Material	Symbol	Characteristic	Usual Application
Gear	GLG	High temperature	On gears or sliding bearings under hot conditions.
General	CG	Semisolid	Automotive lubrication fittings. Not to be used on ball bearings.
Rifle	RH	Resists water. Prevents rust.	Moving parts of rifles and machine guns.
Silicone	--------	High temperature. Antiseize.	High temperature antifriction bearings. Threads of optical instruments.
Special	GM	High temperature	Ball bearings.
Water pump	WP	Hard and waterproof	Packing grease for water seals. Not above 212°F.
Oils:			
Castor		Viscous, vegetable oil.	Rubber connectors. Storage of natural rubber. Some shock absorbers.
Chain—rope	CW	Viscous, tacky	On chains, wire ropes, and cables to protect from weather, water, etc.
Clock and watch	OCW	Resistant to gumming and corrosion.	Clocks, watches, transits, timing devices.
Conditioning		Gum and varnish solvents.	To clean crankcases and oil systems.
Cutting	ML		Cutting tool coolant.
Engine	OE	Heavy duty	Crankcases and transmissions.
Engine	PE	Rust preventative	Automotive engine storage and shipment.
Engine	OES	Good viscosity range	To be used in subzero weather in crankcases.
General		Highly refined	All purpose oil for bearings at usual loads and conditions.
General purpose	OGP	Low evaporation. Rust prevention.	General application under usual loads and conditions.
Instrument	OAI	Synthetic base. Low evaporation.	Aircraft and ground electronic instruments.
Insulating	OT		Transformers, capacitors, reactors.
Kerosene		Light, not permanent	Rust-removing, freeing threads, to dilute or thin oils.
Lard	OL		Thread-cutting lubricant.
Light	LO	No additives	Sighting and fire-control instruments, office equipment, small machines.
Light recoil	RL	Special viscosity properties.	Recoil mechanisms.
Lineseed		Sticky	Rifle stocks. Tool handles.
Variable resistor	OP	Very thin	Instrument use where prescribed.
Preservative	PL	Has rust inhibitor	General preservative and lubricant.
Preservative special	PL Spec	Low temperature	For prevention of rust at low temperatures. Frequent lubrication.
Railway	OC	Highly refined	Railway locomotive, cars, gun carriages.
Special recoil	RS	Great viscosity stability.	Recoil mechanisms—some hydraulic systems.
Steam cylinder	OSM	Pure—no additives	Noncondensing steam engines.
Vacuum		Vacuum treated	Use with vacuum pumps.

Table II. Typical Lubricants—Continued

Material	Symbol	Characteristic	Usual Application
Hydraulics:			
Castor oil		Low pour point	Houdaille rotary shock absorbers.
Hydraulic fluid	HB	Nonpetroleum	In systems with natural rubber seals.
Hydraulic fluid	HBA	Low temperature	For subzero temperature operation.
Hydraulic fluid	OH	Petroleum base	Hydraulic systems but not brake systems.
Hydraulic fluid	OHA	Low temperature	Low temperature operation.
Hydraulic fluid preservative.		Petroleum base containing additives.	Preservative and flushing oil for hydraulic systems.
Shock absorber fluid	SAH	Nonmineral oil	Use only in Houde shock absorbers above −20° F.
Miscellaneous:			
Corrosion preventatives	CH	Nondrying petroleum base.	Long term storage of metal parts.
Corrosion preventatives	CM	Applied hot.	Long term storage of metal parts.
Corrosion preventatives	CL	Film moist.	Long term storage of metal parts.
Corrosion preventatives	AXS	Can be sprayed as film dry to touch.	Long term storage and shipment/of metal parts.
Molybdenum disulfide	--------	Antioxidation	Mechanisms of missiles.
Permanent antifreeze	--------	Contains rust inhibitor.	Used as antifreeze in radiators in subfreezing temperatures.
Silicone	--------	Nonpetroleum	Gaskets, O-rings, certain hydraulic fittings.

CHAPTER 5
LUBRICATION EQUIPMENT

31. General

a. General. Standardization of lubricants not only reduces the number of items to be stocked, but also the amount of equipment necessary to apply them. Lubricating equipment is designed to reduce the possibility of contamination when transferring the lubricant from its container to another container or a mechanism. The equipment itself also must be cleaned before and after use as a further means of preventing contamination of the lubricant. Lubricating equipment and accessories are furnished in standardized sets.

b. Cleanliness. The great need for extreme cleanliness in handling lubricants and lubricating equipment cannot be overstressed because introduction of dirt or other contaminants may cause materiel failure at most inopportune times, as for example in battle. Lubricant containers will be kept covered when not in use and in places where they will not collect dirt, water, or other contamination. Oil measures and grease guns should not be laid on the ground. Be sure lubricating fittings are cleaned properly before using oil-cans, oil guns, or grease guns. Never put a grease coupler onto a damaged lubricating fitting or pull a coupler straight off a fitting. The following points must be remembered:

(1) Dirt may be a cause of malfunctioning of equipment.

(2) Dirt from equipment may contaminate the lubricant and case malfunctioning of the materiel to which it is applied.

(3) When not in use, keep equipment in a clean place.

(4) When in use, equipment should not be laid on the ground or other places where it is likely to become dirty.

(5) Keep lubricants in clean containers and in places where they will not accumulate dirt, water, or other contamination.

32. Oil Pumps

a. Oil Barrel Pump. An oil barrel pump is used to dispense oil directly from a barrel into measures or other containers. The lower end of the pump has two sizes of threads, so the pump can be screwed into either the end opening or the bunghole of a barrel. The intake or suction pipe telescopes in order to reach to the bottom of barrel or drum up to 50-gallon capacity. The shaft of the operating handle has a gear on the inner end which engages teeth cut in the side of the piston rod, giving sufficient mechanical advantage to permit the pumping of heavy oils. An adjustable stop screw acting on the end of the piston rod permits adjustment to pump 1 quart per stroke, and a spring-operated drip return tube automatically swings under the discharge nozzle and returns any overflow or drip to the barrel. Great care must be used to insure that the pump and, particularly, the intake pipe and attaching threads are absolutely clean before the pump is installed in a barrel; use cleaning solvent if necessary. The most frequent difficulty is loss of prime. This usually can be overcome by moving the pump handle rapidly back and forth through a small arc, keeping the drip return tube in place under the discharge nozzel. If this does not remedy the trouble and the intake pipe, intake pipe packing nut, operating shaft packing nut, and tie rods are tight and do not leak, disassemble the pump by removing the tie rods. Inspect, clean, and replace interior parts, as necessary.

b. Recoil Oil Pump. The recoil oil pump (fig. 18) is used to pump oil into recoil cylinders at a pressure of several hundred pounds per square inch. The pump consists of a base or reservoir with a lever-operated, high-pressure, plunger pump built into the top or cover, and serves to pump oil from the reservoir into the recoil mechanism.

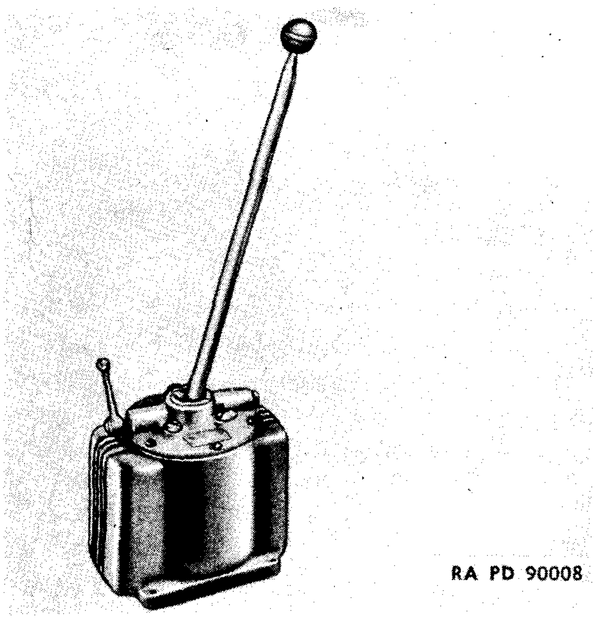


Figure 18. Recoil oil pump.

33. Lubricating Devices

a. Lubricating Fittings and Couplers. Materiel formerly was equipped with a variety of fittings for the lubrication of bearing surfaces, but these required a variety of lubricating guns, adapters, and equipment. A new fitting and coupler were adopted as standard in 1943. Lubricating guns were modified accordingly, and the new type of fittings were installed on existing materiel. The new type of fitting (fig. 19) is a modification of the hydraulic or push-type fitting but is more sturdy, easier to clean, provides a better seal against dirt, and allows a freer and faster lubricant flow. The old and new hydraulic-type fittings and old and new hydraulic-type couplers may be operated interchangeably. If leakage is encountered between a coupler and the lubricating fitting, it may be caused by dirt on the coupler or fitting, a defective fitting, or worn coupler jaws. Remove dirt with dry-cleaning solvent. Replace defective fittings. Worn coupler jaws may be reversed (or replaced if worn on both ends).

b. Oil Cups and Fittings. Lubricating devices for oil are generally of the screw or drive type with ball, spring, or hinged covers (fig. 20).

34. Oil Guns

Oil guns vary in type and size depending upon their uses for either high- or low-pressure operation. They are all of the cylinder and piston type and may have one cup leather for pressure operation only, or may have two cup leathers, back to back, allowing both pressure and suction operation. Low-pressure guns for introducing considerable quantities of oil into inaccessible lubrication points, emptying or filling housings, etc., operate by hand pressure only on the end of the piston or follower rod and are filled by suction. A bucket pump gun (fig. 21) used for dispensing variable resistor oils at low pressure consists of a housing or reservoir with a cover incorporating a plunger pump operated by the long lever. Oil guns require little servicing aside from regular and thorough cleaning and the replacement of follower cup washers when necessary.

35. Grease Guns

a. General. Grease guns are furnished in various styles and types depending upon the use to which they are put. Housings, such as automotive housings and rear ends, ordinarily are replenished from a low-pressure, hand-operated, bucket-type gun with a capacity of 25 to 50 pounds of lubricant. The greater part of the bearings on which lubricating fittings are installed/are lubricated with high-pressure guns of either the hand-operated or air-operated types.

b. Low-Pressure Guns. Figure 22 shows two low-pressure guns; one a hand lever-operated gun with a capacity of about 1 pound; the other a floor type with a lever-operated pump of such size that a standard 25-pound pail may be set inside the container and the lubricant pumped directly from it, or 50

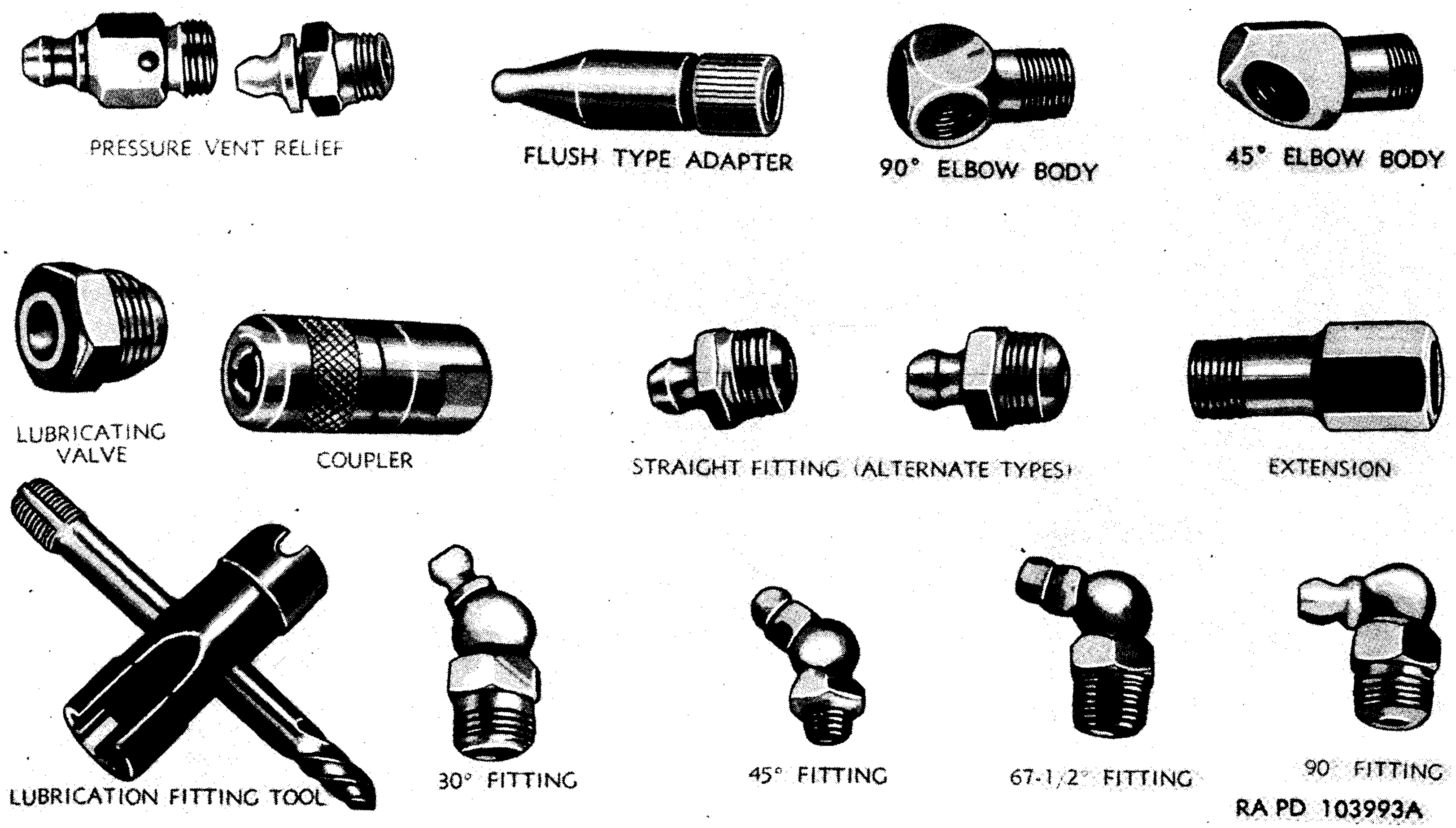


Figure 19. Grease lubrication fittings and appliances.

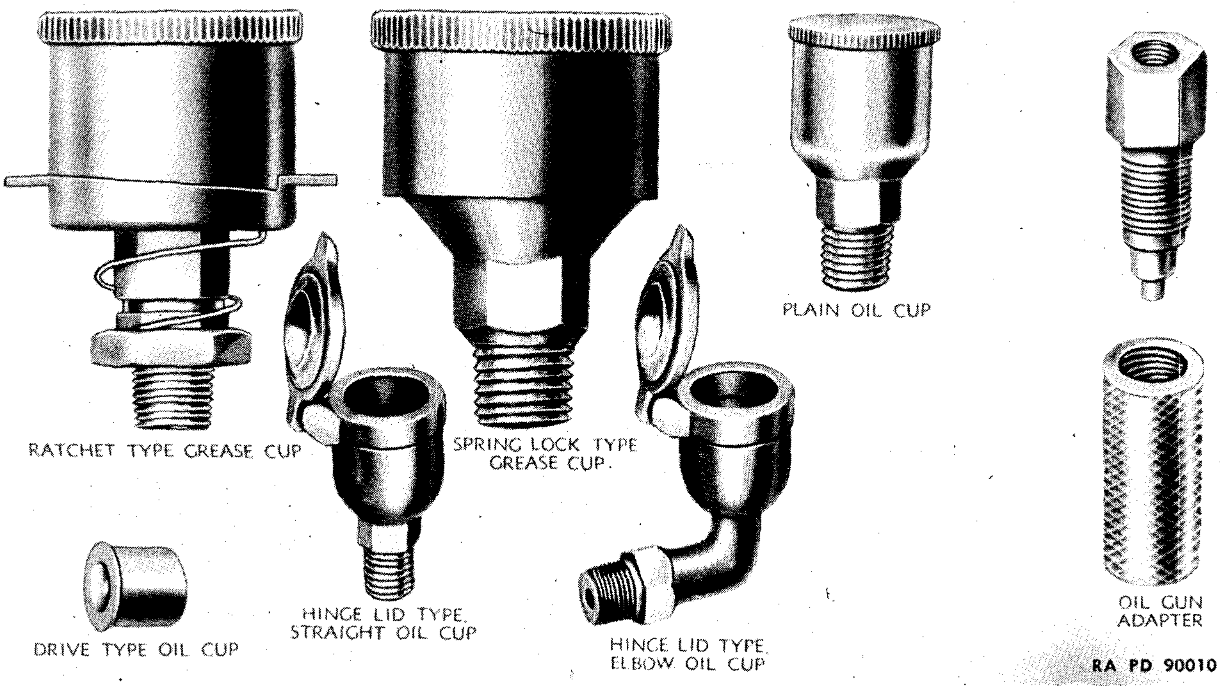


Figure 20. Oil and grease cups.

pounds of lubricant may be poured directly into the container. Pumps are of the plunger type with few moving parts and about the only cause of improper operation is dirt under the intake valve at the end of the pump tube. Proper handling of the lubricant should prevent entrance of dirt but, if failure occurs, the pump must be disassembled and thoroughly cleaned and inspected. The lubricant in the container also must be checked and discarded if found to contain any dirt. The hand gun may be filled by connecting the filler fitting to the discharge nozzle of the floor gun, or may be filled by hand by unscrewing the barrel from the head, inserting it in the lubricant, and pulling back on the follower rod. In hand-filling, use care to prevent formation of air pockets in the lubricant as these will interfere with the proper operation of the pump.

c. Push-type Guns. Push-type lubrication guns (fig. 23) are used in the lubrication of artillery, fire control instruments, motorcycles, and automotive vehicles. Although made in various styles, they operate on the same principle. In the K-type gun, the plunger is operated by movement of the hand knob, this operation forcing lubricant out of the coupler under high pressure. In the other gun the plunger is operated by pushing forward on the handle while the coupler is on the lubrication fitting, this operation moving the pump cylinder and pumping grease out through the coupler. In both types a faster and more positive prime is assured by a spring-operated follower. These guns develop pressures up to 5,000 pounds per square inch and cause little trouble if only clean lubricant is used. In filling, use care to prevent air pockets as they cause irregular action. If gun fails to operate or to develop the correct pressure, remove the ball check in front of the piston, clean thoroughly, and check for defective parts.

d. High-pressure Guns. High-pressures lubrication guns (fig. 24) now are furnished in two types, hand-operated guns and air-operated guns. Both are of the floor type with the pump on a removable cover and with the container of such size and construction that a standard 25-pound pail may be set in and the

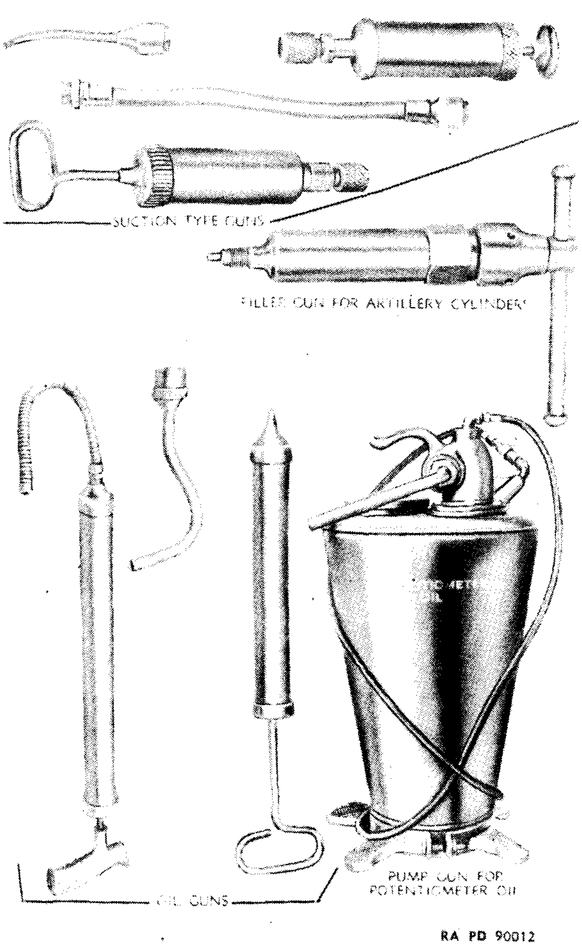


Figure 21. Typical oil guns.

lubricant pumped directly from it, or 50 pounds of lubricant may be placed directly in the container. The hand-operated gun is very similar to the low-pressure gun previously described except that the pump plunger is smaller, with the result that the volume of lubricant pumped is smaller but the pressure is much higher. The only variation in the air-operated gun is that compressed air is used as the source of power in place of hand power. Aside from the valves of the air motor which are to be grease-lubricated by removing the plug near the bottom of the cover plate, there is little of the mechanism in either gun that is liable to cause trouble unless dirt is allowed to get into the lubricant. Guns should be inspected at least once a month. If a gun fails to operate properly, it should be disassembled, thoroughly cleaned with dry-cleaning solvent, and inspected for defective parts.

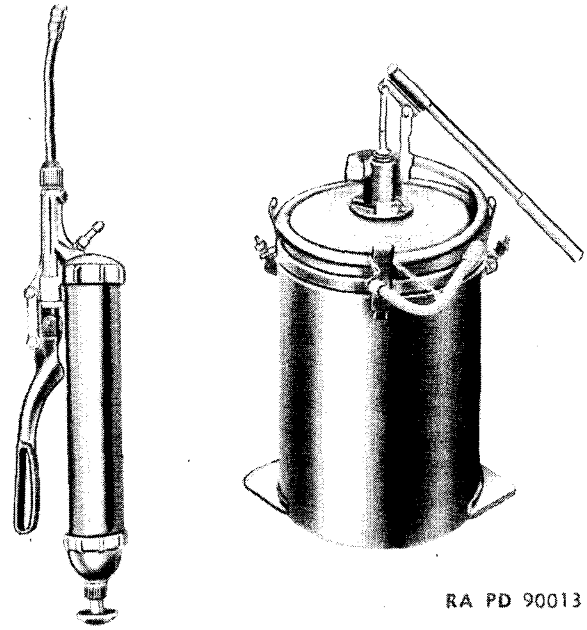


Figure 22. Low-pressure, hand-operated lubricating guns.

36. Miscellaneous Equipment

a. General. Aside from the various types of lubricating equipment previously covered, there also are available miscellaneous appliances necessary or useful in handling oils and greases. They include wheel-bearing lubricators, spray oilers, engine cleaners, oilers, oil measures, hydraulic brake fillers, funnels, oil spouts, drain pans, lubrication fitting tools, and tool boxes.

b. Wheel-bearing Lubricators. The lubricator (fig. 26) is used to renew the lubricant in antifriction bearings of vehicle wheels or other such items. The bearing is put into the cone-shaped opening over the center spindle and held in place by the thumb nut threaded onto the outside of the spindle. Grease forced from a gun through the lubricating fitting on top of the hollow spindle passes through holes in the spindle into the inside of the bearing and into the spaces between the balls or rollers, carrying the old grease out of the bearing ahead of it.

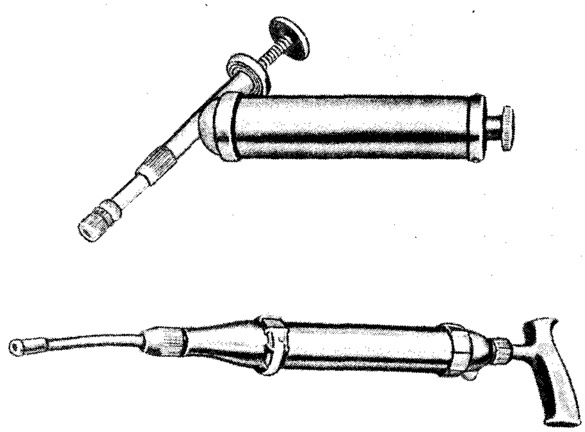


Figure 23. Typical push-type lubricating guns.

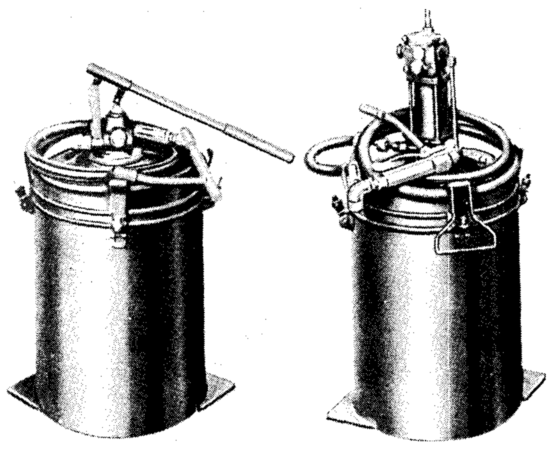


Figure 24. Pressure lubricating guns.

c. Spray Oiler. The spray oiler (fig. 25) is a trigger-operated pump type used for spraying oil. Its capacity is 1 quart. Dirt in the pump valves or in the spray nozzle will cause improper operation. Only clean oil should be used and the parts should be cleaned and inspected at regular intervals.

d. Engine Cleaner. The engine cleaner (fig. 25) is air operated and may be used with various fluids. Compressed air discharges the fluid under pressure and the long nozzle permits small inaccessible places to be reached. The fluid discharged is regulated by adjustment at the nozzle, and the air pressure by adjustment of a screw on top of the handle. The adjustments should be such that little of the fluid is atomized.

e. Oilers. Oilers are furnished in several sizes and types (figs. 25 and 26). Pressure to eject the oil is secured either by a push-buttom or by a lever- or trigger-operated pump. Few failures to operate should be encountered, but oilers should be cleaned and inspected regularly.

f. Oil Measures. Oil measures are supplied in a variety of styles and types. The most commonly used measures are of 400-cc, 1-liter, 1-quart, 2-quart, 4-quart, and 8-quart capacities.

g. Hydraulic Brake Fillers. There are two types of fillers for hydraulic brake systems. The lever-operated type is similar to the lever-operated oiler, except that a flexible tube is used in place of the spout and is used to replenish the fluid in the master cylinder (fig. 25). The lever operates a plunger-type pump that draws the fluid from the reservoir and forces it out the nozzle. The parts should be thoroughly cleaned and inspected at regular intervals. The pressure-feed filler (fig. 26) consists of an airtight tank or reservoir, mounted on casters, and equipped with a hose and fittings to attach the hose to the filler opening of the master cylinder. The reservoir is partially filled with hydraulic brake fluid, the rest of the spaces being filled with compressed air. When the hose is connected to the filler opening of the master cylinder and the valve in the hose is opened, the entire hydraulic part of the brake system is subjected to the pressure of the compressed air in the filler reservoir and the brakes may be bled by one operator without the necessity of pumping the brake pedal. Any hydraulic brake fluid withdrawn from the brake system by bleeding is replaced from the supply in the filler reservoir.

h. Funnels. Funnels are furnished in a considerable variety of shapes, styles, and sizes. They are made of copper, galvanized iron, and tin plates; with and without strainers; and with various types of fixed or removable spouts.

i. Can Spout. The spout (fig. 25) is equipped with a steel cutter and is used to open and pour oil from 1- and 5-quart cans. With the can standing on end, the guide is placed against the side of the can and the cutter is pushed down into the top of the can just inside the corner bead. The cutter and guide hold the spout in place so that the oil can be poured without leakage or loss.

j. Drain Pan. The drain pan (fig. 26) is used to catch the oil drained from engine crankcases, transmissions, axle housings, and other such points, and has a capacity of about 4 gallons. It is equipped with end handles for lifting when filled, and also with a long handle by means of which it can be withdrawn from beneath the vehicles after the oil has drained.

k. Lubrication Fitting Tool. The lubrication fitting tool (fig. 19) consists of a tap, die, wrench, and remover combined in one tool and is used in connection with the removal and replacement of lubricating fittings. The wrench has a portion of one side removed so that angle fittings may be installed or removed without damage. The tap is used to recut damaged threads before installing fittings, the die to recut damaged threads on fittings, and the remover to remove broken fittings on which the wrench cannot be used.

l. Tool Box. The tool box (fig. 26) of steel with hinged covers and tray is supplied to furnish a convenient clean place to keep and carry hand-lubricating guns and other equipment when not in use.

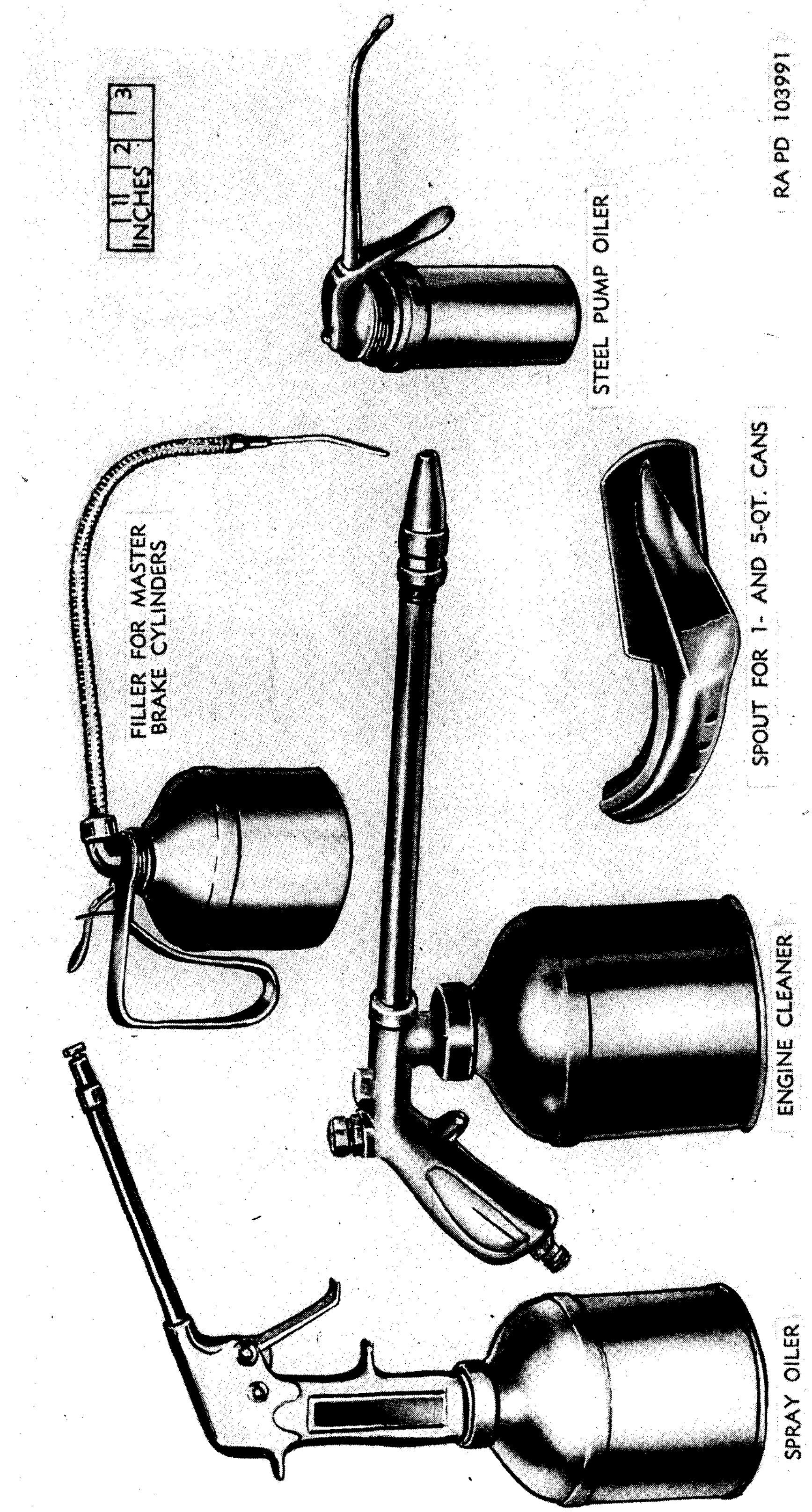


Figure 25. Typical miscellaneous lubricating equipment.

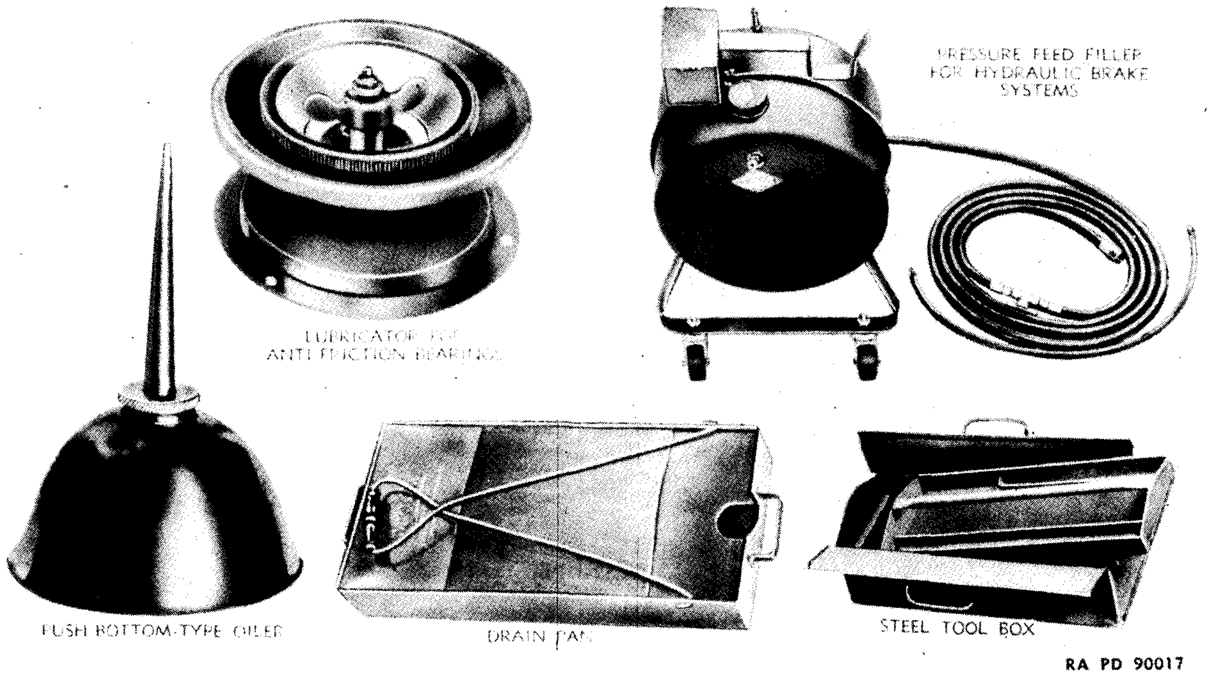


Figure 26. Typical miscellaneous lubricating equipment.

CHAPTER 6
AUTOMOTIVE MATERIEL; ENGINE AND ACCESSORIES

Section I. ENGINE LUBRICATION

37. General

a. Heat. An internal combustion engine is one which gets its power by the combustion of fuel in its cylinders. The energy of the fuel is converted to heat and the heat energy is in turn converted by the engine into mechanical energy. Approximately one-third of the energy of the fuel is obtained. Two-thirds of the energy of the fuel is lost through heat which has not been turned into mechanical energy. The dissipation of this large quantity of heat becomes a matter of basic importance to lubrication.

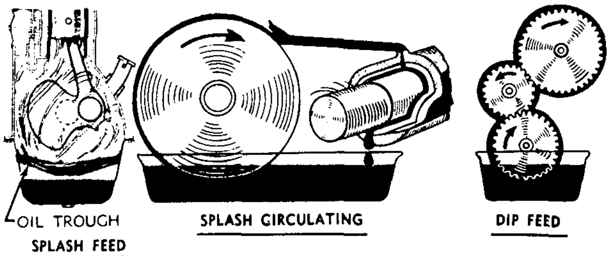
b. Heat Dispersion. Lubrication is directly connected with the method used for cooling an engine. The oil in the crankcase is used to conduct heat from the hot cylinders and pistons. The oil must be cooled to keep its effectiveness. This is done by restoring to a large reservoir or by cooling through radiators. A large amount of heat is transfered from the cylinder walls by circulating water. In some engines, considerable volumes of fast-moving air remove heat from the cylinder walls.

c. Oxidation Problem. The oil being applied to cylinder walls and piston rings is subject to high pressures and temperatures. These conditions tend to deteriorate the oils and destroy their lubricating values. There has been a continued demand for stable oil as the pressures and temperatures of engines advanced.

38. Lubricating Systems

a. General. At the present time, most of the internal combustion engines used in automotive materiel incorporate, or are provided with, a centralized reservoir or container from which oil is distributed to the various scattered lubrication points. Several different methods or systems are used to transfer the oil from the reservoir to the lubrication points and, while these are more or less similar, they employ different mechanical methods to obtain the desired results. The systems known as splash, dip, gravity, and pressure circulation are treated in *b* through *e* below.

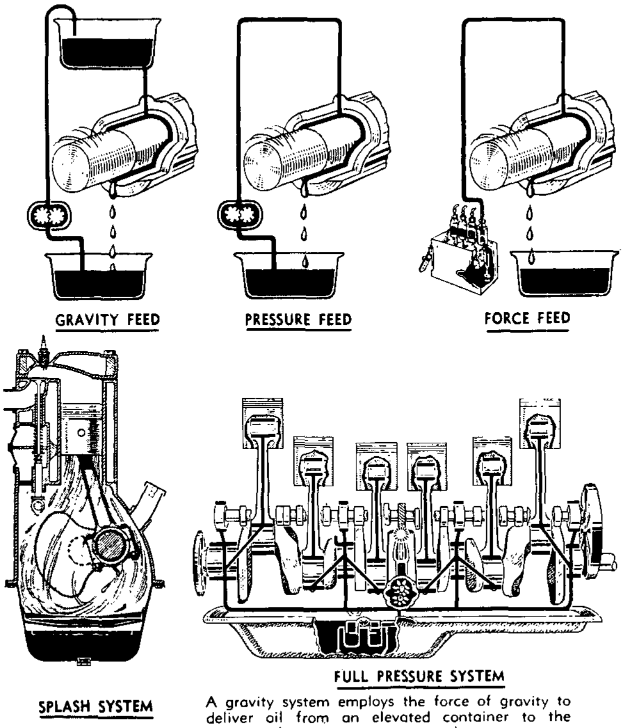
b. Splash Lubricating System. Splash lubrication is the simplest system commonly used for the distribution of lubricating oil to the various bearings (fig. 27). The moving parts of the mechanism (generally the connecting rods) dip into or strike the oil and splash it into the various parts requiring lubrication. Bearings which the splash will not reach generally are connected to small pockets or reservoirs by oil lines or grooves. The splash fills the pockets or reservoirs and the oil flows by gravity to the bearings. In systems of this kind, lubrication consists in maintaining the oil in the reservoir at the indicated level and changing it at required intervals. In most engines the connecting rods dip into troughs instead of into the main reservoir, the troughs being installed at such a height that the connecting rods give the correct amount of splash when the troughs are filled with oil. The troughs are kept filled to the overflow point by a pump drawing oil from the main reservoir, the overflow returning to the reservoir automatically. In this manner, the splash is kept constant during normal variations of the quantity of oil in the main reservoir. Most modern engines do not rely on the splash system alone.



A splash system uses the force of a moving part to splash into and spray oil onto the parts to be lubricated. A splash circulating system uses a rotating part to pick up and deliver oil to a trough which is, in turn, connected to the part to be lubricated. A dip feed system is one wherein the gears that are submerged in the lubricant carry a supply of lubricant to the teeth of the adjacent gears.

RA PD 85961

Figure 27. Splash and dip methods of oil distribution.



A gravity system employs the force of gravity to deliver oil from an elevated container to the bearing. A pressure system employs a constant flow pump to force oil from a supply container to the bearings. A force feed system employs variable flow pumps of the plunger type which force the oil contained in the pump body to the bearing in measured quantities.

RA PD 85962

Figure 28. Types of lubrication systems.

c. Dip Lubricating System. In dip lubrication (fig. 27), some rotating parts, such as a gear or a wheel, is partially submerged in oil. The oil adheres to it as it rotates and is carried directly to the surfaces to be lubricated. Typical examples are timing gears or chains. It often is used in combination with other oil circulating systems.

d. Gravity Circulation Lubrication. The gravity circulation system (fig. 28) is similar to the systems of splash, splash circulation, and dip, in that it does not use a pump as the source of oil pressure. As the name implies, advantage is taken of the natural laws of gravity to conduct oil from an elevated source of supply to the various parts to be lubricated. This usually is accomplished by having a supply tank located well above the level of the bearings to be lubricated. From this tank, oil is conducted through various lines, etc, to the desired points, some type of metering arrangements to give the desired rate of flow being generally incorporated. Sometimes such a system is accompanied by a recovery unit which is simply a sump or reservoir where the surplus or used oil is collected after having performed its lubricating function. From this sump, the oil can be returned to the elevated reservoir by means of a pump.

e. Pressure Circulation System. In a pressure circulation system, a pump draws the oil from the supply container or reservoir and circulates it under pressure to the various lubrication points on the machine. If all moving parts or bearings are supplied, the system also may be referred to as a full-pressure lubrication sys- system. The speeds and loads handled by the bearings in modern internal combustion engines demand positive delivery of the oil under considerable pressures to most of the moving parts, and the pressure circulation lubrication system is the method in most common use at the present time. On in-line engines, the oil reservoir generally is located in the bottom of the crankcase and all unused oil drains back into it by gravity. This lubricating method is known as the wet sump system.

39. Oil Pumps

a. General. The gear pump, the vane pump, and the plunger·pump (fig. 29) are three general types of pumps in common use on automotive materiel. The oil pump of an engine generally is located in the lower part of the crankcase where it is constantly submerged in oil and primed ready to start pumping on the first turn of the engine. When used on a dry sump engine to transfer oil which collects in the sump to the oil reservoir, the pumps are required to maintain only sufficient pressure to overcome the friction in the pipe conducting the oil back to the reservoir. When used for pressure lubrication, pumps are usually of such capacity that they will maintain an oil pressure of from 15 to 80 pounds per square inch on the bearings and circulate the entire crankcase capacity from 5 to 10 times per minute under normal operating conditions. Pumps are built with either a bypass or pressure relief valve as shown in the gear pump, or one is provided in the oil line (fig. 29). This construction not only prevents excessive pressures in the lubrication system but also allows the pump to be built with sufficient overcapacity to maintain proper oil pressure even though the bearings or the pump may become considerably worn.

b. Gear Pumps. A gear pump (fig. 29) consists of two meshed gears housed in the pump body, one gear driving the other. As the gears revolve and a tooth moves out of a space on the inlet side of the pump, oil enters this space and is carried around to the outlet side of the pump. Here a tooth again enters the tooth space displacing the oil and forcing it out of the pump outlet. The capacity of such a pump is determined by the size of the gears, the fit of the gears in the body of the pump, and the speed of rotation of the gears. If the gears do not mesh with each other or fit the body of the pump closely, the oil will leak past the gears back to the inlet side of the pump and pressure and capacity will be lost. If a gear pump is disassembled completely or drained, it may be necessary to prime the pump before again putting it into operation, particularly if the pump is located above the level of the oil in the reservoir.

c. Vane Pumps. A vane pump (fig. 29) consists of a cylindrical impeller which is set "off center" so that it almost touches one side of the pump housing. The impeller is not eccentric, but the vanes which are set into it have eccentric motion. As the impeller turns, the vanes are forced outward by springs which hold them in contact with the pump body at all times. Oil, drawn in after one of the vanes through the entrance, is trapped by the following vane. As a vane is rotated to the opposite side of the pump, the space between the impeller and the pump body becomes smaller. This pushes the vane into the rotor against spring pressure and forces the trapped oil out through the outlet. While one space is emptying, the other is filling.

d. Plunger Pumps. A plunger pump (fig. 29) is generally a cam-driven, single-cylinder pump and is operated by the camshaft. The plunger or piston is held against the cam by a spring. The plunger is pushed into the cylinder on its pressure stroke by the rise of the cam, and is returned to the suction stroke by the spring which causes the plunger to follow the drop of the cam. Spring-loaded check valves are used to control the flow of oil. The plunger type pump is used mostly in splash lubrication systems where it acts as an oil circulator pumping oil from the oil pan to the oil troughs.

40. Oil Lever Indicators

The dipstick is the simplest and most common method of determining the amount of oil in a crankcase or reservoir. The dipstick consists of a graduated rod which is suspended into the oil pan or reservoir. In order to obtain a clear reading, the dipstick should be withdrawn, wipea off, reinserted carefully, and again withdrawn. A correct reading cannot be obtained if a dipstick is withdrawn while an engine is running, nor immediately after the engine is stopped. Sufficient time must be allowed for the moving oil to drain back into the reservoir. Some model engines call for a check while running at idle. Individual lubrication orders show correct methods.

41. Pressure Gages

A pressure gage (fig. 30) is used to indicate whether the lubrication system is in operation. It is mounted on the instrument panel and calibrated in pounds per square inch. Most pressure gages are actuated by the pressure of the air trapped above the oil in a very small tube connecting the gage to the lubricating system.

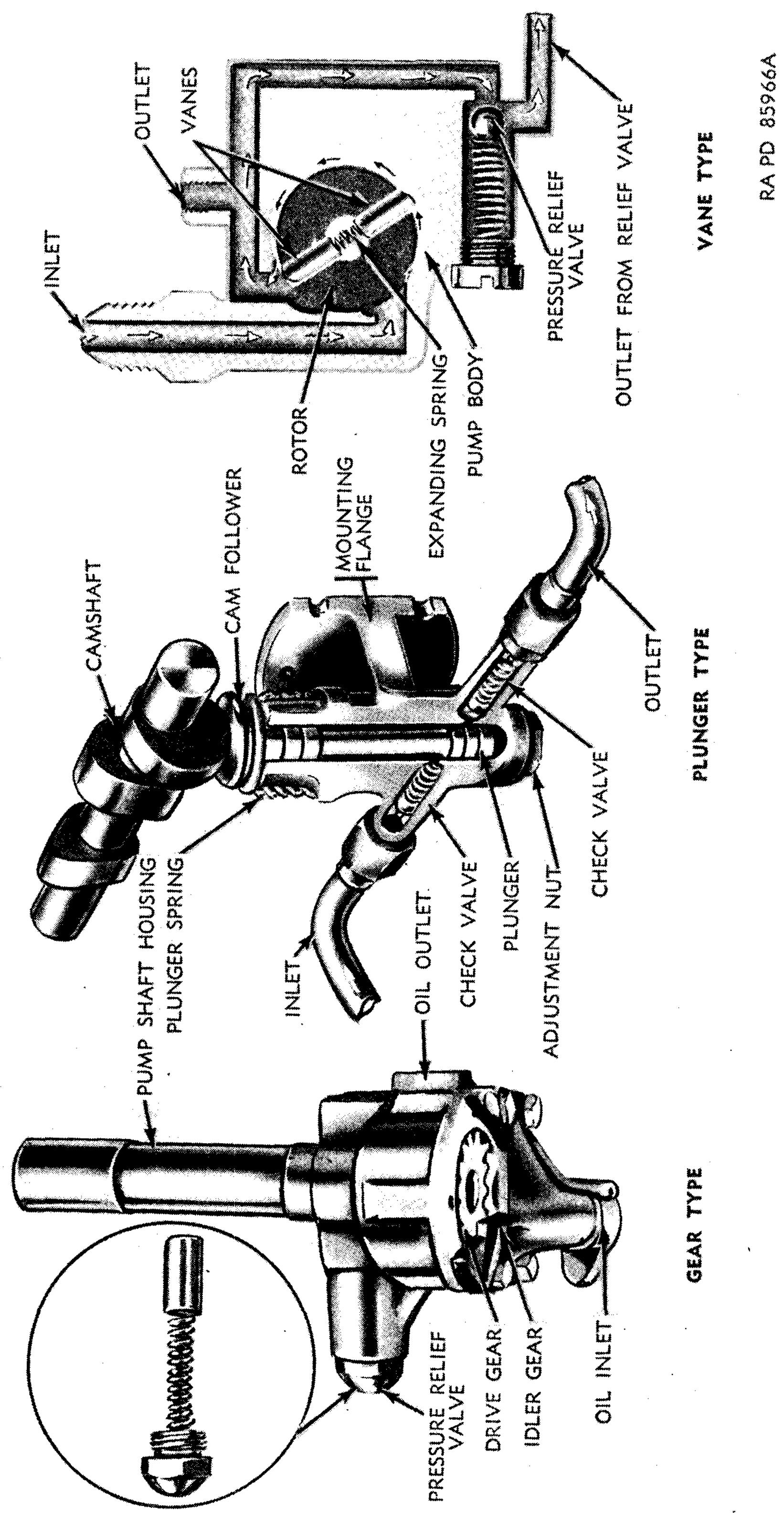


Figure 29. Various types of oil pumps.

The gage consists of a flat metal tube bent into the shape of three-quarters of a circle. One end of the tube is fixed to the gage case and is connected by a tube to the lubrication system, while the other end is sealed and linked to the sector of a gear meshing with a pinion on the pointer shaft. As pressure increases in the circular tube, it straightens slightly and turns the gear sector. This in turn rotates the pinion, pointer shaft, and pointer which indicates the pressure on the dial. Electrically operated warning lights for indicating oil pressures are used in combat vehicles. Thes lights register only abnormal pressures; too high or too low.

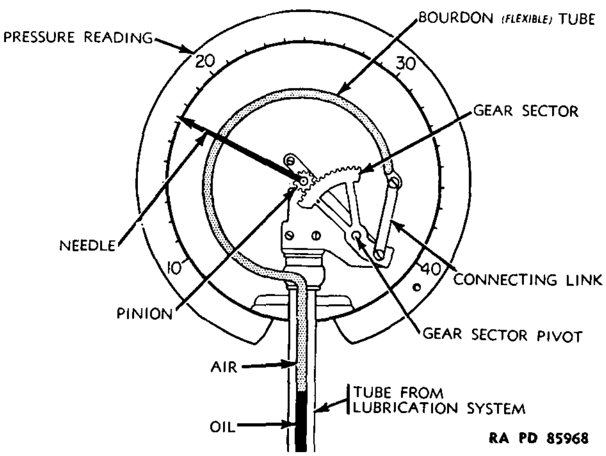


Figure 30. Construction of a pressure gage.

42. Temperature Gages

Occasionally, on heavy-duty engines, oil temperature gages are provided. This type gage is operated by the vapor pressure caused by the expansion of a fluid contained in a bulb immersed in the crankcase oil. As the temperature of the oil increases, the fluid vaporizes and the pressure operates a gage calibrated for temperature on the instrument panel.

43. Oil Filtering Devices

a. Strainers. Most manufacturers of in-line and V-type engines put at least one oil strainer or screen in the lubrication system (figs. 31 and 32). This is usually a fine-mesh bronze screen located so that all oil entering the pump from the oil pan must flow through it. The strainer will usually be hinged to the oil pump inlet so that it floats on top of the oil. Thus, all

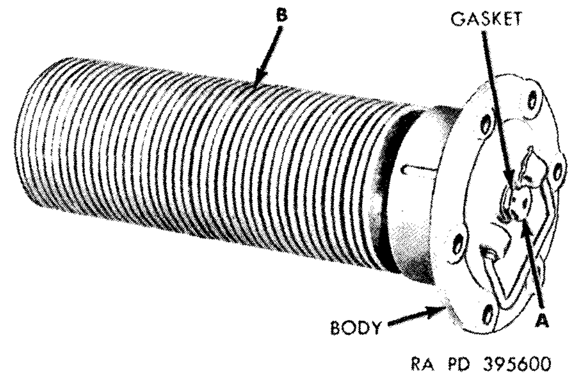


Figure 31. Oil, filter.

oil taken into the pump comes from the surface. This prevents the pump from drawing oil from the bottom of the oil pan where dirt, water, and sludge are likely to collect.

b. Oil Cleaners (Filters). The oil cleaner or filter is placed in the oil line above the pump (fig. 38). It filters the oil and removes most of the impurities that have been picked up by the oil as it has circulated through the engine. Some filters, called full-flow filters, are designed to handle the full output of the oil circulating pump, and all of the oil passes through them before being distributed to the engine parts. Other types divert only a small quantity of the oil each time it is circulated and, after filtering it, return it directly to the oil pan. A typical oil filter is shown in figure 33. The filtering element consists of an arrangement of screens and a filtering material capable of retaining impurities as the oil is forced through. For this reason, most filters are provided with relief or bypass valves which allow the oil to flow around the filter when the back-pressure caused by clogging is greater than the tension of the relief-valve spring. Some filters must be replaced after they are clogged; in others, the filter element can be removed and cleaned.

c. Replacement of Cartridges. The frequency of replacement of the filter cartridge in the removable element type depends upon a great many factors, including atmospheric conditions, the presence of dust and dirt in the air, the mechanical condition of the engine the temperature and loads under which the engine is operated, and the efficiency of the filtering medium itself. Barring accident disk-type filters have a practically indefinite life, but the handle of hand-operated filters should be given two or three complete turns periodically where prescribed by applicable lubrication order and technical manual. Other filters or replaceable elements should be replaced periodically, where prescribed, or oftener if they become plugged or show signs of grit or sludge on the filtering elements. Specific instructions given in the pertinent lubrication order or technical manual for any item of materiel

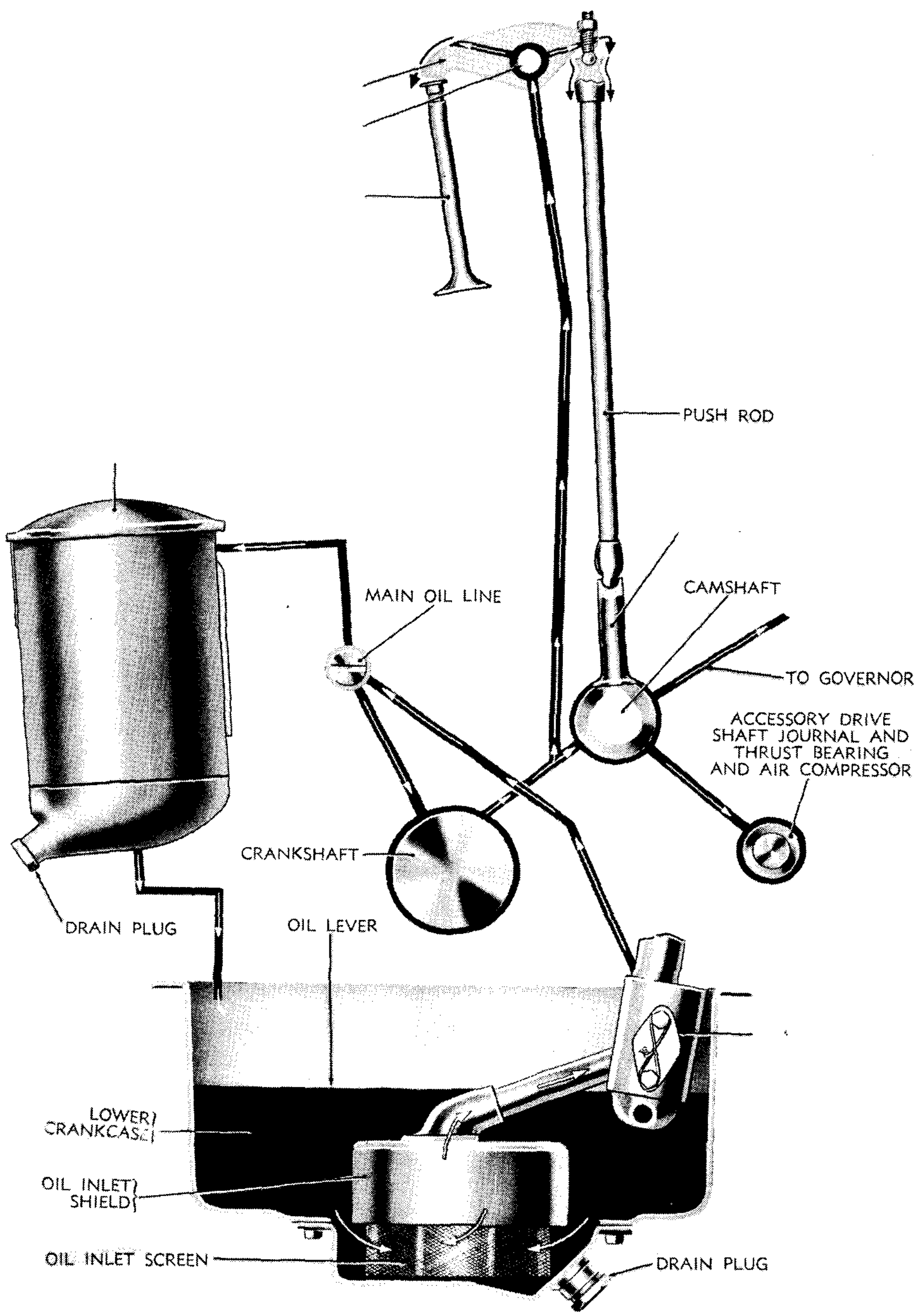


Figure 32. Lubrication system of engine.

should be followed. Prescribed periodic filter service includes checking the oil filter connecting lines for clogging, draining accumulated sedment, and replacement of dirty filter cartridges. For all practical purposes, the value of the oil filter is more dependent upon the cartridge being replaced when required than upon the specific efficiency of the filtering element itself. The replacement of the renewable-type filter element is extremely important if the use of filters is to be fully justified, because if the element is allowed to remain after its useful life has expired, a false sense of security is imparted to the operator. However, the life of a filter unit is difficult to determine in terms of specific miles or hours because of the innumerable variables which influence cartridge life. In any event, when a filter cartridge has accumulated enough contaminating materials to reduce its efficiency, it should be replaced. A fact seldom appreciated is that the more efficient a filter element is, the more frequently it may require replacement. In other words, a fine filter will remove more contaminants from a liquid in a given time than will a coarse filter.

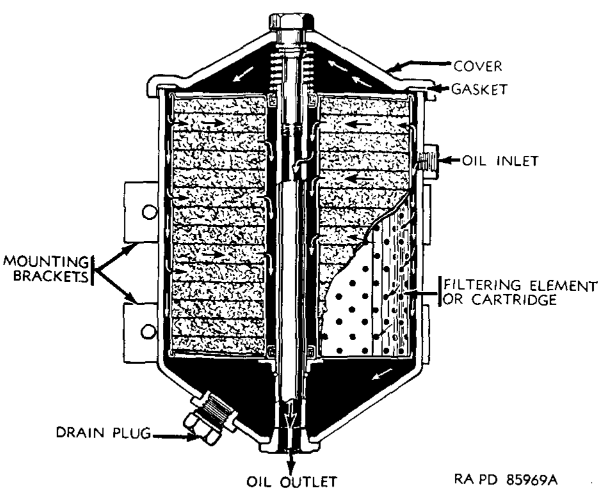


Figure 33. Oil filter with removable filtering element.

44. Oil Cooling

a. Engine Oil Cooler. The oil cooler is used to prevent the oil temperature from rising too high in hot weather. The cooler (fig. 34) makes use of the liquid in the cooling system. It provides a more positive means of controlling oil temperature than does cooling by radiation of heat from the oil-pan walls. The cooling unit is made up of a core and a housing. The core through which the oil circulates is of cellular or bellows construction, and is built to expose as much of the oil as possible to the coolant which circulates through the housing. The cooler is attached to the engine so that the oil will flow through the cooler after passing through the pump. The oil leaves, cooled by the liquid in the cooling system, and enters the oil passages to the engine parts.

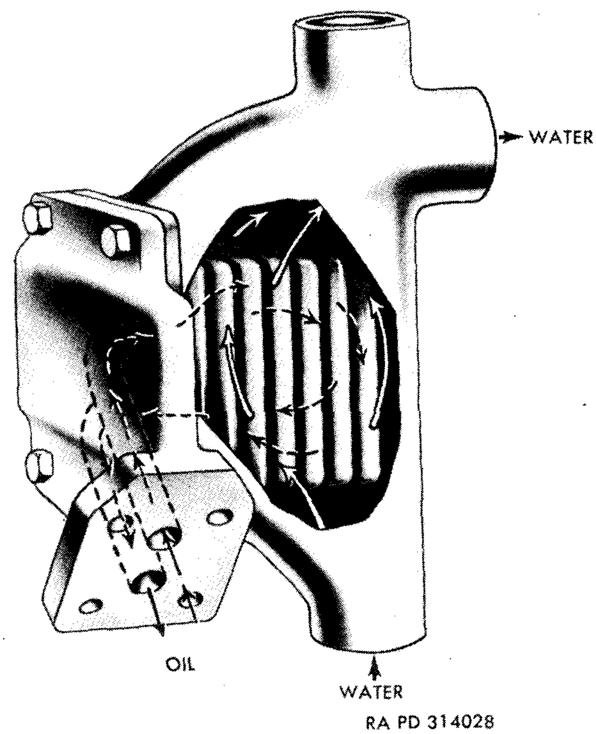


Figure 34. Oil temperature cooler.

b. Radiator-type Oil Cooler. The types of oil cooler used with some combat vehicles consist of a radiator through which air is circulate by movement of the vehicle or by the cooling fan. Oil from the engine is passed through this radiator and back to the engine and to the oil supply. This radiator acts only to cool the oil and does not function as a regulator. Some coolers can moderate both engine and transmission oils if they have separate cores for each. Figure 35 shows the flow of oil through a typical cooling system.

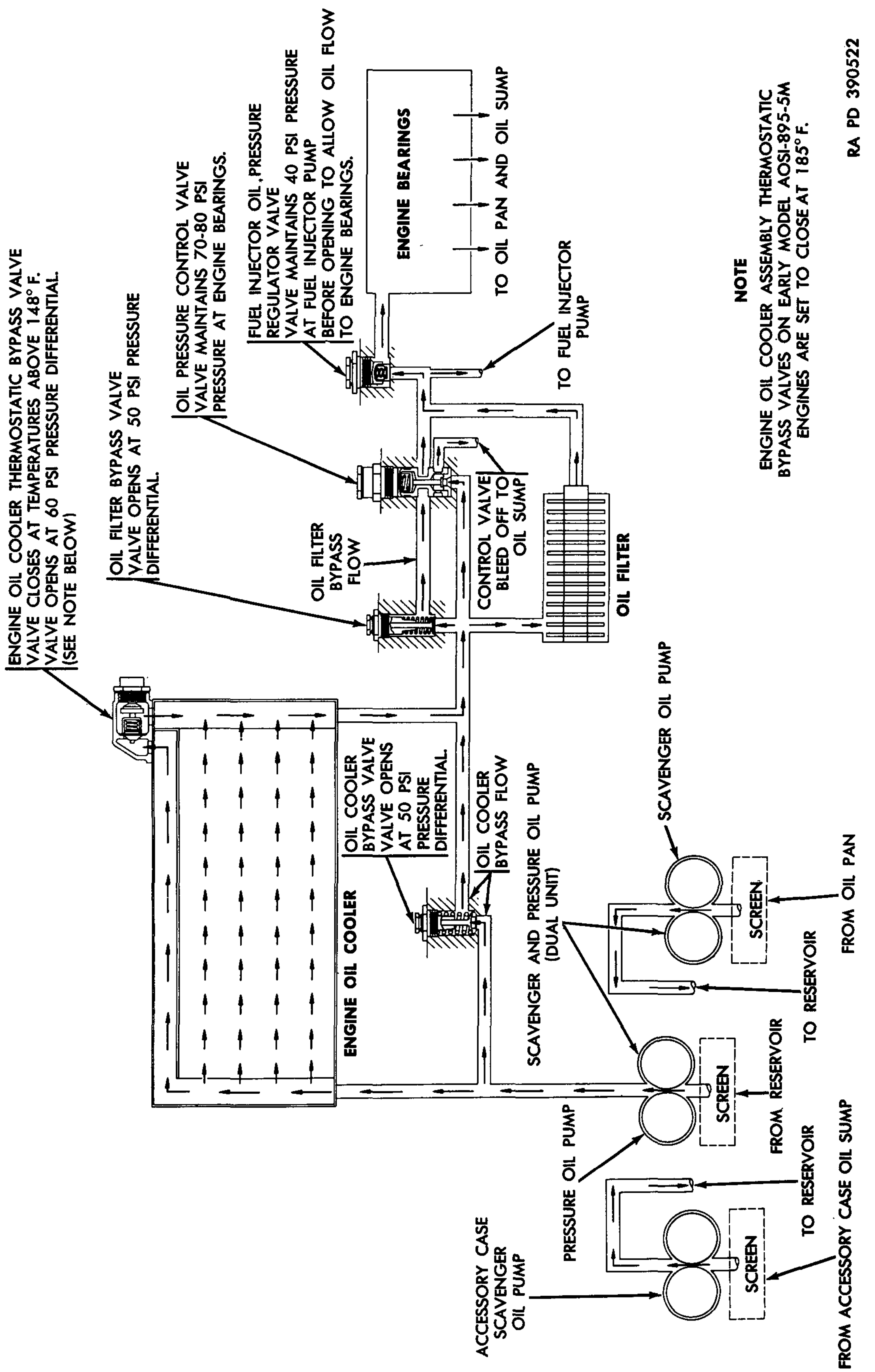


Figure 35. Oil flow schematic.

c. Crankcase Ventilators. Gasoline vapor and steam are harmful if they are allowed to remain in the crankcase oil. Steam will condense and mix with the oil to form a sludge. Gasoline vapor will condense and dilute the oil. There are two methods of removing these vapors from the crankcase. The first, or nonpositive, method consists of a breather tube which depends on the flow of air past its open end to remove the vapors. The second, or positive, method utilizes engine intake manifold pressure to circulate air through the crankcase.

(1) *Breather tube.* One end of the breather tube opens into the crankcase above the oil level; the other end extends down under the vehicle where there is sufficient airstream to create a low pressure at the open end of the tube (fig. 36). The pressure differential between the crankcase and the open end of the tube is sufficient to force any vapors out of the crankcase. Some breather tubes are placed so that air from the cooling fans will flow through the tube and create a pressure differential.

(2) *Positive method.* In the positive method, air is drawn through the engine by intake manifold vacuum; that is, the intake manifold vacuum draws air through the crankcase so that vapors are swept out of the crankcase. The air may follow either of two paths. In one, air is drawn directly into the crankcase through a filter or crankcase breather (fig. 37) similar to a carburetor air cleaner. After circulating through the crankcase and picking up vapors, the air is forced upward and out of the engine through an opening into the valve cover. It is then drawn through a tube connected to the intake manifold. This tube has a restriction to regulate the amount of vapor being drawn into the manifold, and thus minimizes the effect of the vapor on the fuel-air ratio of the mixture being delivered to the manifold by the carburetor. In the second path, air enters through a filter in the crankcase breather which is mounted on top of the valve cover. This breather also serves as a filler point for adding oil to the engine. In operation, air is taken through the shutoff valve (which is open when the ventilating system is operating), through the filter, and into the valve compartment. From there it passes down into the crankcase and is with drawn from the crankcase through a tube connected between the crankcase and the intake manifold. This second arrangement is in general use in waterproofed vehicles. In connection with crankcase ventilation, an engine should be operated at a coolant temperature in excess of 140° F. so that the vapors in the crankcase will stay in a gaseous state, and those that are already condensed will be vaporized and rise above the oil, where they can be removed.

45. Crankcase Lubrication

a. Drain Intervals. Crankcase drain intervals for engines are prescribed by pertinent lubrication orders for each item of equipment. It will be noted that drain intervals prescribed are for normal operating conditions and may be reduced by one-third to one-half when operating under unusual conditions which will cause excessive sludge or undesirable elements in the engine oil. Unusual conditions are excessively high or low operating temperature, prolonged periods of high speed, continued operation in sand or dust, immersion in water, or exposure to moisture which may contaminate or quickly destroy the lubricating and protective qualities of the lubricant.

b. Changing Crankcase Oil. Drain crankcase oil when engine and oil are at operating temperature. If the engine oil and the filter element indicate the presence of an unusual amount of engine sludge, water, or rust, the crankcase is to be flushed with an engine-conditioning oil.

(1) Remove filter cover, discard element, and install cover.

(2) Fill crankcase to low mark with an engine-conditioning oil. Run engine for 30 minutes at a fast idle with engine temperature held to 185° F.
(3) Just prior to stopping engine, return to normal idle for 1 minute. Repeat operation three times.
(4) Stop engine and drain oil.
(5) Remove oil filter cover and wipe interior of filter housing clean, then install new filter element. Be sure gasket is in serviceable condition.
(6) Fill crankcase with the prescribed oil. Refer to applicable technical manual or lubrication order for crankcase capacity.

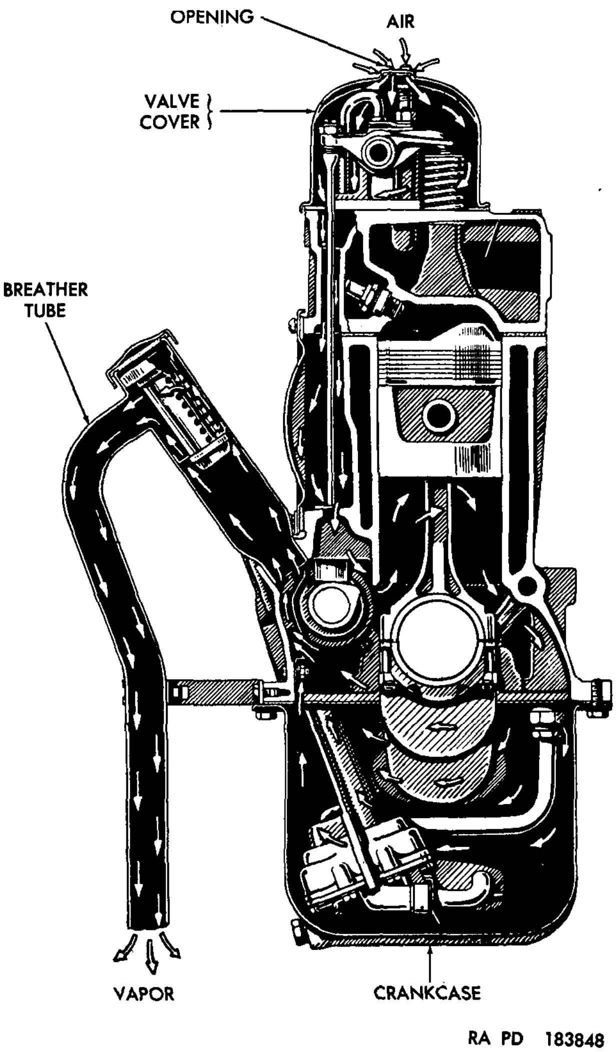


Figure 36. Crankcase breather tube.

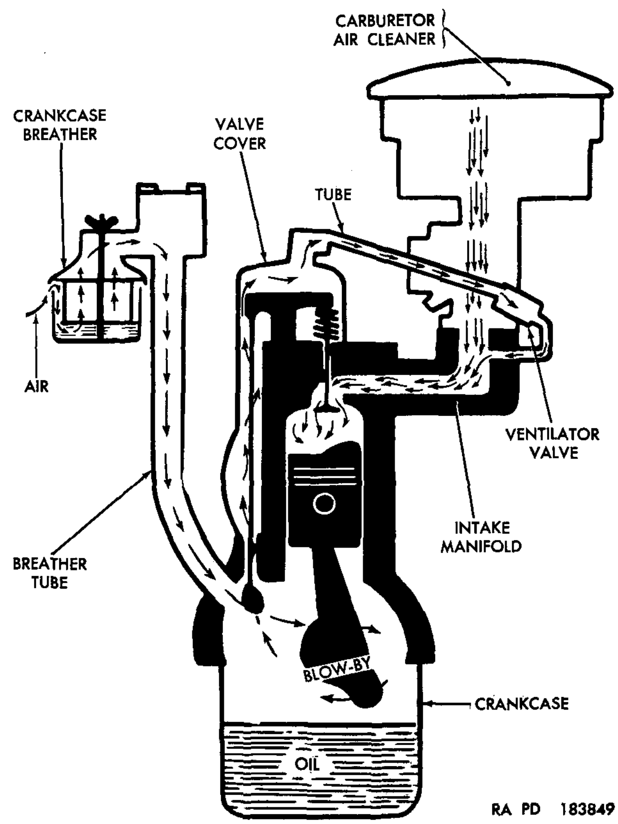


Figure 37. Position crankcase ventilation.

Section II. ACCESSORIES

46. Air Cleaners and Breathers

Air cleaners generally use oil and therefore are serviced at the same time and by the same personnel who do the lubrication work. Air, if not filtered, will carry dirt and dust into the cylinders with resulting abrasive action to cylinder walls, pistons, and other parts. Air cleaners are generally the oil-bath type (fig. 38). In these devices, a reservoir of oil is provided and the incoming air is brought into contact with the surface of the oil. As the incoming air strikes the surface of the oil, the heavier particles of dust are deposited in the bath. The air reverses its direction and picks up minute particles of oil which it deposits, together with remaining lighter particles of dust, on a filter through which it passes before entering the engine. Some engines are equipped with dry-type air cleaners. These filters may be cleaned by gently tapping the cartridge and blowing off with compressed air.

47. Coolants, Pumps, and Fans

a. Need for Cooling. All internal combustion engines are equipped with some type of cooling system because of the high temperatures they generate during operation. High temperature is necessary since it results in the high gas pressures which act on the head of the piston. Without high temperature, power cannot be produced efficiently. However, it is not possible to use all of the heat of combustion without producing harmful results. There is no accurate method of measuring the temperature in the combustion chamber during the burning of fuel, but it has been determined to be about twice the temperature at which iron melts. Therefore, if nothing is done to cool the engine during operation, valves will burn and warp, lubricating oil will break down, pistons and bearings will overheat, and pistons will seize in the cylinders.

(1) Heat created by combustion must be dissipated by the cooling system. Other important, but often overlooked, mediums of cooling an internal combustion engine are the fuel and the lubricant. Cooling is not their primary purpose, but they nevertheless dissipate and appreciable amount of heat. Additional heat is lost through the exhaust. There must be careful control over the amount of heat dissipated because thermal efficiency is proportional to the operating temperature of the engine. For liquid-cooled engines, the ideal operating temperature is just below the boiling point of the coolant used if this temperature is not so high that it breaks down the lubricant.

(2) Cooling systems usually are classified as liquid or air. Diesel and gasoline engine cooling systems are similar mechanically; however, the diesel generates less heat and it is not necessary that the cooling capacity of its cooling system be as large as that of a gasoline engine. Diesel engines usually have the same size radiators as gasoline engines, but the speed and size of the fans are reduced.

b. Coolants. Water is the most widely used coolant for liquid-cooled engines. It should be clear and soft. Water is usually available, it costs practically nothing, and its boiling point falls within the range of efficient operating temperatures. The main objection to the use of water is that it has a high freezing point and cannot be used alone at temperatures below 32° F. Ethylene glycol is used in some liquid-cooled aircraft engines where the cooling system is sealed. Its advantages are that it does not evaporate in use, has a higher boiling point than water, does not require renewal unless lost through leakage. TB ORD 651 covers the use of approved antifreeze compounds for military vehicles.

c. Additives.

(1) When a vehicle is operated where the atmospheric temperatures fall below 32° F., an antifreeze solution must be added if water is used as the cooling liquid. The solution in common use is ethylene glycol, prepared for use and called arctic compound. Ethylene glycol (antifreeze compound) has a

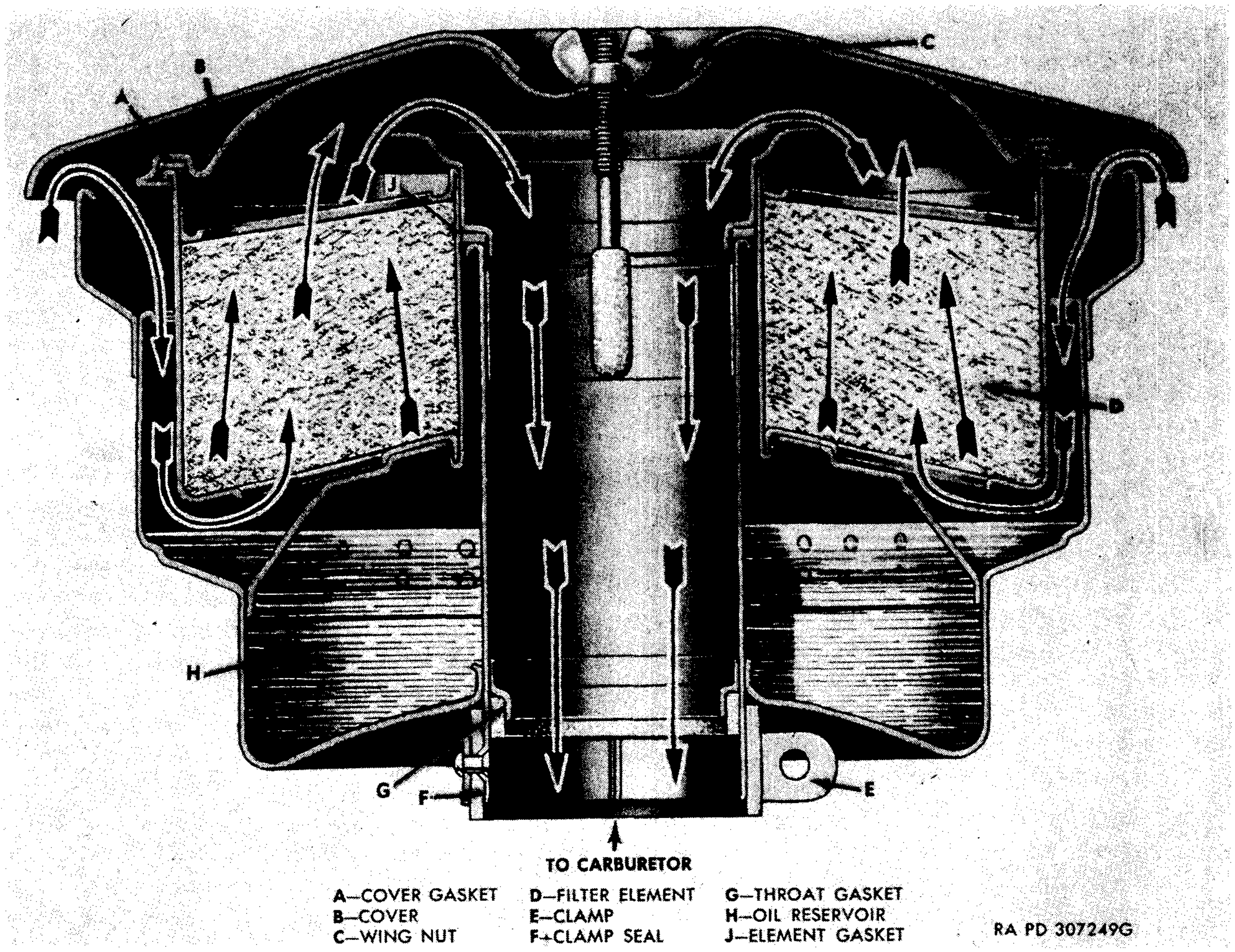


Figure 38. Air cleaner.

high boiling point, does not evaporate in use, is noncorrosive, has no odor, and gives complete protection when used in the proper amount. The maximum protection from freezing is obtained from a solution of 40-percent water and 60-percent ethylene glycol antifreeze compound. This mixture gives protection at temperatures as low as –65° F. A higher concentration of ethylene glycol antifreeze compound will only raise the freezing point of the solution. If 100-percent ethylene glycol antifreeze compound is used, the freezing point is about 10° F. Other antifreeze solutions, however, do not show this increase of freezing point with increasing concentration. For instance, methyl alchol freezes at –144° F., while ethyl alcohol freezes at –174° F.

(2) The cooling system must be free of rust and scale in order to maintain its efficiency. The use of inhibitors or rust preventatives will reduce or prevent corrosion and the formation of scale. Inhibitors are not cleaners and do not remove rust or scale already formed; they are merely added to the cooling liquid to arrest further rust or corrosion. Most commercial antifreeze solutions contain an inhibitor. If water alone is used as the coolant, an inhibitor should be added.

d. Flow of the Coolant. A simple liquid cooling system consists of a radiator, coolant pump, piping, fan, thermostat, and a system of jackets and passages in the cylinder head and cylinder block through which the coolant circulates. Some engines are equipped with a water distribution tube inside the cooling passages that directs additional coolant to the points where temperatures are highest. Cooling of the engine parts is accomplished by keeping the coolant circulating and in contact with the metal surfaces to be cooled. The pump draws the coolant from the bottom of the radiator, forces it through the jackets and passages, and ejects it into the upper tank on top of the radiator (fig. 39). The coolant passes through a set of tubes to the bottom of the radiator and again is circulated through the engine by the action of the pump. A fan draws air over the outside of the tubes in the radiator and cools the liquid as it flows downward. It should be noted that the liquid is pumped through the radiator from the top down. The reason for this direction of flow is that thermosiphon action aids the pump to circulate the coolant. This simply means that as the coolant is heated in the jackets of the engine, it expands, becomes lighter, and flows upward to the top of the radiator. As cooling then takes place in the radiator tubes, the coolant contracts, becomes heavier, and sinks to the bottom. This desirable thermosiphon action cannot take place if the level of the coolant is permitted to become low.

e. Engine Water Jacket.

(1) The water passages in the cylinder block and cylinder head form the engine water jacket (fig. 39). In the cylinder block, the water jacket completely surrounds all cylinders along their full length. Within the jacket, narrow water passages are provided between cylinders for coolant circulation. In addition, water passages are provided around the valve seats and other hot parts of the cylinder block.

(2) In the cylinder head, the water jacket covers the combustion chambers at the top of the cylinders and contains water passages around the valve seats when they are located in the head. The coolant flows from the cylinder block up into the cylinder head through passages called *water transfer ports.* A tight seal at the ports between the cylinder head and block is very important. The watertight seal at the ports, as well as the gastight seal at the combustion-chamber openings, is obtained with one large gasket called the *cylinder-head gasket.* It has two functions to perform: it must seal the extreme pressures of combustion within the cylinders and, at the same time, maintain a tight seal in the coolant joints at the water transfer ports.

f. Radiator. Radiators for automotive vehicles using liquid-cooled systems consist of two tanks (fig. 39) with a core between them to form the radiating element. The upper tank contains an outside pipe called the *radiator inlet* and usually has a coolant baffle inside and above or at the inlet opening. The radiator filler neck is generally attached to the upper part of the upper tank and has an outlet to the overflow pipe. The lower tank also has a pipe opening (radiator outlet).

(1) The upper tank collects incoming coolant and distributes it across the top of the radiator core. The baffle in the tank assists in distributing the coolant to the water tubes and also prevents coolant from being thrown out of the radiator. The overflow pipe provides an opening from the radiator for escape of coolant or steam that otherwise might cause excessive pressure, which would rupture the thin metal walls of the radiator. The lower tank collects coolant flowing from the core and discharges it through the radiator outlet.

(2) Some liquid-cooling systems have tubular radiator cores which consists of a large number of vertical water tubes and many horizontal air fins around the tubes. Water passages in the tubes are narrow, and the tubes are made of thin metal. The core divides the coolant into very thin columns or

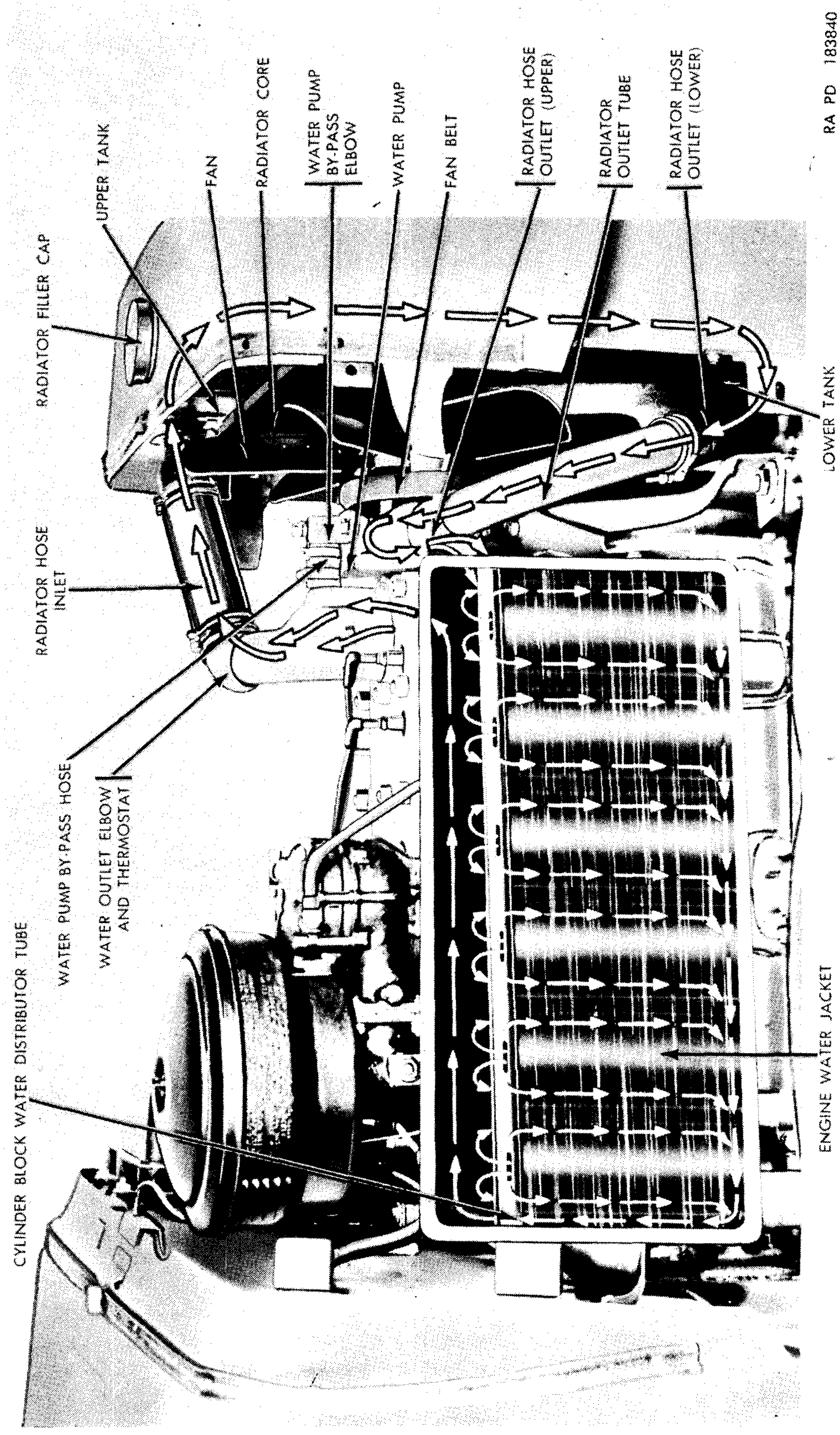


Figure 39. Cooling system circulation.

ribbons, thus exposing a large radiating surface to the volume of liquid to be cooled.

g. Water Pump. All modern cooling systems have water pumps to circulate the coolant. The pump (fig. 40), usually located on the front or side of the engine block, receives coolant from the lower tank and forces it through the water jacket into the upper tank. The pump is a centrifugal type and has an impeller with blades, which force the coolant outward as the impeller rotates. The pump and fan usually are driven from a common V-belt which is driven by a pulley at the front end of the crankshaft. Advantages of the centrifugal pump are that it is inexpensive, circulates great quantities of liquid for its size, and is not clogged easily by small particles of dirt. Another advantage is that it permits limited circulation by thermosiphon action even if the engine is not running. Some water pumps are not lubricated, while others take GAA grease quarterly or every 750 miles.

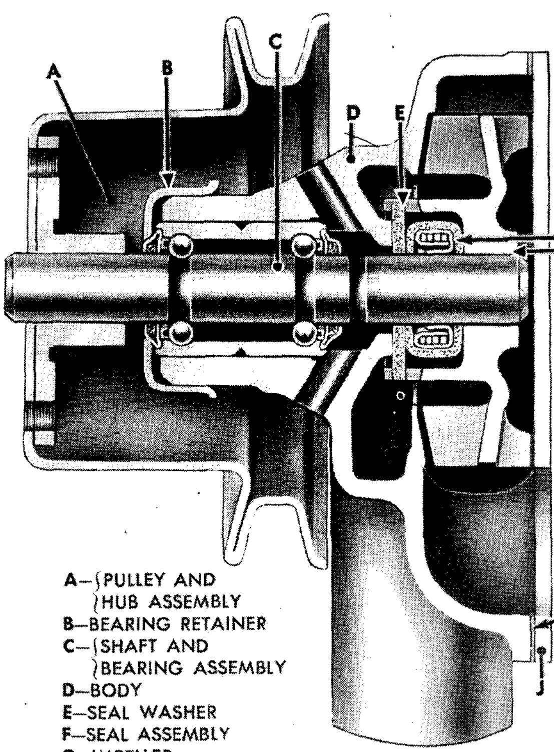


Figure 40. Water pump.

h. Fan and Shroud. The fan circulates a large volume of air through the radiator core. In addition to removing heat from the radiator, this flow of air also provides some direct air cooling of the engine. Military vehicles are often equipped with a funnel-like structure (shroud) around and behind the fan. The shroud directs the flow of air for most effective cooling.

i. Thermostat. The water pump starts the coolant circulating through the system as soon as the engine is started, no matter how low the temperature, so a thermostat must be installed to insure quick warmup and to prevent overcooling in cold weather. A thermostat regulates engine temperature by automatically controlling the amount of coolant flowing from the engine block to the radiator core.

(1) The thermostat is merely a heat-operated unit which controls a valve between the water jacket and the radiator. A typical thermostat (fig. 41) consists of a flexible-metal bellows attached to a valve. The sealed bellows, which is expandable, is filled with a highly volatile liquid such as ether. When the liquid is cold, the bellows chamber is contracted and the valve is closed (fig. 42). When heated, the liquid is vaporized and expands the chamber. As the chamber expands, the valve opens (fig. 43). When the engine is cold, the thermostat is closed and the coolant is recirculated through the water jacket without entering the radiator. As the engine warms up, the valve slowly opens and some of the coolant begins to flow through the radiator, where it is cooled. Other types include a sealed copper bellows containing only air; another is bimetallic and for its operation depends upon the difference in coefficients of expansion of the two metals.

(2) The thermostat is located between the water jacket and the radiator, usually in the housing of the cylinder-head-water-outlet elbow (fig. 39). It should be constructed so that, if it

fails to function properly, it will fail in the open position, allowing free circulation of water through the engine.

(3) Some military vehicles are equipped with air inlet screens or shutters. They have no direct connection with the cooling system and are primarily for protection. However, they may be used to supplement or replace the action of a thermostat, and are operated either by hand or automatically by a thermostatic device. The shutters restrict the flow of cool air through the radiator when the coolant is below a predetermined temperature. When the coolant reaches the proper temperature, the shutters start to open.

j. Pressure Radiator Cap. Some cooling systems are sealed and use a pressure radiator cap (figs. 44 and 45) to close off the overflow-pipe opening. If the overflow pipe were open, the surging movement of the coolant as the vehicle moved would allow some of the coolant to overflow into the pipe and be lost. The pressure cap serves to prevent overflow loss of coolant during normal operation. It also allows a certain amount of pressure to develop within the system, which raises the boiling point of the coolant and permits the engine to operate at higher temperatures without coolant overflow from boiling. The cap contains two spring-loaded valves, normally closed, which seal the system. The larger is the pressure valve and the smaller is the vacuum valve. The pressure valve acts as a safety valve to relieve extra pressure within the system; the vacuum valve opens only when the pressure within the cooling system drops below the outside air pressure as the engine cools off. Higher outside pressure then forces the vacuum valve to open, allowing air to enter the system by way of the overflow pipe.

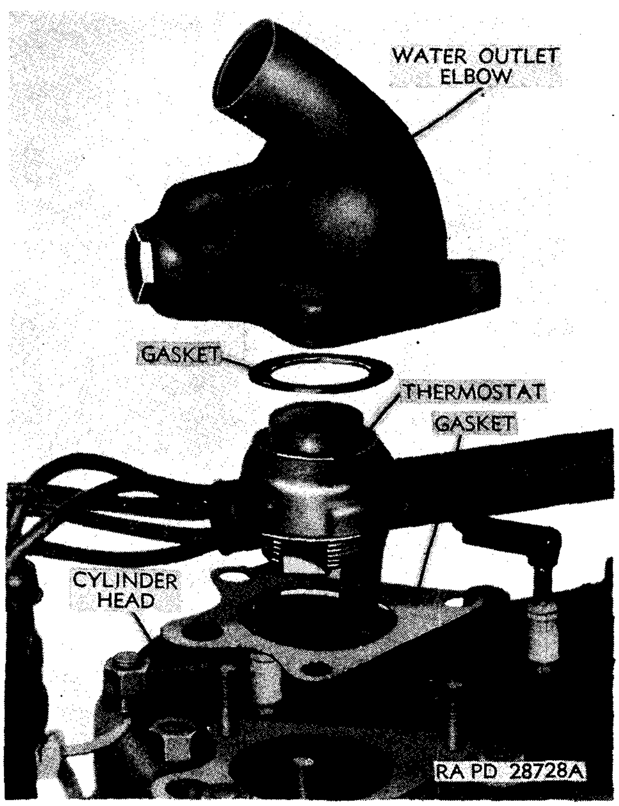


Figure 41. Thermostat.

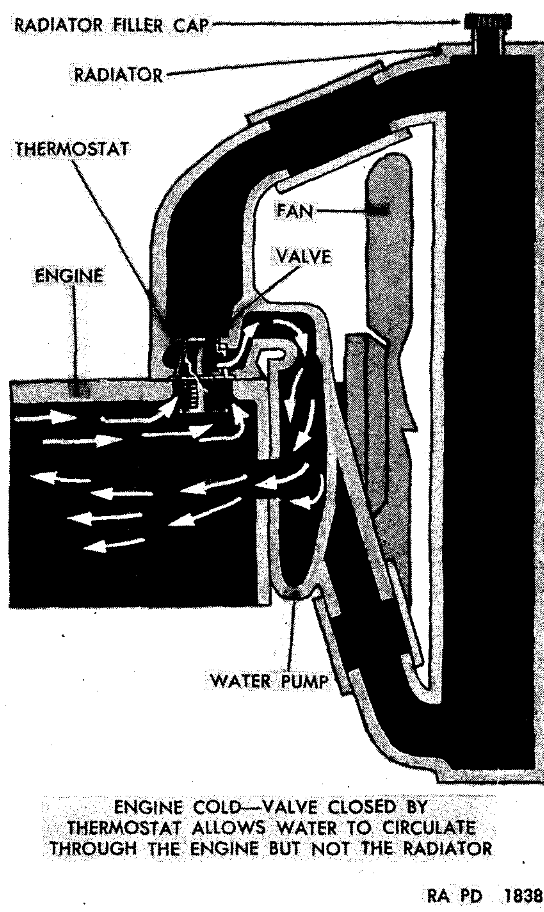


Figure 42. Thermostat closed.

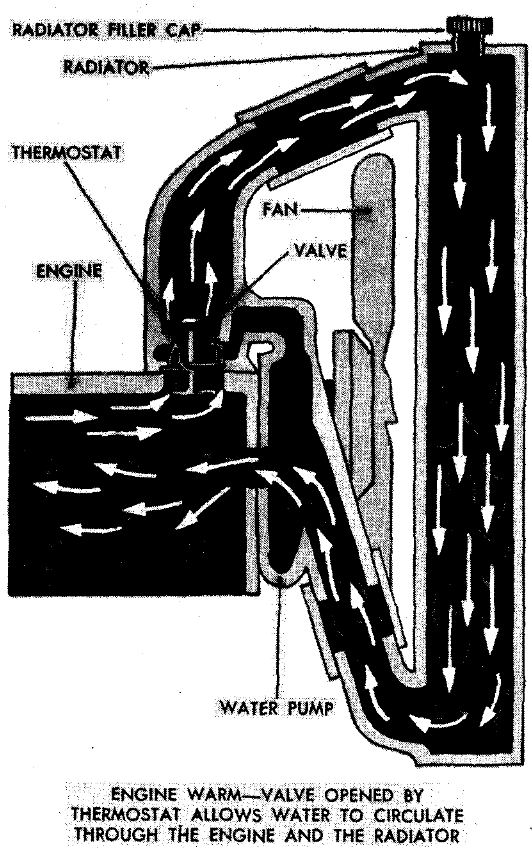


Figure 43. Thermostat open.

k. Overflow Tank. When the cooling system is equipped with an overflow tank, the pressure cap is placed on the tank instead of on the radiator, and a plain cap is used on the radiator. Overflow, or surge, tanks are special equipment for operation in hot or dry country. The coolant expands as it is heated and contracts as it cools; consequently, the level of the coolant in the radiator is constantly changing as the engine operating temperature changes. This condition is further aggravated when the temperature becomes high enough to change the water to steam. The expansion is much greater and the pressure is also increased. The overflow tank makes it possible to keep the radiator full at all times. Overflow from the radiator, caused by the expansion or surging of steam vapor within the cooling system, passes through a tube to the overflow tank. The pressure cap on the overflow tank controls the pressure within the system in the same manner as described in *j* above. The plain cap on the radiator effectively seals the radiator opening so that the only vent to the atmosphere is through the cap on the overflow tank. When the coolant cools off, it contracts and the pressure in the upper part of the radiator drops below atmospheric. The pressure in the overflow tank, which is maintained above atmospheric by the pressure cap, forces the liquid to return to the radiator to be recirculated through the engine.

48. Starters, Generators, Distributors, and Magnetos

a. General. Starters, generators, distributors, and magnetos must be lubricated according to pertinent lubrication orders. Care must be taken not to overlubricate them as they are electrical devices. Excess oil or grease is liable to find its way into windings, onto contact points, brushes, etc., which would cause insulation deterioration, short circuits, excessive arcing or sparking at brushes, etc.

b. Starters. Starters operate only intermittently and then only for short periods. They are generally equipped with oilless bearings. Some, however, are equipped with snap-top oil cups for one or both armature bearings and some for heavy duty are equipped with ball bearings. When equipped with oil cups, starters occasionally should receive a few drops of oil where directed in lubrication orders or technical manuals. Ball bearings used on starters ordinarily are packed with grease and require no lubrication between rebuilds.

c. Generators. There are two common types of bearing arrangements in generators (fig. 46)—ball bearings at both ends of the armature, and a ball bearing at the drive end and a plain bronze bushed bearing at commutator end. This bushing is lubricated by means of an oil cup on the commutator end of the generator. Generators should be inspected to determine whether lubrication service is required. Where the oil cup is present on the commutator end of the generator, it should be filled with 6

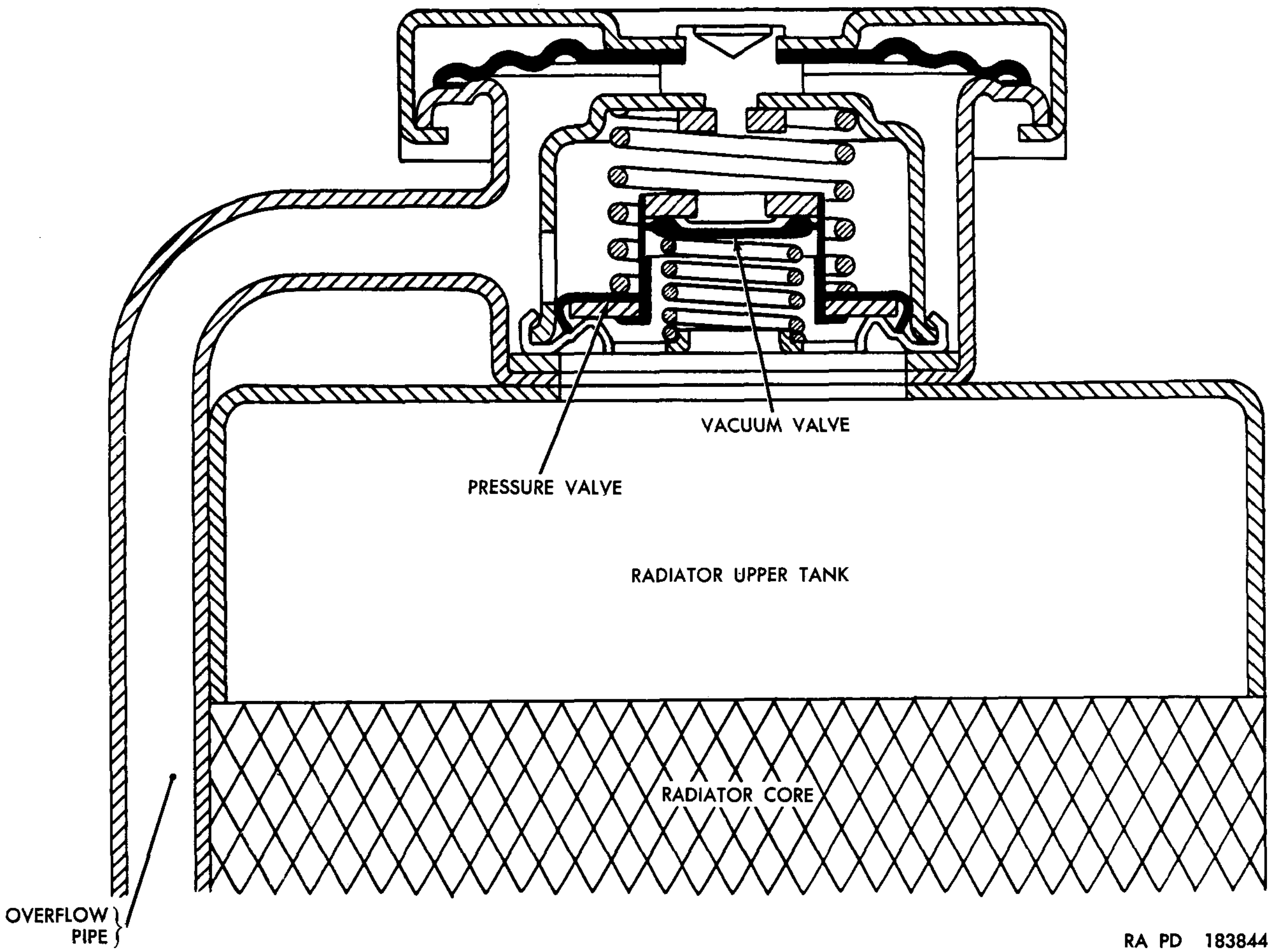


Figure 44. Pressure radiator cap.

to 8 drops of oil where prescribed by the lubrication order. Oil of the same grade used in the engine generally is used for lubrication regardless of the type of bearings. Do not overlubricate oil cups in generators.

d. Distributors. Distributors (fig. 47) commonly use plain bronze bearings lubricated by a single grease cup. A turn clockwise will force grease into the shaft bearing. The cap should be checked and kept filled with GAA grease. The felt in the top of the cam beneath the rotor should be lubricated with oil. Care must be taken not to overlubricate the felt as this will cause carbon deposits and short circuiting of the distributor points. The breaker cam must be wiped lightly with grease where directed in pertinent lubrication orders or technical manuals.

e. Magnetos. Ball bearings are used on shafts of most magnetos and generally are oil-lubricated through snap cover oilers. Some magnetos also incorporate an oil-saturated wick which maintains lubrication on the breaker cam. As with other electrical devices, care must be taken that overlubrication does not occur, as this may cause short circuit and other troubles. The lubrication instructions given in pertinent lubrication orders and technical manuals should be followed carefully.

49. Miscellaneous

Other parts of an engine require lubrication to keep them in working order. Some of these areas are—

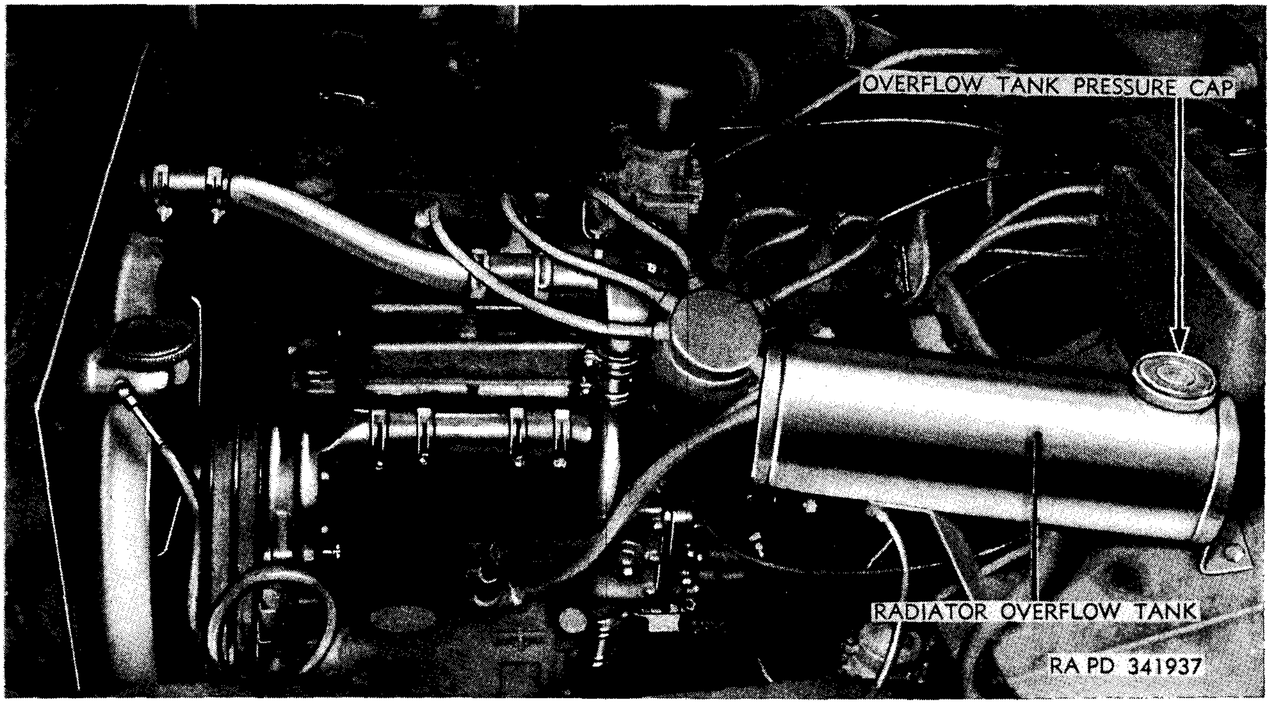


Figure 45. Overflow tank and pressure cap.

a. Governors. Most governors are of the centrifugal type and incorporate plain friction-type or ball bearings. These bearings generally are oil lubricated, the oil being automatically furnished from the engine crankcase.

b. Linkages. A number of controls linkages, levers, rods, flexible wires, etc., are always found on any engine. These have various connections and guides where friction can occur. Such parts must be lubricated with oil or grease following instructions in the pertinent lubrication orders or technical manuals.

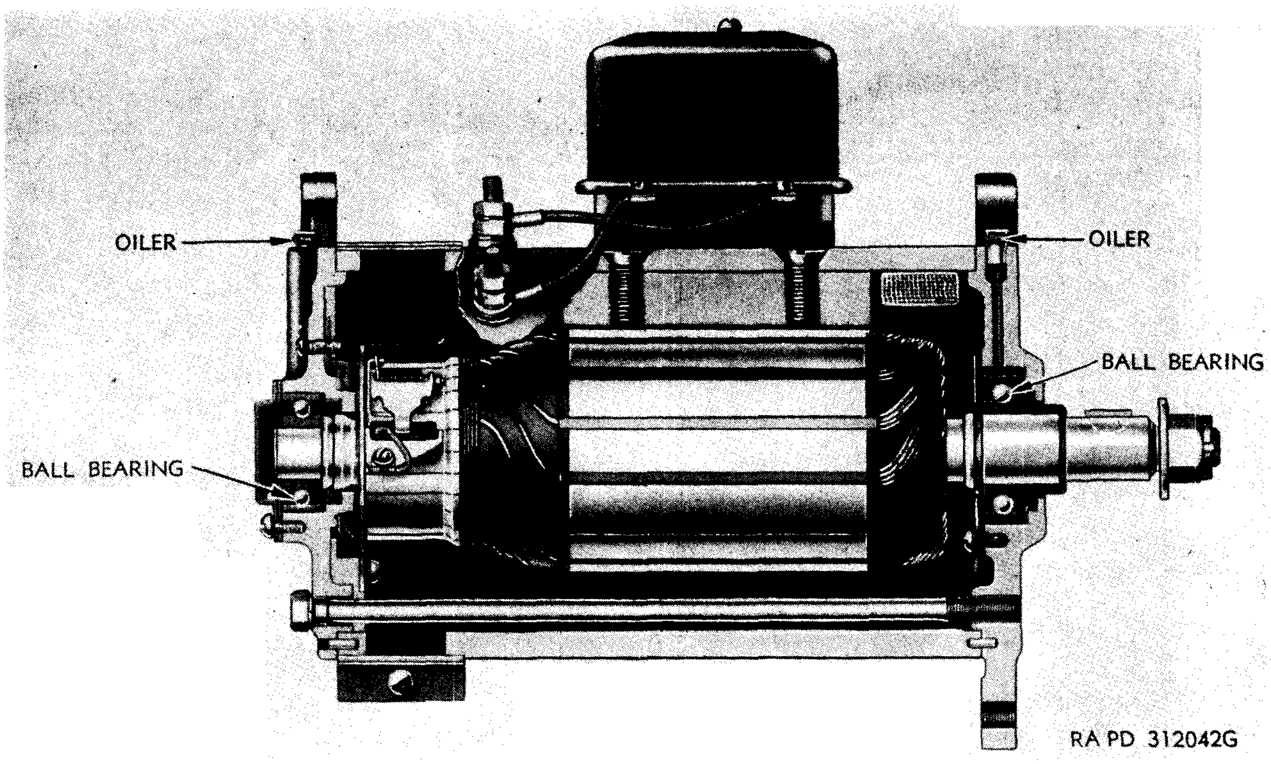


Figure 46. Cross section of typical generator.

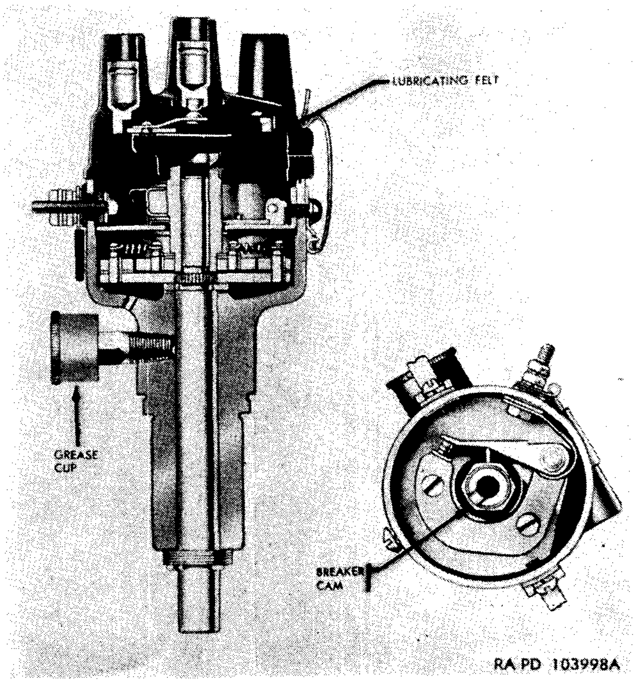


Figure 47. Typical distributor.

CHAPTER 7
AUTOMOTIVE MATERIEL; DRIVE MECHANISMS

Section I. CLUTCHES

50. General

Automotive clutches depend upon friction for their operation, whether it is solid friction as in a plate clutch, or fluid friction as in fluid couplings. A clutch provides a means of connecting and disconnecting the engine from the drive system.

51. Types of Clutches

a. Dry Clutches. The clutch assembly (fig. 48) is made of two faces, one which is attached to the engine and one which is applied to the drive system. These faces may be machined cast-iron or they may be covered with some suitable frictionable material. In either case no lubrication is required between the faces. Lubrication is needed in the pilot bearing, yoke, and release bearing so that the driven face will move freely into and out of contact with the driving face when the clutch pedal is released or depressed.

b. Fluid Clutches. The principle of this type of drive is illustrated by the action of two electric fans facing each other, one with the power on and one with the power off. As the speed of the power-driven fan increases, the flow of air transmits power to the motionless fan and it begins to rotate. The free-running fan gains speed until it is rotating almost as rapidly as the power-driven fan. The same action takes place in the fluid clutch except that oil instead of air transmits the power. The only parts of a fluid clutch (fig. 49) requiring lubrication are the bearings upon which the driving and driven shafts rotate. These bearings are oiled by the clutch oil.

c. Torque Converters. The torque converter (fig. 50) acts as both a clutch and a transmission. It uses fluid as a medium for transmitting motion and power. The converter consists of four major parts; a centrifugal pump driven by the engine, a coaxial three-stage rotor attached to the output shaft of the engine, a hydraulic housing, and reactor blades attached to the inside of the housing. Oil is forced against the blades of the rotor (fig. 50) causing it to rotate in the same direction as the pump. Reversing blades on the rotor change the direction of the oil after it has delivered its energy. The oil re-enters the pump with its motion corrected. The torque converter requires oil of very high stability because violent churning action at high temperatures takes place. Generally, a cooling radiator is required to keep the oil within safe operating temperatures. Pertinent lubrication orders must be followed when servicing a torque converter. The bearings are self-lubricated by the fluid being used.

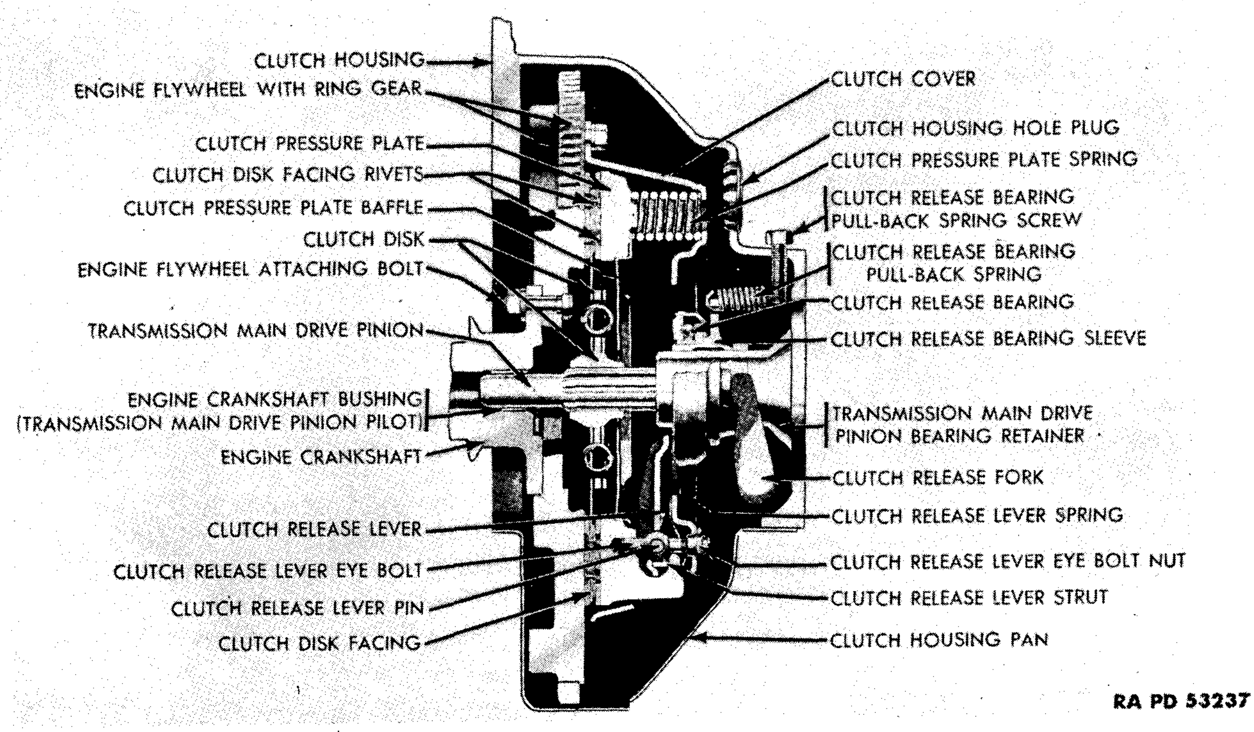


Figure 48. Single plate dry clutch.

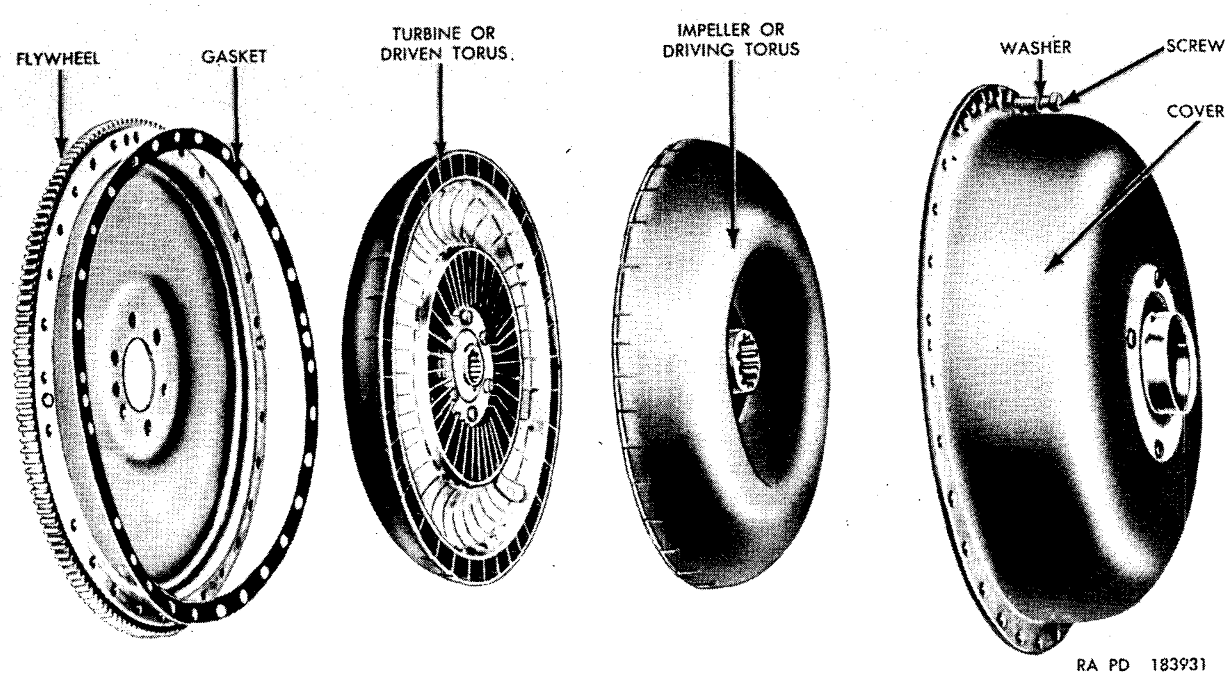


Figure 49. Fluid clutch disassembled.

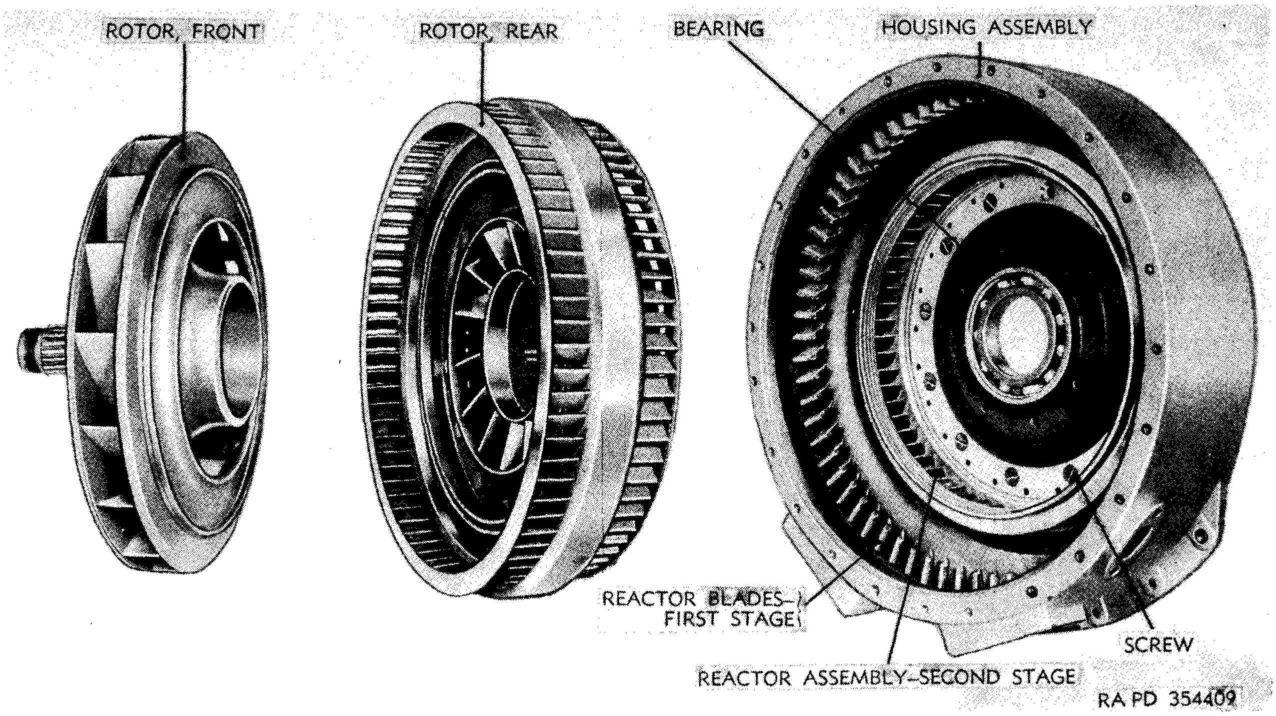


Figure 50. Torque converter showing rotors, housing, and reactors.

Section II. TRANSMISSIONS, DIFFERENTIALS, AND DRIVE SHAFTS

52. Transmissions

The more common devices used in transmissions and which require lubrication are rotating and sliding friction-type bearings, ball bearings, roller bearings, tapered roller bearings, thrust bearings, splines, synchronizing clutches, gear teeth, shifting yokes, oil pumps, etc. Lubrication of all the bearing surfaces in a transmission generally is accomplished by making the lower part of the transmission housing a reservoir into which certain of the gears dip, the remainder of the bearing surfaces being lubricated by the dip or splash systems or a combination of these. Some transmissions, particularly those for tanks or other heavy unit, combine the dip and pressure circulation systems, lubricating oil being delivered to certain bearing surfaces by the dip system and to others by an oil pump built into the transmission. Most transmissions which incorporate a pressure circulation system for oil also make use of an auxiliary radiator to cool the oil between trips through the transmissions. Figures 51 and 52 show various transmissions. Figure 51 is a cross section of a selective gear transmission and shows the various parts and surfaces to be lubricated. Parts to be lubricated include plain friction-type bearings both rotating and sliding, splined shafts, gear faces, ball bearings, straight roller bearings, tapered roller bearings, etc. Figure 52 shows a synchromesh tank transmission incorporating five speeds forward and reverse, and an oil pump (not shown) furnishing pressure circulation of oil to the gears on the upper or driving shaft which is above the level of the oil in the bottom of the housing. Although not shown in the illustration of this transmission, all the change gears mounted on the driving and driven shafts run on tapered bearings. Oil from the pump enters the hollow driving shaft, flows out through the roller bearings, runs over the gear teeth, and falls back into the bottom of the housing. Some units provide for cooling the oil before it goes to the bearings. With the lubrication system of the transmission in operation, enough oil finds its way onto the friction surfaces of the transmission to keep them properly lubricated. Transmissions for vehicles equipped with auxiliary units such as winches, cranes, etc., requiring power drive generally are so constructed as to allow power takeoff. Surfaces to be lubricated in the power takeoff are of the same types as in the transmission and are lubricated by the dip system from oil in the transmission housing. Since the construction of transmission is so varied, the lubrication instructions in pertinent lubrication orders and technical manuals should be followed carefully. Special attention should be given to checking the oil levels, proper draining and flushing, and cleaning of magnetic drain plugs. Many types of tracked vehicles use a cross-drive transmission system in which a torque converter, a lock up clutch, and a planetary geared transmission are combined to transmit power to track-driving sprockets. Lubrication of these systems is done periodically (semiannually or each 1,000 miles) by draining, cleaning, and refilling with oil (OE). Daily checks of the oil level is required.

53. Universal Joints

a. Universal Joints for Drive Shafts. Basically the universal joint in most common use (fig. 53) consists of two U-shaped yokes fastened to the ends of the shafts or parts that are to be connected. A cross-shaped piece, located within these yokes, has four trunnions fitted into bearings on the yokes. At the present time, these bearings are generally of the needle type. A lubricating fitting and relief valve generally are incorporated. One of the yokes often includes a slip joint which takes care of slight variations in length necessary because of movement of the axles or wheels. The lubricant for this slip joint is the same as for the universal joint. On some slip joints, it

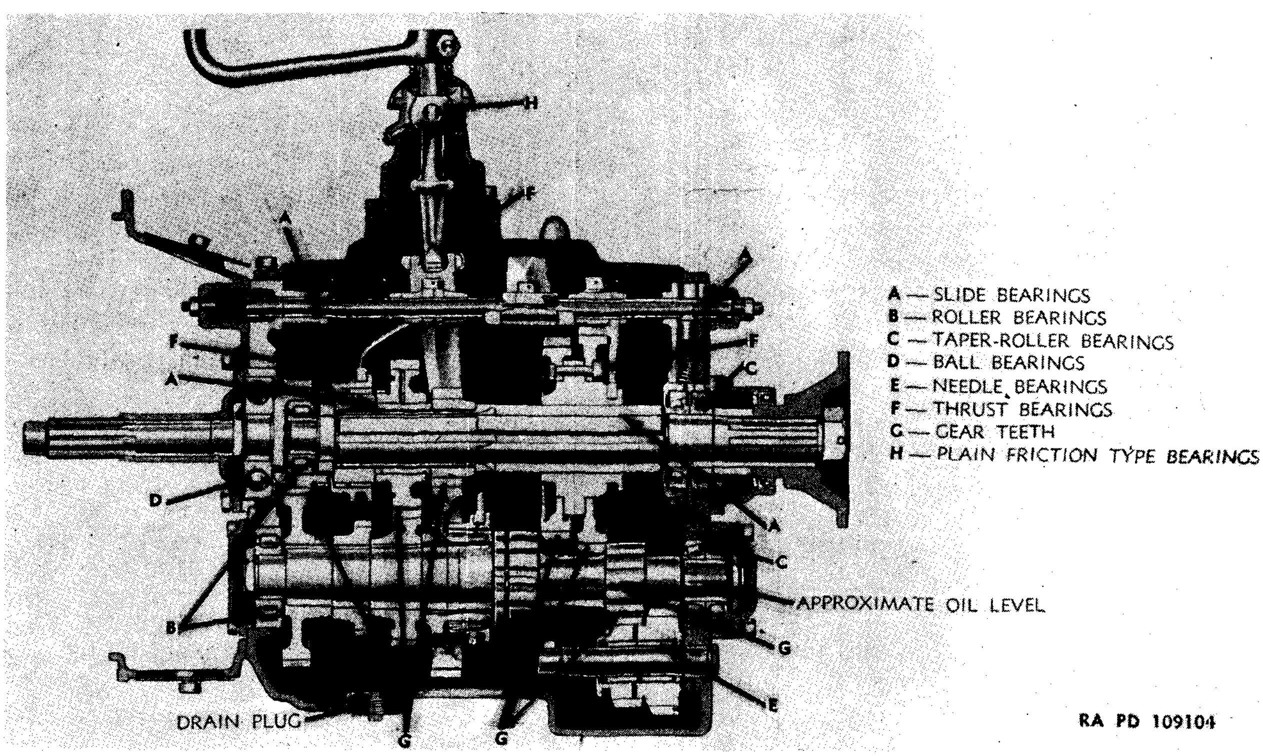


Figure 51. Cross section of typical five-speed transmission.

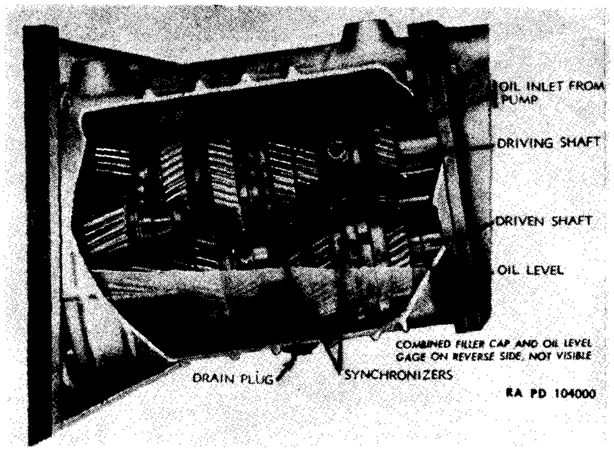


Figure 52. Synchromesh tank transmission incorporating pressure circulation system.

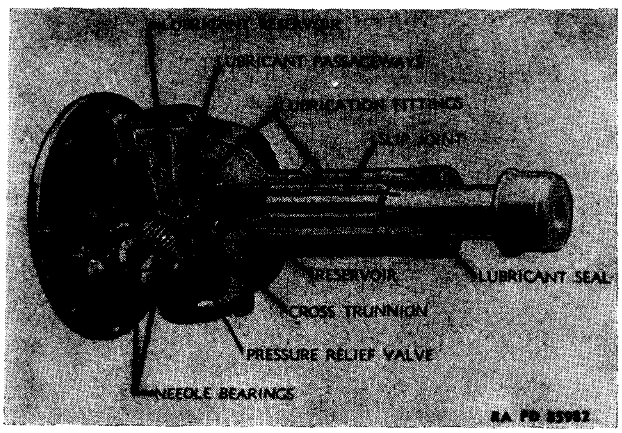


Figure 53. Typical universal joint with slip joint.

is necessary to remove a plug and install a lubrication fitting to lubricate the joint. The lubricating fitting must be removed and the original plug installed after lubrication. A change of fittings might be sufficient to throw the shaft out of balance and cause serious vibration.

b. Universal Joints For Propeller Shafts. Propeller shaft universal joints on some wheeled vehicles may still carry manufacturer's instruction plates which specify the lubricant to be used for the lubrication of universal joints. This instruction may be in contradiction to the lubricant prescribed by the applicable lubrication order and therefore must be ignored. Instructions on applicable lubrication orders will be followed regardless of contrary instructions of manufacturer's plates. At time or rebuild or removal from vehicle, the manufacturer's instruction plate should be defaced.

c. Universal Joints For Front Wheels. The use of front wheels for driving as well as steering purposes made necessary a universal joint in which the angular velocity of the driven shaft was not affected by the angle of drive. Several joints of the constant velocity type have been developed (fig. 54). Front wheel universals are usually inclosed by parts of the axle and although the surfaces to be lubricated vary, they are usually lubricated with GAA grease. Instructions in pertinent lubrication orders or technical manuals must be followed. It is important that universal joints and splines be lubricated adequately. Not only is the full power of the engine carried through these small joints, but when the vehicle is going down hill using the engine as a brake the stress is reversed. The housings are not to be filled above the inspection plug hole. Grease expands as the temperature increases if too much lubricant has been added, the pressure may rupture the grease seals due to the heat of operation. Lubricate in accordance with instructions in pertinent lubrication order and technical manual.

54. Driving Gears, Differentials, and Associated Mechanisms

a. General. Most of the lubrication of these mechanisms concerns gears of various types and the shafts or bearings on which they rotate. In practically all cases, the housings serve as reservoirs for the oil and lubrication is by the dip system. The lubricating oil must be changed at regular intervals as specified in pertinent lubrication orders and technical manuals. This should be done directly after the vehicle has been operated for a considerable period, at which time the oil is comparatively warm and fluid. Compressed air should not be used to hurry the draining of a reservoir, for this may result in oil seals being blown with possible leakage of oil onto the brakes or other parts. A reservoir must not be filled above the oil level specified. Particular care is necessary in cold weather as the thick lubricant may pile up at the end of the filling

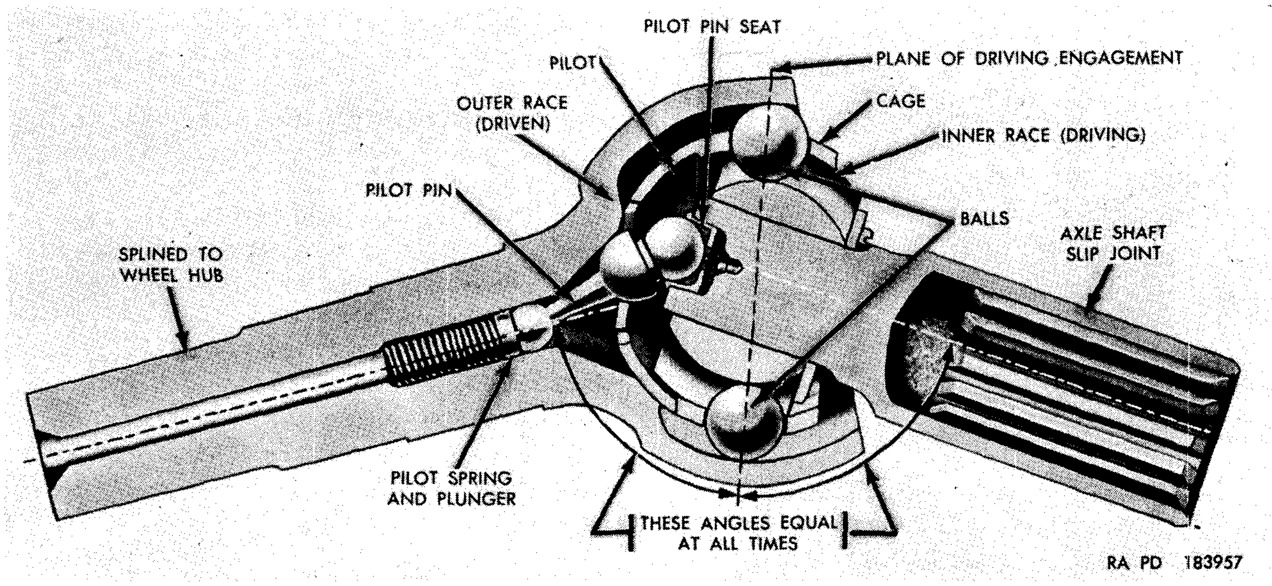


Figure 54. Constant velocity universal shaft sectional view.

nozzle and give an incorrect indication of the amount of lubricant introduced.

b. Driving Gears. Driving gears may be divided into the following classification: straight bevel gears, spiral gears, hypoid gears, and worm gears. There are other types of driving gears but in general the above are the main types. Hypoid gears present a particular problem due to the fact that rolling action and considerable sliding action are combined. It is necessary, therefore, that a special lubricant be used with hypoid gears. In general, driving gears as well as their antifriction bearings are lubricated by the dip system. Operating temperatures normally are low and a lubricant of comparatively heavy body generally is used.

c. Differentials. A differential (fig. 55) is the mechanism by which the torque on the two driving axles is equalized. The bearing surfaces of a differential requiring lubrication are the antifriction bearings on which the differential cage rotates, the teeth of the differential pinions and side gears, and the bearings of the differential pinions in the cage. All of those bearing surfaces are lubricated by the dip system from oil held in the bottom of the housing. The bearings between the differential pinions and the cage operate intermittently and then only at low speeds. They are generally friction-type bearings for both the radial and thrust loads, and sometimes incorporate a thrust washer of bronze or some other such bearing material (fig. 56). The drive gears and the antifriction bearings of the cage, however, require careful lubrication. The oil in the housing must be kept at the correct level and pertinent lubrication orders and technical manuals must be followed in regard to checking, draining, and replenishing.

d. Driving Axles. The inner ends of nearly all driving axles used on automotive materiel are splined to the differential side gears, and such lubrication, as is necessary, is furnished by the oil in the axle housing. The outer ends of the driving axles are splined or keyed and, except for those of the semifloating type, carry none of the weight of the vehicle and have no bearings. An axle of the semifloating type carries the weight of the vehicle on its outer end and has an antifriction bearing installed between the driving axle and the outer end of the axle housing. This bearing carries a combined radial and thrust load, and secures the axle in place longitudinally in the housing. Such an antifriction bearing generally is lubricated either through a lubricating fitting or

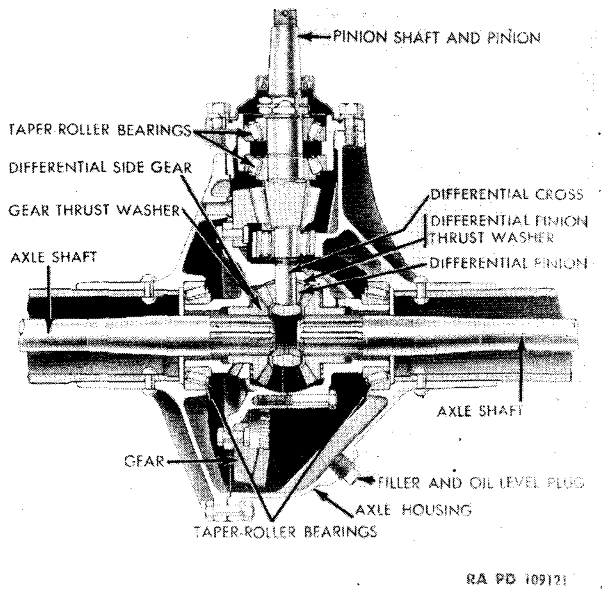


Figure 55. Drive gears and differential.

by removing and repacking with grease where directed in pertinent lubrication order and technical manual.

e. Controlled Differentials. Controlled differentials (fig. 57) are used in full track laying vehicles and, not only automatically equalize the torque applied to the two tracks, allowing them to travel at different speeds to compensate for slippage, irregular ground, etc., but provide a means for steering. Steering is accomplished by two brakes by means of which resistance may be applied to either side, resulting in the slowing of the track on that side. Although the gears are of a different type and greater in number, the lubrication problems of the more common forms of controlled differentials are practically the same. Steering brakes must be lubricated and cooled because friction resulting from the braking action in steering results in considerable heat. Cooling is done by dipping the contacting surfaces of the ferrous metal drum and the friction lining of the brake bands into the lubricant in the bottom of the housing. The oil lubricates the friction surfaces and cools the drum and bands. It is general practice to use an oil pump to circulate the oil from the bottom of the housing through a radiator or cooler to dissipate the excess heat. In some vehicles the transmission is often included in the same oil circulation system.

f. Final Drives. On tanks or other slow moving vehicles, another speed reduction often is incorporated as a final drive between the driving axle coming from the differential and the final drive shaft. The parts to be lubricated in such a drive (fig. 58) generally consist of antifriction bearings carrying both thrust and radial load and a set of gears. Lubrication is by the dip or splash systems from oil held in the bottom of the housing.

g. Transfer Case. A transfer case consists of a housing inclosing a series of gears by means of which power is transferred from the main drive line to any auxiliary units that may require power for their operation. Transfer cases provide for the operation of front wheel drives, pulleys, hydraulic pumps, winches, cranes, dual rear axles, and other mechanisms. Figure 59 shows a typical transfer case incorporating high- and low-speed driving ranges, drive to front axle, and drive to the rear axle. In general, transfer mechanisms are similar to transmissions in principle, surfaces to be lubricated, and lubrication problems, and nearly always are lubricated by the dip system from oil held in the bottom of the housing.

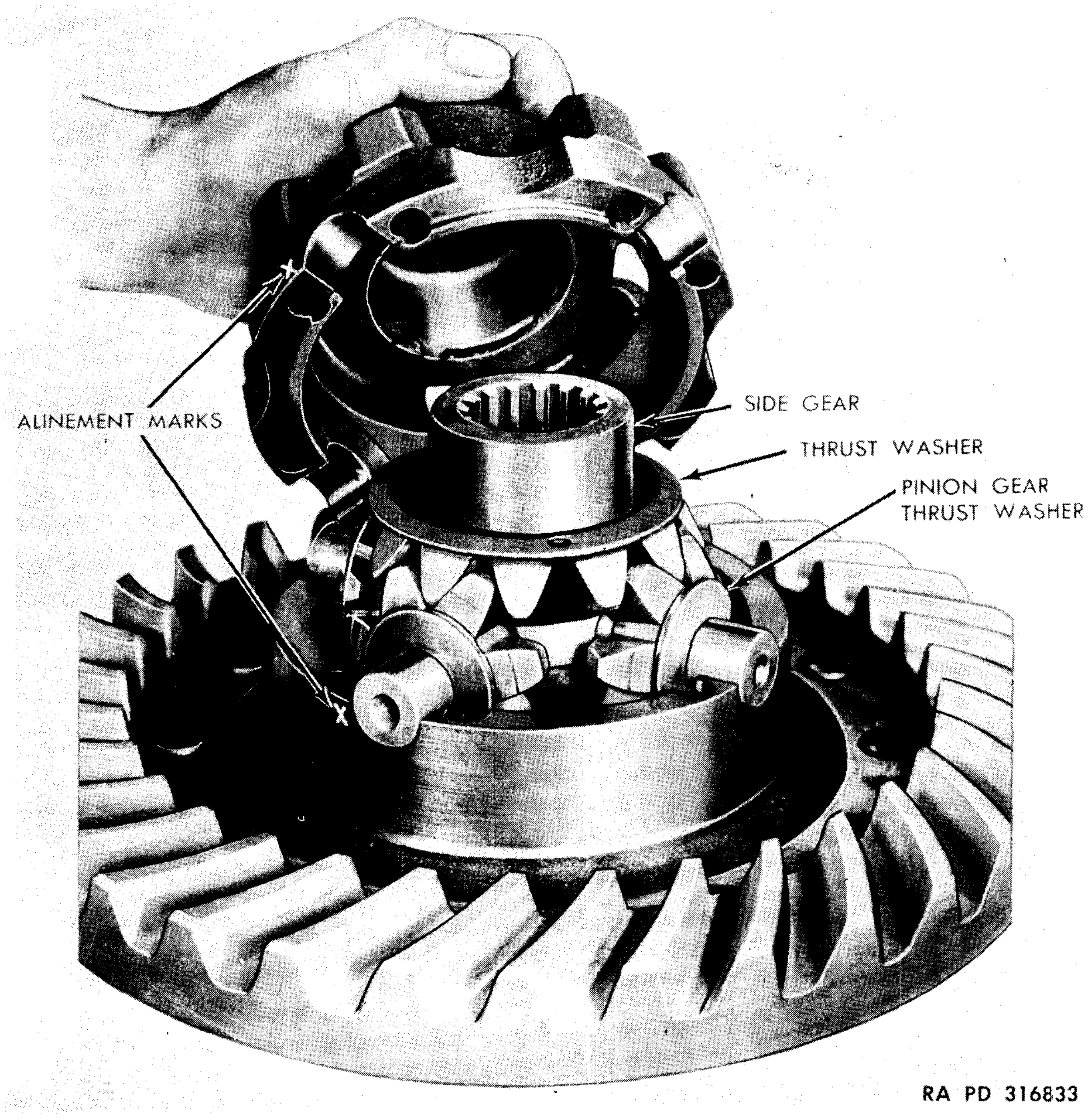


Figure 56. Differential with half of cage removed to show construction.

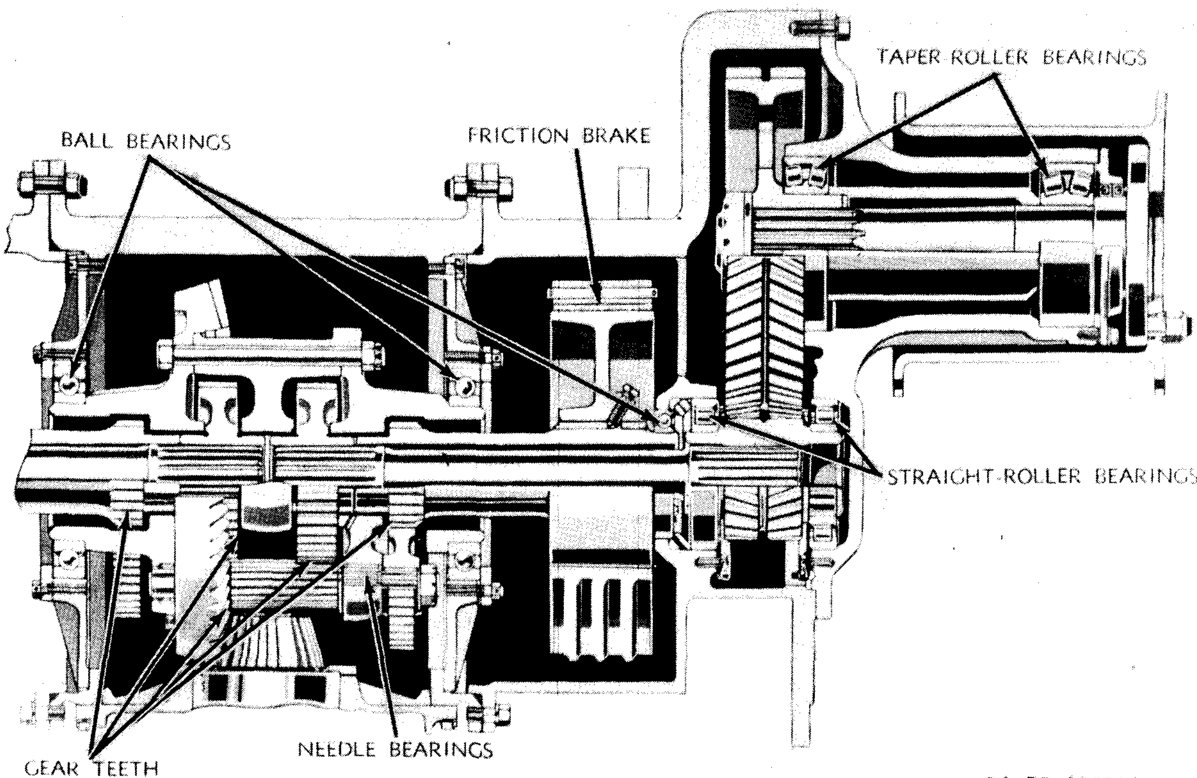


Figure 57. Partial section of a controlled differential and final drive with steering brake.

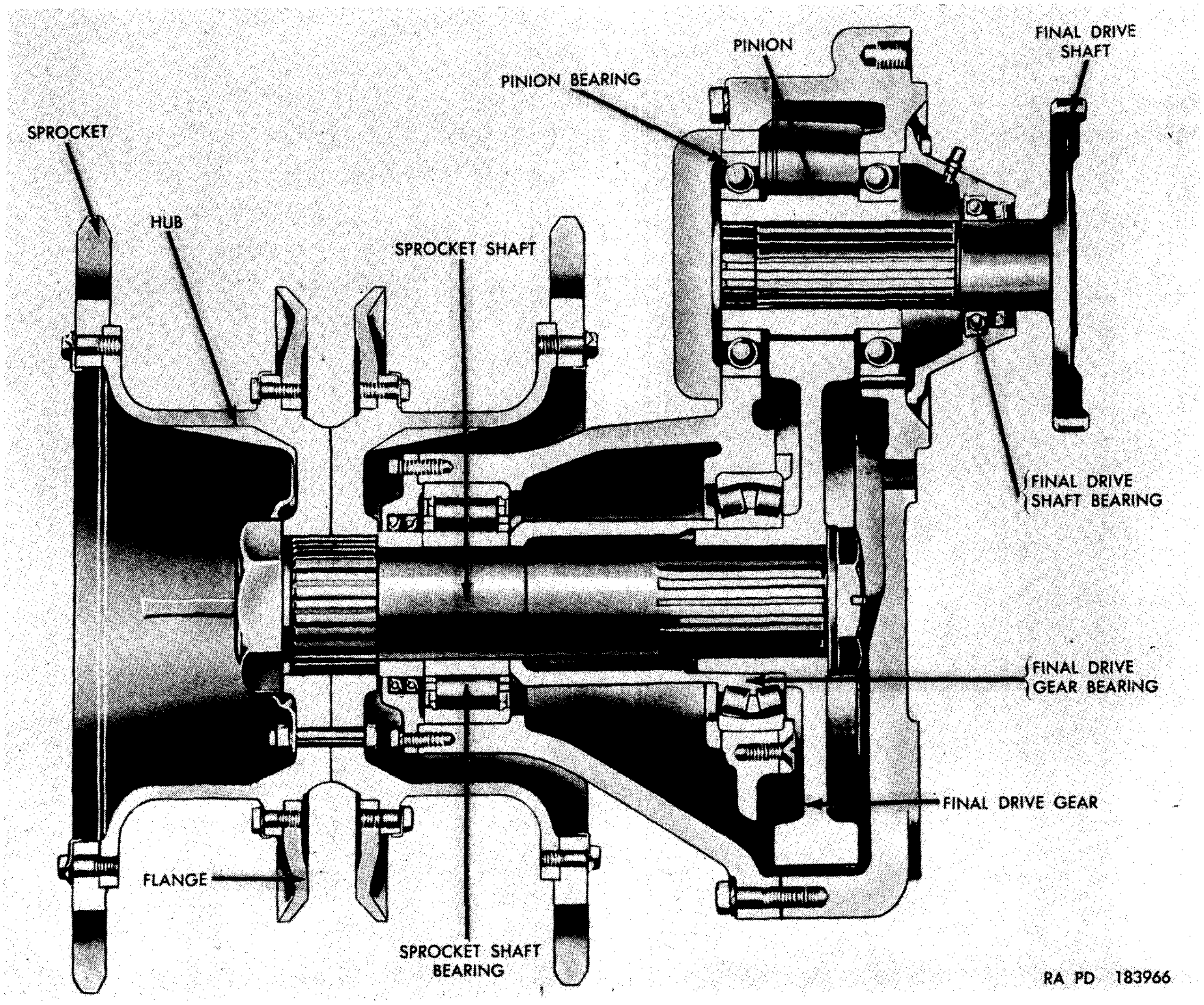


Figure 58. Final drive cross-sectional view.

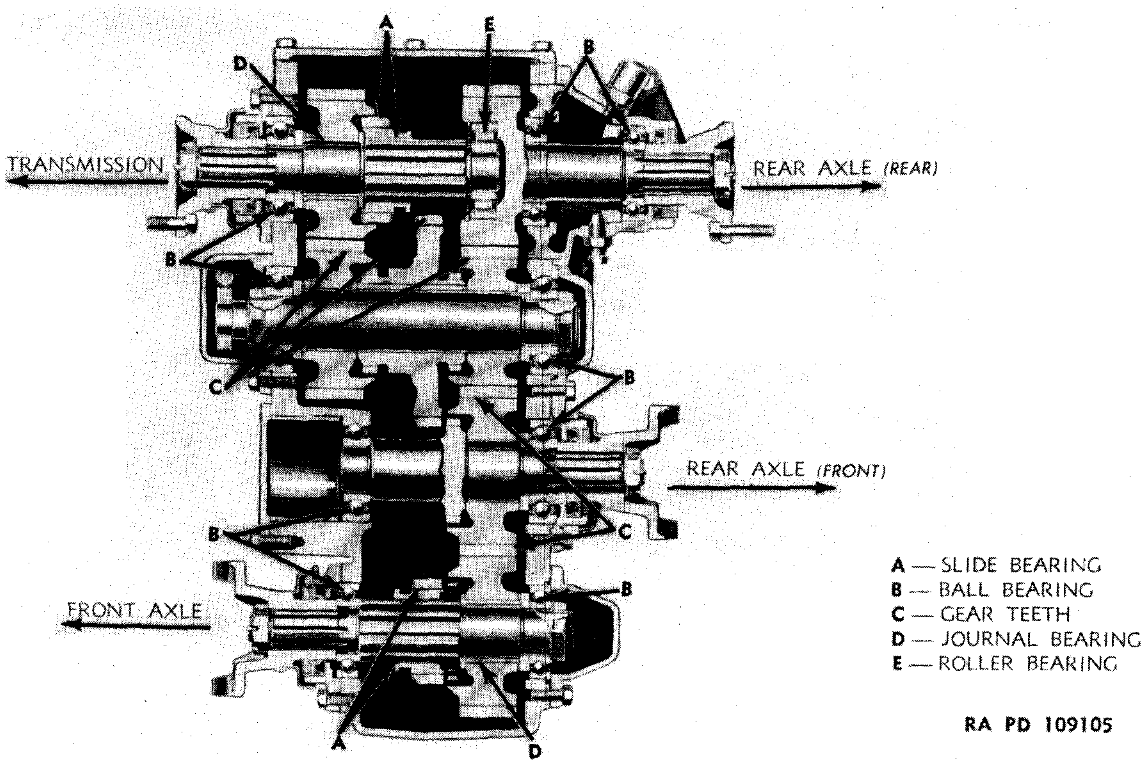


Figure 59. Cross section of a typical transfer case.

CHAPTER 8
AUTOMOTIVE MATERIEL; BRAKING, STEERING, AND SUSPENSIONS

Section I. BRAKING

55. General

Friction does not always act to our disadvantage. In our discussion on clutches it was shown that friction can be used to transmit power. Braking action, too, is the advantageous use of friction to retard or stop a motion. In defining friction we said that it is the resistance to relative motion between two surfaces in contact. In automotive braking we bring a stationary surface into contact with a moving surface. This supplies the necessary factor—relative motion—to create the resistive force-friction. The moving surface will surrender its motion to friction. While the basic duty of automotive equipment is movement, it is equally important to stop the motion; sometimes very quickly. The braking action of vehicles must be equal to the action of the engines and driving mechanisms. In cases of emergency it must be far greater. It is possible to accelerate a 100-horsepower vehicle in 36 seconds to 80 miles per hour. By full application of braking, the same vehicle can be stopped in 4.5 seconds. Thus, we can see that the braking power is 8 times the engine power.

a. Braking Mechanisms. All braking systems have basic parts: they are rotating or moving parts, stationary parts, and means to bring them together. One means of contacting the moving parts and the stationary parts is done by hydraulics. This manual is concerned with lubricants and hydraulic liquids so only this system will be discussed.

b. Brakedums, Shoes, and Plates.

(1) *Brakedrums.* The rotating part of a brake system is made of cast iron or steel. It is circular and is tightly secured to a rotating member such as a shaft or a wheel.

(2) *Brakeshoes.* The stationary member consists of a metal form on which ceramic or asbestos material is fastened. The lining or facing has the ability to absorb and dissipate heat without bonding or seizing to the drum.

(3) *Plates.* Brakes designed with plates are used when larger surfaces are required. The facings on the plates are the same materials as those used on the shoes.

(4) *Linkages.* The cables and anchor bearings require a periodic lubrication with general purpose oil.

56. Hydraulic Systems

a. General. The pressure applied to the brake pedal is transmitted by a liquid to the wheel cylinders. This is possible because a liquid cannot be compressed and a confined liquid transmits a force equally in all directions.

b. Operations. The brake pedal, when pushed down, moves the piston in the master cylinder, forcing the liquid from the cylinder through tubes to the wheel cylinder. The fluid pushes against pistons in the wheel cylinders forcing them to activate a linkage which brings the shoes in contact with the drums.

c. Fluid. The liquid used for hydraulic braking is called brake fluid. It is generally a mixture of an alcohol and a vegetable oil. The combination will not evaporate or freeze at temperatures encountered in year-round operation of vehicles.

d. Bleeding. Air will enter the hydraulic brake system if the fluid level is too low in the master cylinder or if fluid leaks anywhere. Since air seriously effects braking efficiency, the hydraulic system should be bled whenever brakes are adjusted. The fluid in the master cylinder should be maintained at full level.

Section II. STEERING AND SUSPENSIONS

57. Steering and Wheel Bearing Mechanisms

a. General. This paragraph will discuss the lubrication of the various wheel bearings, steering gears, linkages, tracks, track rollers, driving sprockets, idlers, bogie wheels, springs, spring shackles, shock absorbers, individually sprung front wheels, etc., on which many vehicles are suspended and transported. Detailed instructions for any particular vehicle are given in pertinent lubrication orders and technical manuals; instructions contained therein must be followed.

b. Front Wheel Bearings. Front wheel bearings (fig. 60) of the automotive vehicles of today are of the antifriction type carrying both radial and thrust loads. It is necessary that the wheel bearings be packed with a grease that will give proper lubrication over considerable mileage, and the grease must be of such a type that it will cling to the bearings, stay in, and not creep out onto the brakes. Most wheel bearing lubricants are a short fiber sodium soap product having a high melting point, a minimum tendency to separate or creep, yet sufficient tackiness to cling to the balls or rollers under the centrifugal force developed in the bearings at high speeds.

(1) *Lubrication procedure.* In lubricating front wheel bearings, the wheel is removed, all old grease is washed out of the bearings with dry-cleaning solvent, and the bearings dried. In drying bearings, with compressed air, it is possible to damage the bearings and also cause rusting if the air contains moisture. See TM 9–214 for methods of drying with compressed air. In packing bearings, the lubricant must be introduced carefully between the balls or rollers by hand or with a packer and must not be just smeared on the outside. Great care must be exercised to see that dirt, grit, lint, or other contaminants are not introduced into the bearings. If bearings are not to be installed immediately, they should be wrapped in clean oilproof paper to protect them from dirt. Before installing repacked bearings, grease retainers should be checked to see that they are in proper condition and replaced if necessary. The old-time method packing the hub cap with grease and using it as a grease cup is not to be used under any circumstances, as this procedure may rupture the grease seal and result in grease-soaked brake linings. Coat the spindle and inside of the hub with a thin layer of grease (not over 1/16 inch) to prevent rusting.

(2) *Adjustment of bearings after lubrication.* A necessary part of the task of lubricating front wheel bearings is their proper adjustment after repacking. The adjusting nut should be drawn up until the wheel binds slightly and then backed off so that the wheel will turn freely. The amount the nut should be backed off depends upon the pitch of the thread, the type of bearing, etc., but explicit directions will be found in the pertinent technical manual. Some bearings give better service if correctly preloaded. Adjustment is quite critical and, while it is necessary to draw the adjusting nut up tight enough to seat the cones, cups, etc., firmly, care

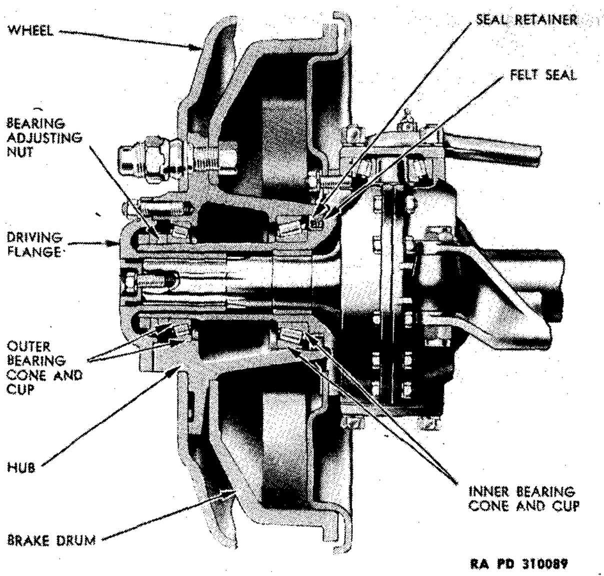


Figure 60. Section of typical front wheel bearings

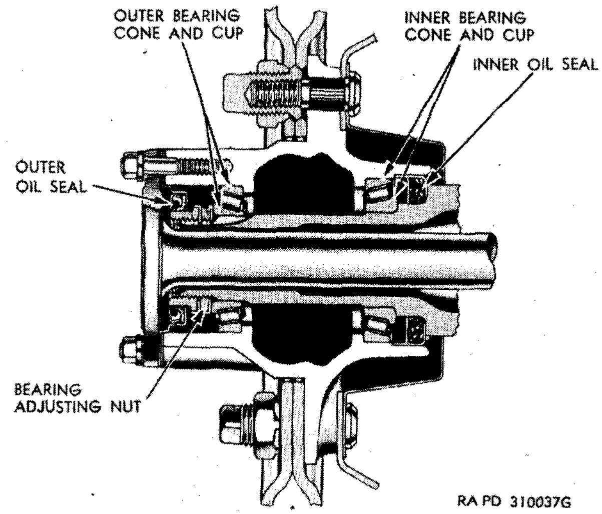


Figure 61. Sectional view rear wheel bearing.

must be taken not to tighten it sufficiently to injure the balls or rollers.

c. Rear Wheel Bearings. Rear wheel bearings (fig. 61) of automotive materiel are also of the antifriction type (fig. 63) and generally are grease-lubricated. The method of introducing the lubricant varies according to the type of axle construction, the most common method is removing the wheels and packing the bearings manually. When lubrication fittings are used, the lubrication order for the particular vehicle must be carefully followed, since the application of grease in too great quantities or too frequently may result in the rupture of oil seals forcing grease on the brakes. In some cases the wheel bearings are lubricated automatically from the rear axle, the maintenance of the lubricant at the proper level in the rear axle housing being about the only service necessary. If a drain or vent is incorporated, and the bearings packed with grease manually, the instructions given for front wheel bearings in *b* above apply.

d. Steering Systems. A steering system (fig. 62) comprises all mechanisms between the steering wheel and the connections at the ends of the steering arms on the front wheels, and includes friction and antifriction bearings, gears, cams, worms, ball and socket joints, levers, links, etc. The most important is the mechanism at the lower end of the steering column which changes the rotary motion of the steering wheel into the push and pull motion necessary at the steering wheels. There are four types of these mechanisms in common use at present; namely, ball bearing, cam and lever, worm and roller, and worm and sector, each of which will be treated in following paragraphs. During the periods when a vehicle is moving, all parts of the steering system are subject to violent whipping action due to the roughness of the terrain being traveled, and this introduces shock loads and high bearing pressures that are liable to pound the lubricant out from between the bearing surfaces leaving the rubbing surfaces bare. For this reason, it is necessary that regular and careful attention be given to lubrication and that the specified lubricants be used. The lubricant used must have good adhesive quality and sufficient fluidity to flow back onto surfaces from which it has been pounded. A steering gear generally is filled through a hole in the upper part of the housing and the lubricant used generally is universal gear lubricant. Care must be used not to force the lubricant up through the steering column when filled through a lubricating fitting.

(1) *Ball bearing type.* In a steering gear of the ball bearing type (fig. 63),

the principle of the nut and screw is employed although the parts are known commercially as a ball or worm nut and a worm. This construction gives the action of a screw but substitutes rolling for sliding friction. This type of steering gear requires lubrication of friction radial and thrust bearings on the shaft, the rack and gear, the balls transmitting motion from the worm to the nut, and the antifriction bearings of the worm. Lubrication of all bearings is accomplished by filling the housing with lubricant which should be checked, drained, and replaced as directed in pertinent lubrication orders and technical manuals.

(2) *Cam and lever type.* A steering gear of the cam and lever type (fig. 63) employs a special cam or worm of variable ratio which engages a tapered stud or studs on a lever mounted on the end of the Pitman or steering arm shaft. This type of steering gear requires the lubrication of friction-type bearings carrying radial and thrust loads, antifriction bearings on the worm and studs, and the rolling or sliding bearing of the stud or studs against the worm. All of the bearing surfaces are lubricated by oil contained in the housing. This oil must be replenished, drained, and replaced as directed in pertinent lubrication orders and technical manuals.

(3) *Worn and roller type.* A steering gear of the worm and roller type (fig. 63) utilizes a worm or screw meshing with the edge of a disk-shaped roller carried on a lever on the steering arm shaft. Some heavy-duty steering gears use two rollers instead of one to give more bearing area and strength. The surfaces to be lubricated are about the same as in other steering gears; namely, friction-type bearings of the steering arm shaft and of the roller on its shaft, sliding and rolling between the roller and the worm, and the antifriction bearings on the worm shaft. All lubrication is provided by oil held in the housing. This oil should be replenished, drained, and replaced as directed in pertinent lubrication orders and technical manuals.

(4) *Worm and sector type.* Figure 63 shows two types of steering gears using a worm and sector. In one type the sector is in the same plane as the wormshaft and the teeth are cut on the edge of the sector, while in the other type the sector is offset and the teeth are cut on its face. In the first type the worm varies in diameter, while in the second type the worm is of constant diameter throughout its length. The surfaces to be lubricated are gear and worm teeth, plain friction bearings, and antifriction bearings. Methods of lubrication are the same as for other types of steering gears.

(5) *Hydraulic steering gears.* On the very large wheeled vehicles, a hydraulic aid to steering sometimes is incorporated. It consists essentially of an oil reservoir, hydraulic pump driven by the engine, control valve, and double acting hydraulic cylinder. The piston rod of the hydraulic cylinder is connected to an extended arm of the lever of a cam and lever type steering gear. With the oil pump operating and the steering wheel stationary, the hydraulic pressure on the two ends of the piston is balanced, and no force is exerted on the steering lever in either direction. While the steering wheel is being turned, the control valve operates to create different pressures on the two ends of the piston, and force is exerted on the steering lever to help turn the wheels in the desired direction. As soon as rotation of the steering wheel stops, the pressure differential ceases to exist and force no

longer is exerted on the steering lever. Surfaces to be lubricated in the hydraulic system include antifriction bearings, plain bearings with rotary and longitudinal motion, oil seals, etc., but these are lubricated automatically by the oil used in the system. The oil supply in the hydraulic system reservoir must be replenished, drained, and replaced as directed in pertinent lubrication orders or technical manuals.

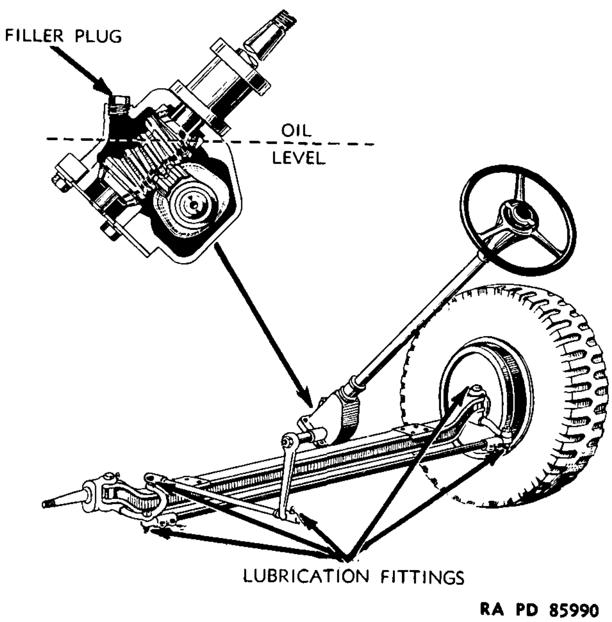


Figure 62. Schematic layout of a steering system.

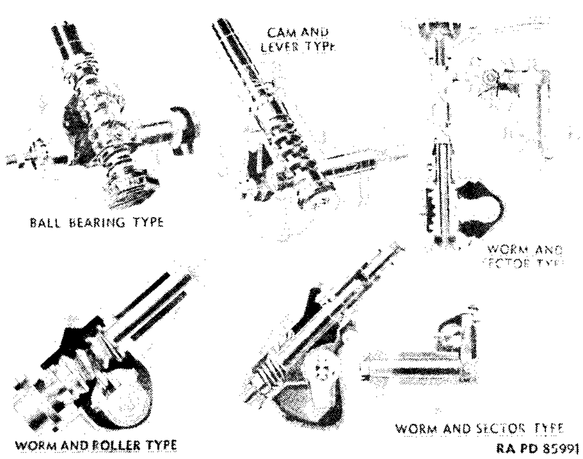


Figure 63. Steering gears of various types.

e. Tracks, Track Rollers, Driving Sprockets, Idlers, and Bogie Wheels. Tracks are used on vehicles that are expected to negotiate rough, sandy, wet, or muddy terrain. Many of the bearing surfaces, such as those between the tracks and the sprockets, idlers, road wheels, guides, or other contracting parts, are not lubricated because the lubricant would cause dirt and grit to stick, work into the lubricated surfaces, and cause more wear. Other bearings on spring seats, road wheel supports, and rubbing plates, receive no lubrication for the same reason. Road wheels, track support rollers, and idler wheels or sprockets are mounted on antifriction bearings equipped with grease seals, and must be lubricated frequently and carefully on account of the severe service to which they are subjected. They are equipped with relief fittings to protect the grease seals if too much grease is forced into the bearings. Such bearings generally are lubricated frequently with GAA grease but pertinent lubrication orders and technical manuals should be consulted for specific cases.

58. Suspensions

a. Springs. A majority of the springs used for supporting antomotive vehicles are of the leaf type in which a number of flat spring steel strips of varying lengths are assembled together into one unit. To support the load and cushion against road shock, a spring must depend upon one or both of two mechanical principles—friction between the leaves of the spring and bending of the spring steel itself. Leaf springs which depend on both bending and friction are not to be lubricated as oil or grease will destroy the desired friction between the leaves and make the riding action too soft. Modern passenger cars generally use helical springs instead of leaf springs (fig. 64). The spring itself needs no lubrication as it depends entirely on the bending of the steel to cushion the load. The plain friction-type bearings in the control arms are lubricated with grease through lubrication fittings. Helical springs used on rear axles operate between the rear axle and the vehicle frame and need no lubrication.

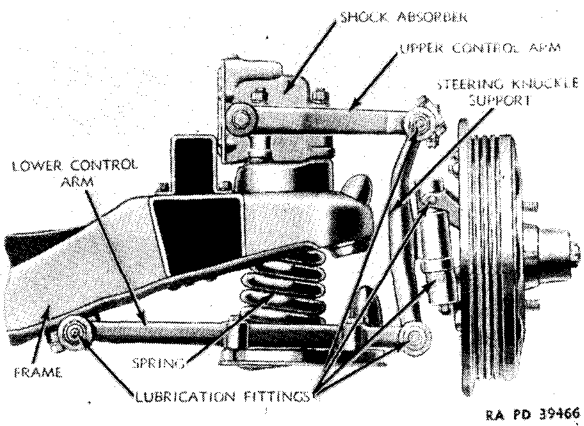


Figure 64. Front wheel suspension using a helical spring.

b. Spring Shackles. One end of the leaf-type spring ordinarily is held to the vehicle frame by a short shackle. As the bearings in shackles receive severe service and have to operate in the presence of considerable dirt, dust, and grit, lubrication is difficult. The original bolt-type shackle, or a slight modification using pins held in the links by clamp bolts, is the most common style used on United States Army materiel. The life of the lubricating film in any shackle depends more upon the conditions under which the vehicle is operated than on design. Dirt, wet weather, hot weather, fording operations, and frequent washing all tend to destroy the film faster than would otherwise be the case and make more frequent lubrication necessary. Pertinent lubrication orders and technical manuals should be consulted for specific instructions. Some shackles use rubber instead of bearings to absorb the motion. Do not use petroleum oil on these units as it will deteriorate the rubber. If squeaks develop, they can be eliminated with water or hydraulic brake fluid.

(1) *Bolt or pin-type shackles.* A shackle of the bolt or pin type (fig. 65) carries two hardened steel bolts or pins which turn in bronze bushings pressed into the frame bracket and the eye of the spring. The bolts or pins are drilled and have a lubricating fitting in one end through which grease is fed to the center of the bearing.

(2) *Threaded- and U-type shackles.* In shackles of the threaded type, either straight or U-shaped (fig. 65), the bushings are held firmly in the spring eye and the frame bracket. The bushings are threaded on the inside and the bolts on the outside, the motion taking place between these two threaded surfaces. The bolts are drilled and have lubricating fittings through which grease is fed to the center of the bearings. Straight bolts are held together by two side plates held in place by draw keys on the bolts or by a center bolt passing through the two side plates. On shackles of the U-type, the bushing is threaded outside and inside and screws onto the bolt and into the bracket or spring eye in the same operation.

c. Shock Absorbers. Three types of hydraulic shock absorbers are in general use—the double-acting piston type, the single-acting piston type, and the direct-acting or telescopic type. The operation of all hydraulic shock absorbers makes use of the fact that considerable energy is required to force a fluid through a small orifice. Relative motion between the frame of the vehicle and the axle is transmitted to the shock absorber and causes relative motion between a piston and its cylinder or a vane and its housing, the displaced fluid being forced through a small orifice into another section of the absorber. The resistance set up in the absorber as the fluid is forced through the orifice is transmitted back through the absorber and restricts or damps the motion between the vehicle frame and the axle. Lubrication of the internal parts is by the operating fluid of the shock absorbers and external linkage generally are rubber-bushed and require no lubrication. Only the fluids specified in lubrication orders or technical manuals will be used. Different shock-absorber fluids should not be mixed. The filling of many shock absorbers requires removal, this being due to the inaccessibility of the filler holes or, in case of telescopic absorbers,

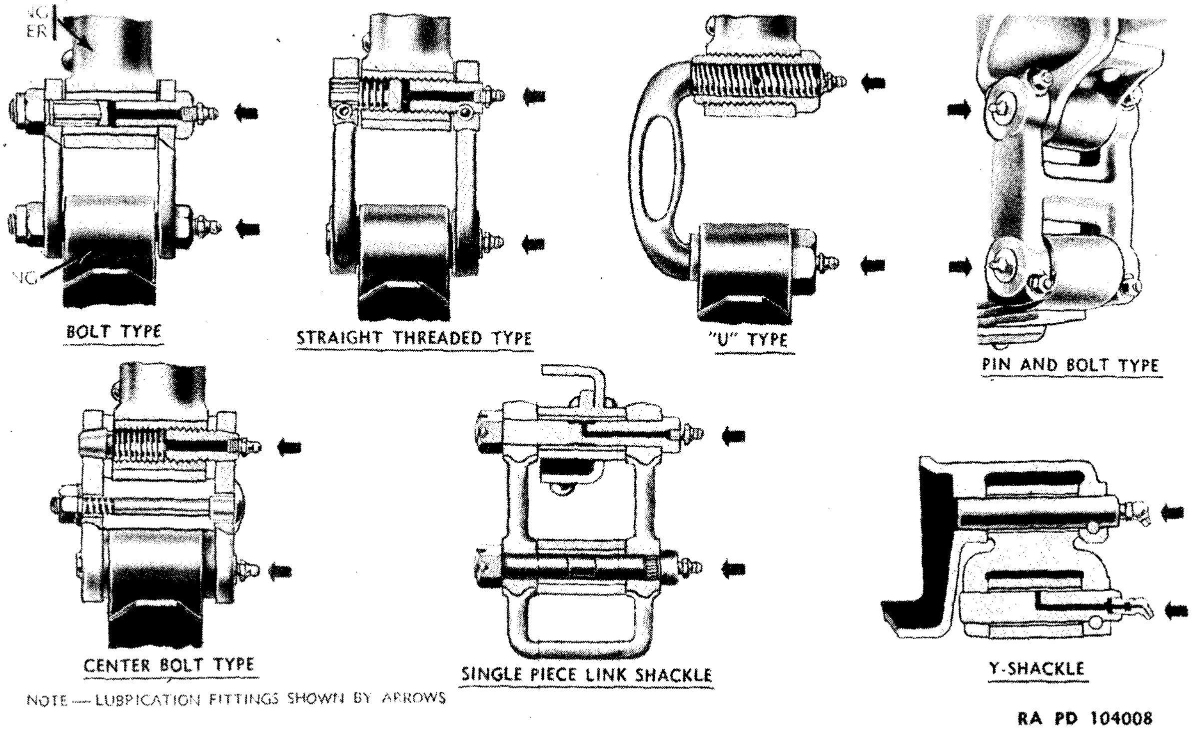


Figure 65. Spring shackles of various types.

to construction. The maintaining of fluid levels in hydraulic shock absorbers is generally not required of user personnel. Rather, faulty equipment, as determined by excessive operating temperatures, is replaced by authorized maintenance personnel.

(1) *Piston-type shock absorbers.* Figure 66 shows a section of a double-acting shock absorber of the piston type. The bearings to be lubricated are between the cylinder and piston; the piston and the cam; and the camshaft and the housing; and the relief valves, springs, and caps. They all involve either sliding or rotary motion of plain friction surfaces and are lubricated by the operating fluid. The single-acting type is practically the same except that the resistance to motion is in one direction only and the fluid forced through the orifice flows into the reservoir around the cam. Connections between the operating arm and the axle are either rubber-bushed and require no lubrication or have lubrication fittings.

(2) *Direct-acting shock absorbers* (fig. 67). Shock absorbers of the direct-action or telescopic type utilize the same principle (a piston forcing fluid through a small orifice) as is used in the piston type. However, instead of the cylinder and piston being incorporated in a housing fastened rigidly to the vehicle frame, one part is attached to the vehicle frame and the other part to the axle, and the motion between the frame and the axle is transmitted directly to the parts of the absorber. The parts to be lubricated are the cylinder, piston, piston rod, and valves; this is accomplished by the operating fluid. The attaching points usually are rubber-bushed and need no lubrication. Currently used direct-acting shock absorbers cannot be refilled and are replaced when they become inoperative.

d. Individually Sprung Front Wheels. Individually sprung or suspended front wheels (fig. 64) are used on some 4 by 2 vehicles and

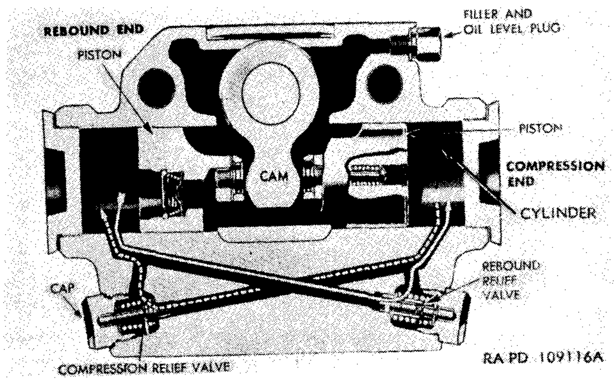


Figure 66. Double-acting piston-type shock absorber.

on M151 1/4-ton 4 by 4 trucks. They were designed primarily to improve riding comfort and permit one wheel to rise and fall in going over obstructions without the action being transferred directly through a solid axle to the other front wheel. The control arms or A-frames are pivoted to vehicle frame or shock absorbers and to the steering knuckle support, and these plain friction-type bearings are lubricated with grease through lubrication fittings as directed in applicable lubrication orders. The upper control arm is actually the shock absorber arm and the shaft on the inner end is part of the shock absorber. The helical spring requires no lubrication.

e. Turntable Fifth Wheel. A turntable or fifth wheel (fig. 68) is used on a tractor truck to support the front end of the trailer and to couple the trailer to the truck. Parts to be lubricated included the top of the turntable, coupler pin, locking jaw and guides, parts of the kingpin locking device, the supporting shafts, pickup ramps, and fifth wheel base. The bearings are subjected to only slight movement and are all of the plain friction type. Engine oil generally is used on the kingpin locking device and general purpose grease on the other bearings, but pertinent lubrication orders or technical manuals must be consulted for specific instructions. If the turntable, coupler jaws, ramps, or base accumulate grit or sand, they should be cleaned and lubricated thoroughly.

f. Torsion Bars. On heavy tracked vehicles suspension is obtained by the use of a linkage system involving torsion bars. Lubrication of these is usually prescribed by the lubrication orders to be done at disassembly and assembly.

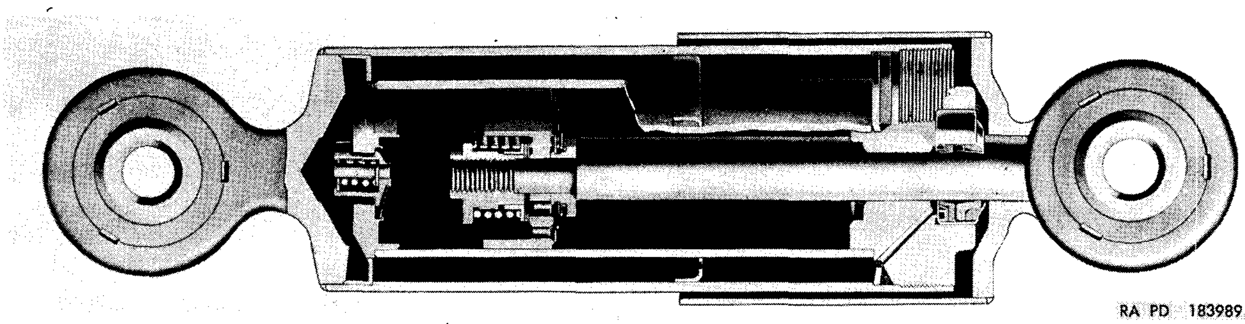


Figure 67. Direct-acting shock absorber.

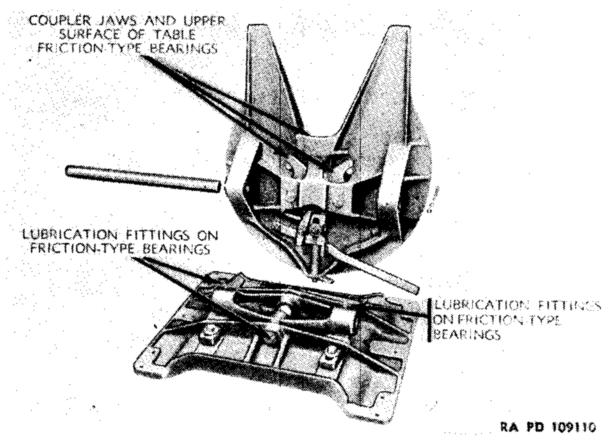


Figure 68. Fifth wheel partially disassembled.

CHAPTER 9
ARTILLERY MATERIEL

59. Basic Lubricated Surfaces

Artillery uses the same two basic types of bearings, friction and antifriction, that are used in other materiel. Such friction bearings in artillery as trunnions, hinge pins, shackles, pintles, shaft bearings, etc., are essentially journal bearings. Trunnions are located on the sides of a weapon; they support its weight and allow it to be elevated or depressed. Pintles, of either the pin type or ball and socket type, serve as a center or pivot about which a cannon is traversed and are essentially a form of journal bearing, in some cases supporting the entire weight of small caliber weapons. The slide bearings which permit a weapon to recoil on its cradle, the circular base ring and racer by means of which large cannon are supported and traversed, axle traverse, the pistons and rods in recoil and recuperator mechanisms, etc., are all essentially guide bearings. Antifriction bearings are used in various places on artillery such as the trunnions breech block carrier, and base ring of large artillery; the wheels of mobile carriages; and various places in power-driven elevation and traversing mechanisms. Lubrication may be either by grease or oil as indicated by pertinent lubrication orders. On fixed artillery the rollers, base ring, and racer are often quite difficult to lubricate, but it is extremely important that proper lubrication be maintained at this point because on it may depend the accuracy with which the gun is traversed. All of the common types of gears may be found in the control mechanisms for artillery. Gears inclosed in oiltight cases are protected from dirt and offer no particularly difficult lubrication difficulties, while exposed gears require frequent cleaning and lubrication. In some cases lubrication, or a change of lubricant as required by temperature changes, requires partial disassembly of the materiel. Lubrication of specific items of artillery will be performed in accordance with applicable lubrication orders and technical manuals.

60. Tube or Barrel

The bore is cleaned thoroughly and coated with oil which serves to prevent rust or corrosion and is not intended to reduce friction. In cases where the sliding surface for guiding the tube during recoil and counterrecoil is machined directly on the outside of the tube, the bearing between the tube and the cradle or cradle liners in most instances is lubricated with grease. This type of construction utilizes a longitudinal key or flat spot to prevent the tube rotating in the cradle when the gun is fired. The sliding surface that is exposed when the gun is in battery must be protected against rust, and the protecting lubricant collects dirt and dust. This surface must be cleaned carefully and lubricated before firing as any dirt or dust on the surface when the gun is fired may be drawn into the bearing surfaces of the cradle. Using organizations of weapons are directed in the care of the tube, either by technical manuals assigned or by associated lubrication orders. Basically these orders require that upon immediately after firing, and upon two consecutive days thereafter, the bore is thoroughly cleaned with CR. On the third day clean with CR, wipe dry, and lightly coat with oil (PL). Weekly thereafter, when not firing, clean with CR, dry and coat with oil (PL).

61. Recoil Slide Rails

Recoil slide rails serve to guide the motion of the tube during recoil and counterrecoil. Two rails (fig. 69) are customarily used and are attached either at the sides of or below the tube parallel to the bore. The rails move in slide bearings in the cradle, and are lubricated with grease. These are lubricated with GAA grease twice daily during firing. In cases where parts of the bearing surfaces of either the rails or the guide bearings are exposed, they must be kept thoroughly cleaned and lubricated because any dirt or corrosion on these exposed surfaces when the piece is operated may be drawn into the bearings and cause serious trouble.

62. Breech Mechanism
(fig. 69)

The motion between the contacting surfaces of the breech and firing mechanisms is at slow speed. Moreover the parts are somewhat exposed to the atmosphere and powder smoke with the result that corrosion is as much a problem as lubrication. A light film of oil works best for lubricating purposes and regular cleaning with cleaner (CR) followed by lubrication is required to prevent rust or corrosion. On very large breechblocks the hinge may be equipped with antifriction bearings which generally are grease-lubricated either by packing or through lubrication fittings. A very large breechblock may be closed by compressed air cylinders. In such cases the air cylinder and the friction surfaces of the connecting pins are oil-lubricated. Lubrication orders call for breech cleaning and protective lubrication similar to that for tubes.

63. Cradle, Sleigh, Recoil, and Counterrecoil Mechanisms

The cradle, together with the sleigh when one is used, permits the cannon to move lengthwise with respect to the carriage during recoil and counter-recoil. Where a sleigh is used (fig. 70), the whole assembly slides in the cradle while the recoil pistons and rods remain stationary with the cradle. Where no sleigh is used, the cannon assembly, together with the recoil pistons and rods, slide directly in the cradle, the recoil and counterrecoil cylinders being fastened rigidly to the cradle. The surfaces to be lubricated include the slide bearings between the cradle and the cannon assembly or sleigh, and the slide bearings between the various surfaces of the cylinders and the surfaces of the pistons and piston rods of the recoil and counterrecoil cylinders. Where springs are used in the counterrecoil or recuperator cylinders (fig. 70) there is also rubbing contact between the springs and the cylinders as the springs expand or are compressed. There are also various other parts such as valves, rings, seals, etc., which have friction surfaces, all of which are lubricated by the recoil oil used in the cylinders. Using personnel are required to check the recoil cylinders for leakage around the piston rods, plugs, and covers and to replenish the hydraulic level in the reservoirs when necessary. The greatest care must be taken not to use any oil in a recoil mechanism except the grade and kind prescribed. The specific recoil oil to be used with a given weapon is specified in the applicable lubrication order and technical manual provided for the material. Recoil oil should not be transferred from one container to another unless it is properly marked with the exact name of the oil as listed in SB 38–5–3. Great care must be taken to maintain correct labels on all containers. Recoil oils should not be subjected to excessive heat. Containers of recoil oil should never be left open. Dirt and moisture in recoil oils can cause serious damage or malfunctioning of mechanisms.

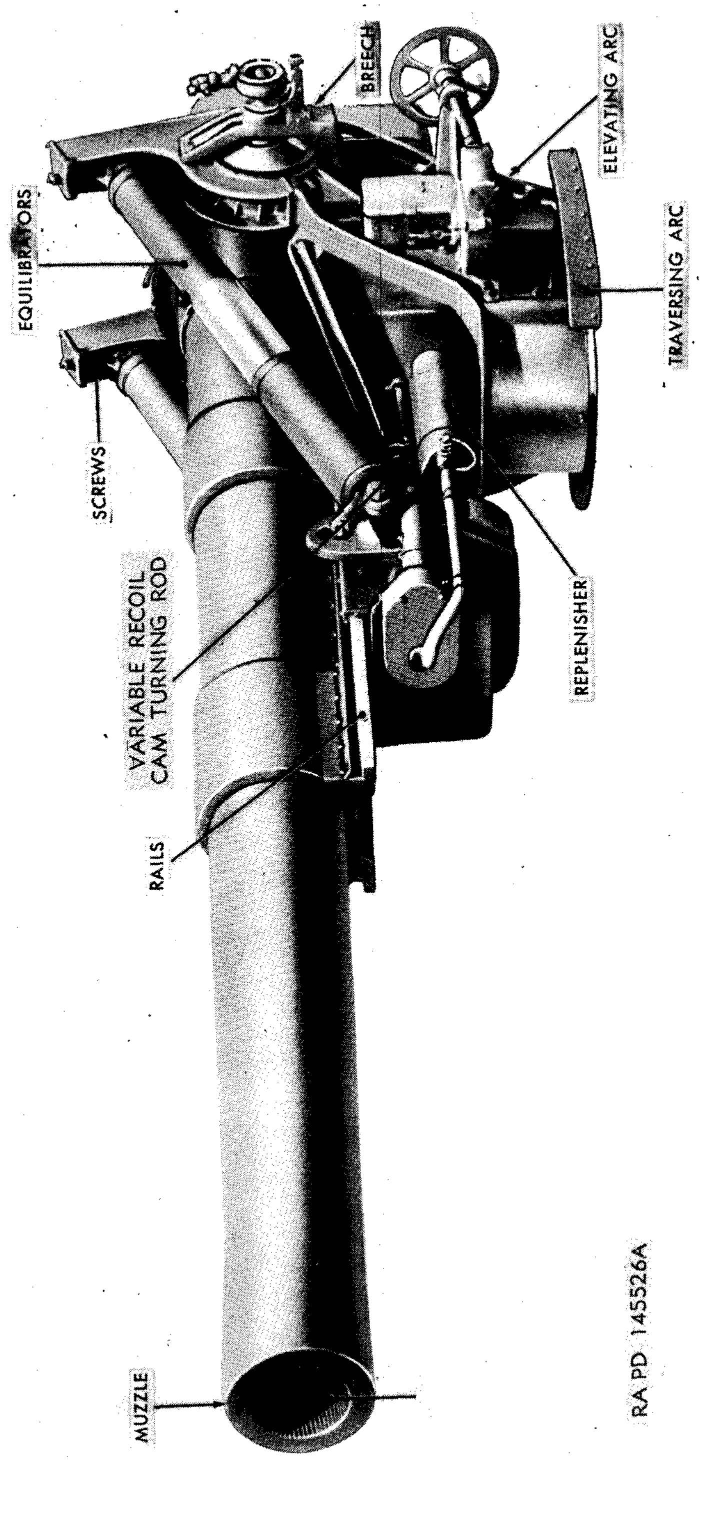


Figure 69. 8-inch howitzer showing lubrication points.

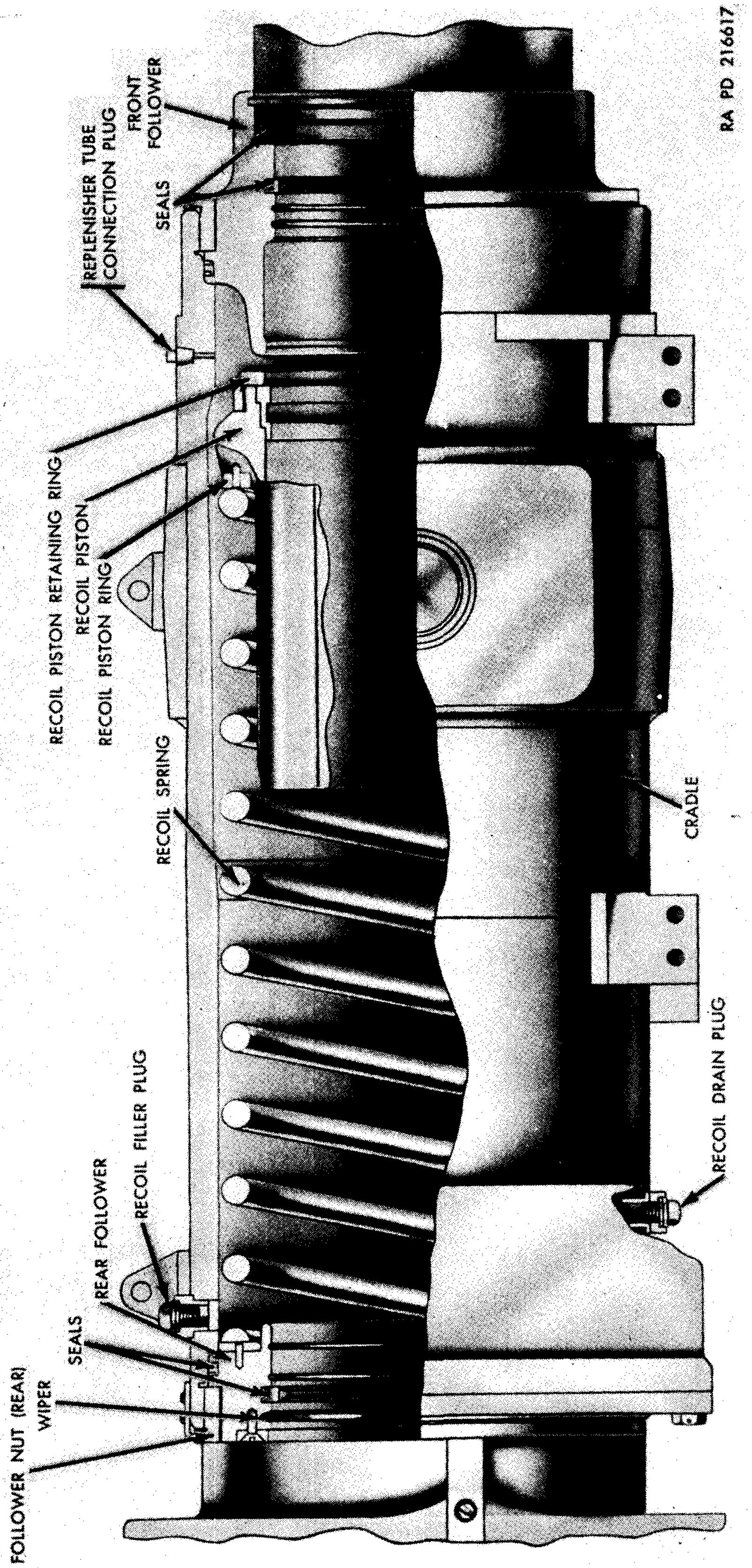


Figure 70. Recoil mechanism—cutaway view.

64. Elevating and Traversing Mechanisms

a. Elevation Mechanisms. An elevating mechanism (fig. 71) consists of devices for elevating and depressing a weapon to an angle and holding the weapon at the angle during firing. The devices may be one of the following, or a combination of these:

(1) Gear train operated by a handwheel.

(2) Hydraulic mechanism controlled by a handwheel.

(3) Remote-control power-driven mechanism.

The motions of most bearing surfaces are at comparatively low bearing speeds and of comparatively short duration. The result is that most of the bearings are of the friction type and are lubricated with oil. Antifriction bearings and gear teeth are lubricated with grease (GAA). Where grease is used, only enough should be applied to furnish a proper lubricating surface film on the working parts and to protect the metal from corrosion. Excess grease (particularly in cold weather) may restrict the movement of the weapon. Trunnion bearings, upon which the motion rotates may be either journal or roller bearing types. Pertinent weapon manuals and lubrication orders will direct the proper lubrication of these bearings. Some lubrication points of an elevating mechanism are shown in figure 71, a phantom view of the gearing used for elevating a typical weapon, either by power applied to the power drive gear, or by a handcrank.

b. Traversing Mechanisms. A traversing mechanism is a device for turning a weapon in a horizontal plane (right or left). The moving parts may consist of the upper part of the carriage, or the entire carriage, except the axle. In the case of self-propelled artillery, a turret may be moved to traverse the piece. Traverse mechanisms are typed by two broad classes—pintle (worm and gear) and ring gear. In the pintle type (fig. 72) the weapon is rotated about a vertical pivot fixed under part of the top carriage. The bottom carriage

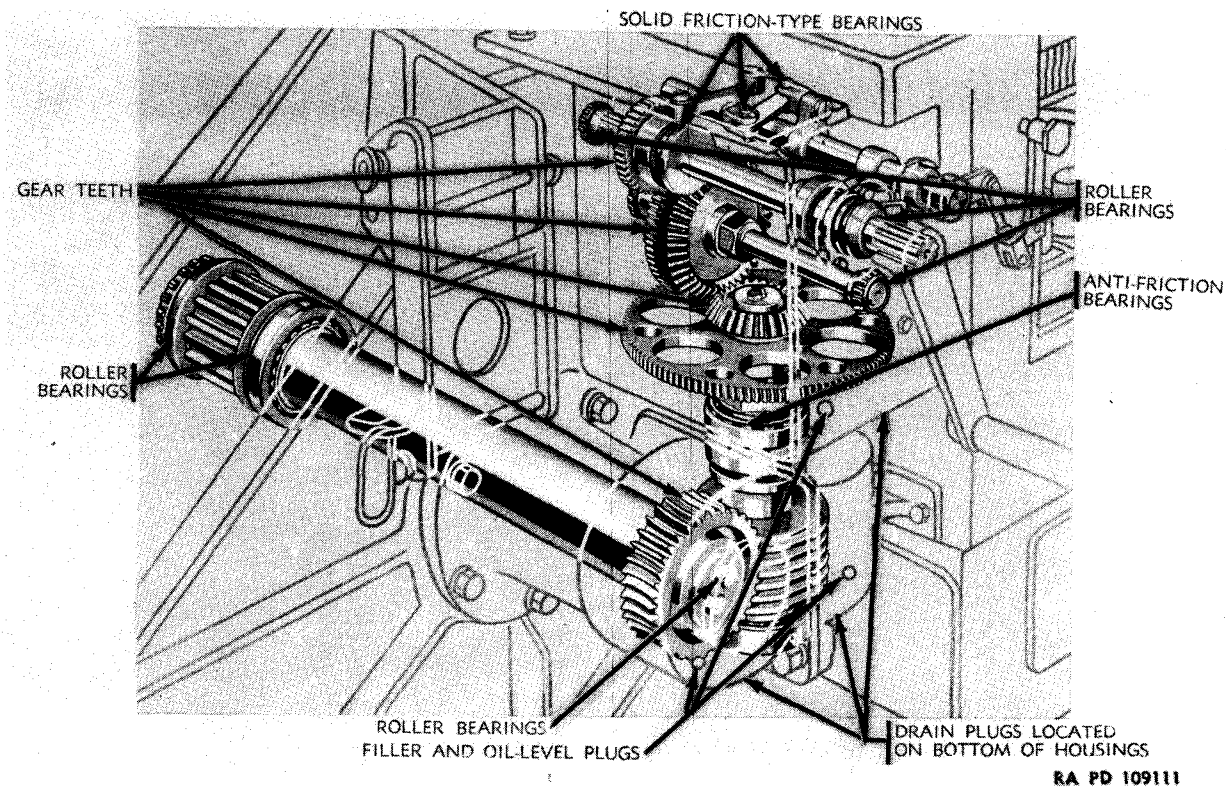


Figure 71. Elevating mechanism.

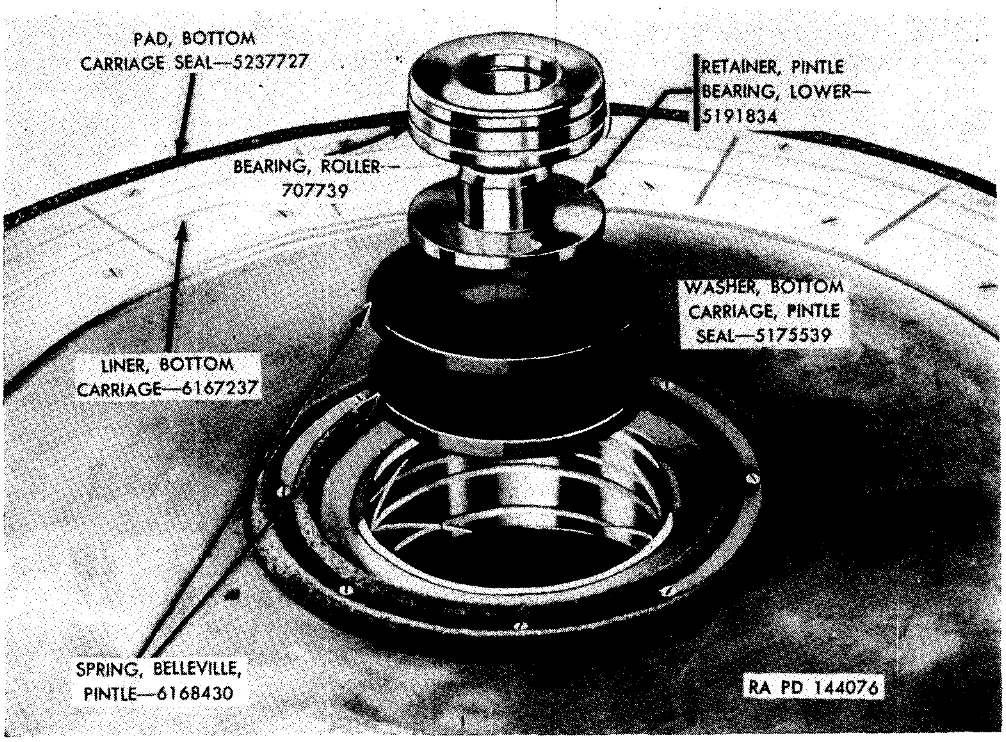


Figure 72. Lower pintle parts.

contains the base on which the top carriage rotates. The mechanism consists of a handwheel and shaft which operates a worm and rack or a pinion and rack. The ring gear type consists mainly of large bearings operating between two bearing surfaces, the base ring and the racer. On tank-type vehicular-mounted weapons, the turret contains the traverse mechanism. It is extremely important that the bearings and gears are cleaned and lubricated according to technical manuals. The same basic principles for lubricating elevating mechanisms apply to traverse mechanisms.

65. Equilibrators

a. Spring-type Equilibrators. In a spring-type equilibrator, there are few surfaces to be lubricated except the hinge pins, rods, etc., used to connect the spring to the cradle and carriage, and these generally are oil-lubricated. Some springs are inclosed in telescoping tubular housings which ordinarily require oil lubrication of the sliding bearing between the two tubes. Some spring equilibrators use cable chains and chain wheels to secure certain desired mechanical motions and advantages. The chains generally are lubricated with oil, and the antifriction bearings of the chain wheels are lubricated with grease through lubrication fittings. The leverage adjusting screws also are oil-lubricated.

b. Pneumatic Equilibrators. In a pneumatic equilibrator the surfaces to be lubricated include the sliding surfaces of the piston, piston rod, and cylinder as well as the journal-type bearings of the pins used to attach the equilibrator to the cradle and carriage. To prevent leakage of gas between the moving points, seals are incorporated. These seals generally are grease-lubricated, this grease providing the necessary lubrication for the piston and cylinder. In order to prevent gas leakage this grease must resist hardening, solidification, or separation over considerable periods of time and at such temperatures and pressures as may be encountered. Unless the grease has these properties, the proper gas pressure cannot be maintained. Lubrication will be done only by specially trained personnel after the equilibrator has been removed from the piece. The attaching pins and leverage adjusting mechanism may be oil- or grease-lubricated. The type of surfaces to be lubricated closely resembles that of the hydropneumatic equilibrator (fig. 73).

c. Hydropneumatic Equilibrators. In a hydropneumatic equilibrator (fig. 73), cylinders, pistons, and interior mechanisms are lubricated by the operating fluid, while the leverage adjusting mechanisms and the pins or other devices used to connect the equilibrator to the cradle and carriage either are grease- or oil-lubricated. The internal lubrication will be done only by authorized depot personnel.

66. Carriage

a. General. The bearing surfaces to be lubricated are incorporated in the wheels or axles on which the materiel is transported, the elevating and traversing mechanisms already mentioned, or in the various mechanisms by which the materiel is converted from firing to traveling positions, and vice versa.

b. Lubrication of Wheel Bearings. At the present time, practically all artillery that is moved on roads or cross country on its own wheels is equipped with pneumatic tires and antifriction wheel bearings. Such bearings usually are removed, cleaned, and repacked periodically as indicated on lubrication orders. Service is the same as prescribed for automotive wheel bearings.

c. Miscellaneous Items. Many of these items require practically no lubrication from the standpoint of preventing friction as the amount of motion and the frequency of movement involved may be extremely limited. In such

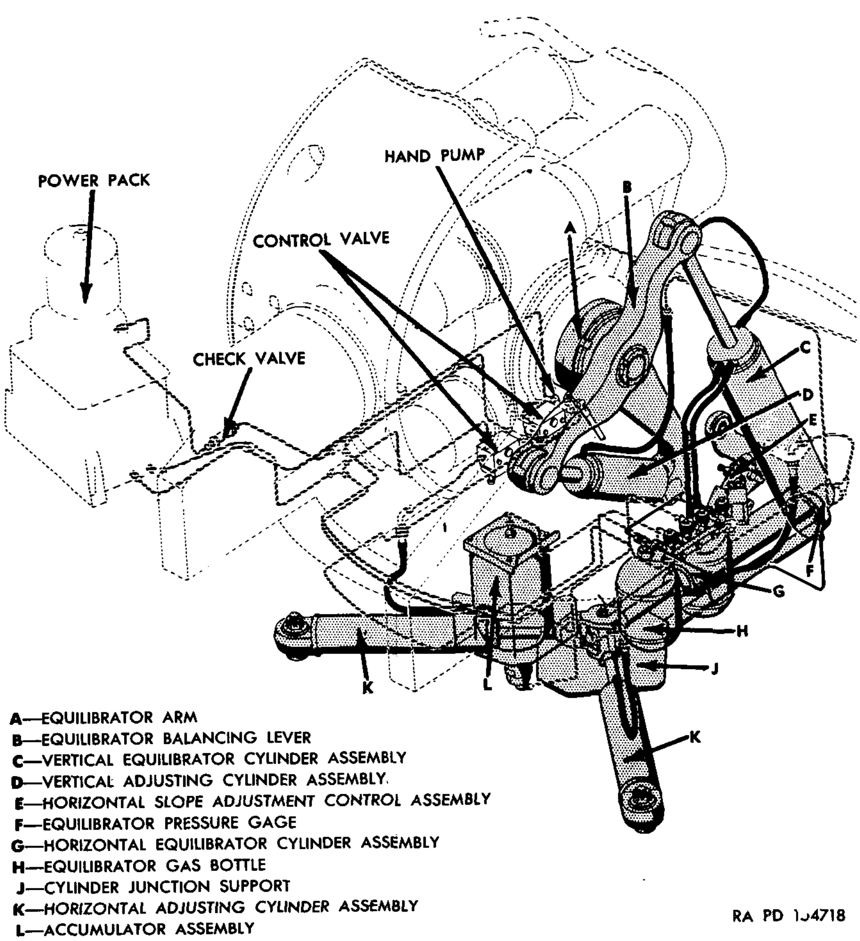


Figure 73. Equilibrator of the hydropneumatic type.

cases the corrosion preventive qualities of the lubricant become more important than its lubricating properties. Specific instructions for lubricating such miscellaneous items as screws, jacks, pins, brakes, draw bars, pintle hooks, levers, etc., may be found in the pertinent lubrication orders and technical manuals.

67. Hydraulic Speed Gears

On artillery using mechanical power for traversing, elevating, or loading, a hydraulic speed gear generally is used between the source and the point of application of the power. The speed gear serves to transmit the rotary power at variable speeds in either direction and without abrupt graduations. The bearing surfaces to be lubricated include journal bearings, roller thrust bearings, roller bearings with radial load, ball and socket bearings, universal joints, pistons, cylinders, stuffing boxes, screw and nut, etc. Lubrication for all of these parts is provided by the hydraulic oil which acts as the operating fluid. The oil is a special low pourpoint oil with particularly high resistance to thickening at low temperatures and oxidation or sludging in service, but inasmuch as the expansion tank is open to the atmosphere and liable to collect moisture, the system should be serviced carefully in accordance with instructions in the applicable lubrication order and technical manual.

68. Rammers, Fuze Setters, and Other Operating Mechanisms

The great increase in the rapidity of operation of fire control apparatus in many cases has made automatic power-driven loading, aiming, and firing of artillery necessary. This has introduced various electric motors, shafts, gears, levers, pins, control apparatus, etc., and resulted in numerous additional bearings to be lubricated. As a general rule, radial or thrust bearings on shafts operating at considerable speeds are of the antifriction type and may be either oil- or grease-lubricated. Where practicable, gear trains and other mechanisms are inclosed in cases or housings and run in an oil bath. Backlash and clearances are generally very small and it is important that the lubricant specified be maintained at the correct level, and that the housing be drained and refilled with new oil and disassembled and cleaned at specified intervals. Pins, shaft, thrust bearings, slide bearings, exposed gears, or other points having slow or intermittent motion generally are oil-lubricated, and exposed friction surfaces must be cleaned frequently to keep them free from dirt or dust.

69. Cold Weather Lubrication

a. Characteristics of Lubricants.

(1) Oils prescribed for use on artillery materiel at high temperatures are designed to maintain adequate body at these temperatures, but in some instances they become too stiff at low temperatures to permit satisfactory operation. As stiffness increases, more power is required to move surfaces of bearings and gears in contact with oil. When solidification occurs, the moving parts cut a channel through the oil, leaving the rubbing surfaces dry and unlubricated. Before friction can develop enough heat to liquefy the oil and establish an oil film, bearing and gear tooth surfaces may score and fail. The effects are similar when rubbing surfaces are fed by an oil pump. The stiffened oil flows too slowly, or not at all, to the pump inlet, and the oil already in the feed lines cannot be forced to the bearings. Therefore, heavy oils must be replaced completely below 0° F. with lighter oils which will remain fluid at the lowest expected operating temperatures.

(2) Grease is a combination of soap and oil, the grade being determined by the percentage of soap and the viscosity of the oil used. The soap acts as a sponge to hold the oil in place, thus preventing leakages which might occur if oil alone were used. As the temperature decreases, both the oil and soap stiffen and retard movement of parts; therefore, in subzero

weather, greases which cause minimum drag must be used, as the presence of only a small quantity of a heavy grade of grease may freeze bearings and prevent manipulation of the materiel at subzero temperatures. All grease prescribed for warm-weather lubrication must be removed from bearings and gear cases and replaced with suitable low-temperature lubricants when subzero temperatures are expected. If necessary, the materiel will be disassembled to accomplish this. Once grease has solidified, it cannot be removed from bearings or gear cases without disassembling the unit and washing the parts with dry-cleaning solvent. Technical manuals and lubrication orders contain lubrication instructions for operation below 0° F.

b. Plans for Winterization.

(1) Preparation of artillery for low-temperature operation requires disassembly, repair, cleaning, adjustment, and lubrication, which operations must be completed before the advent of cold weather.

(2) When preparing artillery materiel for operation in subzero temperatures, it is imperative that parts be alined properly and that adequate clearances exist in bearings and mechanisms employing packings around rotating or reciprocating shafts or rods. Improper alinement may result in binding which will make the mechanism stiff of inoperative regardless of the lubricant used. Scored or roughened bearings and other rubbing surfaces, such as cams and recoil slides, also interfere with easy action and should be smoothed when preparing artillery and fire-control materiel for low-temperature operation.

(3) Cleanliness is imperative. Rust, dirt, gummy oil, and grease in bearing clearances interfere with proper distribution of lubricant, thus causing stiff action, if not complete stoppage, in subzero weather. In preparing materiel for subzero operation, assemblies and mechanisms must be disassembled sufficiently to permit complete removal of heavy oil, grease, and foreign matter. Cleaning is done most efficiently by washing the parts which have been exposed to powder fouling with rifle-bore cleaner solvent cleaning compound (CR) and dry-cleaning solvent small other parts, using brushes and scrapers where necessary. Care must be taken not to overlook the cleaning of small items which may appear insignificant. Field experience has proved that careless repair and excessive lubrication of bearings and other similar parts may cause malfunctioning or failure of equipment in subzero weather.

c. General Subzero Lubricating Instructions. To insure adequate lubrication and satisfactory performance of artillery materiel in cold weather, the following instructions must be followed when subzero temperatures are expected:

(1) *Bearings.*

(*a*) *Ball and roller bearings (grease-lubricated).* It is impossible to replace warm-weather grease in ball or roller bearings by forcing in the grease prescribed for low temperatures. These bearings must be removed from the materiel, washed thoroughly in dry-cleaning solvent, dried, and then coated sparingly with the prescribed lubricant. The balls or rollers, races, and cages must be coated lightly, and the bearing housings filled only enough for the lower balls to dip into the lubricant.

(*b*) *Ball and roller bearings (oil-lubricated).* Oil-lubricated ball and roller bearings preferably will be removed and cleaned. If this is impracticable, a thorough flushing with dry-cleaning solvent, followed by application of the prescribed oil, generally will give satisfactory results. Parts and gear cases must be thoroughly dry before oil is applied, as oil will not adhere to a surface wet with solvent. Oil sumps and reservoirs will be drained and filled with prescribed oil. The wicks of wick-fed bearings will be removed, washed in dry-cleaning solvent, dried, and saturated with the specified low-temperature oil before assembling.

(*c*) *Plain journal bearings and bushings.* It is preferable to disassemble these bearings, remove all heavy oil and grease, smooth off burs, and test for adequate clearances between the shaft and bearing. If disassembly is impracticable, heavy lubricant usually can be forced from the bearings by thorough flushing with subzero lubricant. Reservoirs and wick feeds must be cleaned completely and refilled to prescribed level with the proper oil.

(2) *Gears.*

(*a*) Gears inclosed in oiltight gear case will be checked to insure the prescribed lubricant for the expected temperature during operation is used. If the case does not contain the prescribed lubricant, drain and refill to proper level with the proper lubricant. Do not fill the gear case above the specified level because the surplus oil will result in unnecessary drag on movement of the gears. If no drain or level plug is provided, the gear case will be disassembled, the gears and bearings cleaned with dry-cleaning solvent, dried, slushed with oil, and assembled in the case. The prescribed lubricant then will be poured into the case until the lowest gears are dipping. If gears are inclosed in a case which is not oiltight, the cover will be removed and the gears thoroughly cleaned, smoothed, and coated with oil before replacing the cover.

(*b*) When gears have been lubricated with grease above 0° F., it practically is impossible to wash heavy grease out of a gear case by flushing. Grease-filled cases, therefore, will be disassembled, the gears, case, and bearings washed clean with dry-cleaning solvent, and all parts coated with the lubricant prescribed for extreme cold weather operation by the applicable lubrication order. Use only enough lubricant for satisfactory lubrication when refilling the case.

d. Breech and Firing Mechanisms.

(1) Satisfactory operation depends on extreme cleanliness and sparing application of oil. Clean all parts, except gas check pads, daily with cleaning solvent and dry. Gas check pads will be wiped with a dry cloth and coated sparingly with oil. Do not use dry-cleaning solvent or bore cleaning solution on gas check pad. Apply oil by wiping the rubbing surfaces of the firing pin and attendant parts with a clean cloth which has been wet with oil and wrung out.

(2) After firing, breech and firing mechanisms on weapons using fixed and semifixed ammunition will be disassembled, cleaned with specified cleaning solvents, dried, and oiled sparingly. Mechanisms on weapons using separate-loading ammunition will be disassembled, and all parts, except the gas check pad and electrical firing mechanisms, cleaned with bore cleaning solution, dried, and oiled sparingly. The gas check pad will be wiped with a dry cloth and coated sparingly with oil.

e. Recoil Mechanism.

(1) Refer to pertinent technical manual and lubrication order for prescribed recoil oils and fluids to be used in cold weather operation. Operation of the recoil mechanism will be affected because of a thickening of the recoil

oil or fluid. Hydropneumatic mechanisms also will be affected by the reduction of gas pressure at low temperatures.

(2) Care of recoil mechanisms will be nearly the same during cold weather as it is under normal conditions. Using units must maintain careful check on recoil mechanisms. At times the recoil mechanism may not function normally and the cycle or recoil may take longer than usual. This is caused by the oil becoming thick and not flowing as readily as in normal temperatures. As further firing is conducted, the action gradually warms the recoil oil and thins it so that normal cycle time is obtained. Do not condemn the recoil mechanism until there is definite proof of malfunction.

(3) The recoil mechanism may stick unless it has been exercised frequently, and sticking may result in severe damage to the weapon when it is fired. Intervals of exercise will depend upon the existing temperature—the lower the temperature, the more frequent the exercise. Refer to pertinent technical manuals for methods of exercising.

f. Recoil Slides. Friction between recoil slides and guides absorbs an appreciable amount of the energy of recoil. Thickened or congealed lubricant increases this friction, shortens recoil, and retards counterrecoil. To insure proper recoil and counterrecoil action, thoroughly clean the slides of summer lubricant; smooth all surfaces; and relubricate them sparingly with the prescribed lubricant for cold weather operation. When temperatures rise and remain constantly above 0° F., resume lubrication with products specified in applicable lubrication order or technical manual. Removal of subzero lubricants is not necessary. Instead, start applying the lubricant prescribed for temperatures above 0° F.

g. Equilibrators. Lubricate equilibrators with lubricant prescribed in applicable technical manuals and lubrication orders. The piston rod will be lubricated sparingly and care will be taken to prevent the formation of ice which would freeze it in position. With pneumatic-type equilibrators it may be necessary to adjust nitrogen pressure to provide sufficient equalizing action. On those equilibrators equipped with a low-temperature control, adjustment will be made in accordance with the temperature scale provided. When temperatures rise above 0° F., adjust gas pressure and low-temperature control to the prescribed value.

h. Elevating and Traversing Arcs and Handwheel Shafts. Snow frequently will collect on these parts and cake under pressure of the gears. Since this will interfere with elevating and traversing, the snow must be removed by vigorous brushing with a stiff bristle or wire brush before manipulation of the piece is attempted. After snow is removed, the parts should be lubricated immediately to prevent rusting.

i. Cradle, Sleigh, Carriage, and Mount. Completely disassemble the cradle, sleigh, carriage, and mount mechanisms when it is necessary. Thoroughly clean all parts, making sure that all rust, dirt, and old lubricant are removed before applying prescribed lubricant. Relubricate sparingly with cold weather lubricant as prescribed in applicable lubrication orders and technical manuals.

j. Brakes. Mechanical brakes will be lubricated carefully. Proper lubrication should be applied to all connections and joints. Wheel chocks should be used in preference to setting the brakes when gun is parked. In lubricating the brake, keep lubricant away from inside of drum or shoe. Brake shoes will be kept as dry as possible. Make a thorough check of brake shoes whenever checking the wheel bearings.

CHAPTER 10
MISSILES

70. General

Missiles form a class of weapons in growing use by the Army. These devices contain mechanisms which require special lubrication and lubricants. The missiles, having operating parts such as rudders, elevons, auxiliary power supplies, bearings, etc., cover a wide range of points of lubrication. Further, the lubrication must not only insure operating parts at normal ground conditions, but the rapid change in conditions brought about by launching and in-flight operations, must be considered. Lubrication of the auxiliary equipment (launchers, loaders, transporters) used with the missiles, is similar to that encountered in automotive and artillery equipment. It is imperative that the technicians refer to pertinent technical manuals and lubrication orders for specific missile equipment before performing maintenance. Each missile system has particular requirements. No attempt has been made to compile these requirements into a general discussion because of inevitable conflict with authorized procedures.

71. Component Parts

a. General. Silicone-type grease is the general lubricant for many parts of missiles. It is selected because (1) of its uniformity of viscosity during wide temperature range, (2) it is flame-resistant, (3) it does not cause deterioration to rubber, (4) it does not oxidize readily. Sometimes it is mixed with molybdenum disulfide to lubricate and further protect metal parts from oxidation. Silicone-type greases must be used with extreme caution. They must be used only in the specific areas outlined by pertinent lubrication orders. Indiscriminate use of silicone greases can cause trouble. For example, silicone compounds impregnate themselves into porous metals such as aluminum and megnesium and become extremely difficult to remove by cleaning solvents. Consequently, paint and primer coats will not adhere properly to metals whose surfaces are impregnated with silicones. Silicone compounds also disperse themselves as films on items being cleaned, thus contaminating cleaning equipment, solvents, and other parts.

b. Packings. When O-rings or seals are installed in flange joints, they are lightly lubricated, normally with the fluid being transmitted. Flat gaskets are also treated in the same manner. It is very important that only a very light coating is applied. In pneumatic systems, pneumatic grease (GPS) is used.

c. Threads. Threaded joints, in general, are lubricated with a mixture of molybdenum disulfide and silicone grease to prevent galling and seizing.

d. Internal Mechanisms. Since these mechanisms are lubricated at assembly, there is little need for further lubrication by user or maintenance personnel. However, should parts be removed for repair or replacement, necessary lubrication and hydraulic servicing according to pertinent technical manuals and lubrication orders should be done.

e. External Mechanisms. Stabilizers, fins, etc., will have been lubricated prior to troop issue. If inspection shows lack of lubrication, however, the hinges, bearings, and exposed metal parts must be lubricated with silicone-type lubricants.

CHAPTER 11
FIRE CONTROL AND DETECTING EQUIPMENT

72. General

Fire control equipment used by Ordnance requires a great degree of correctness and completeness. Ordnance fire control materiel is a complex of mechanical and electronic units. Some of the radar detection equipment operates automatically, continuously, and often unattended in remote areas. The lubrication of this equipment must always be correct and complete. Over lubrication is undesirable in some of the delicate electronic gear. Excess or improper lubricants may "creep" onto optical lenses and obscure vision. Excess lubrication may cause binding of delicate mechanisms.

73. Optical Instruments

a. General. In the optical instruments used in connection with fire control materiel, there are practically no friction surfaces except those required for the focusing movements of eyepieces. These friction surfaces usually take the form of some type of screw thread, and motion is so limited that lubrication is seldom required. It is necessary, however, to seal such points to prevent corrosion or the entrance of dust, grit, or moisture; small quantities of aircraft and instrument grease are used. This grease is prepared especially for fire control systems, sighting equipment, etc. Do not overlubricate as excess lubricant may creep onto lenses and obscure vision. Other screw threads, such as those on lens adapters also are sealed with grease in a similar manner. For this reason, the lubrication of optical instruments will be performed only by authorized personnel after disassembling and cleaning. On some of the older instruments which are lubricated with heavier greases at the time of their manufacture, it has been found that the prescribed grease may be too light for use on eyepiece movements when temperatures are normally above +32° F. This condition would be indicated by the bleeding of the lubricant into the interior of the optical instrument or by failure of the eyepiece movements to remain stationary during usage after focusing. In such cases, a heavier grease may have to be used on such eyepiece movements. When temperatures consistently below 0° F. are encountered, such optical instruments as have been lubricated with a heavier grease, will be lubricated with the aircraft and instrument grease. Some optical instruments have adjustable mounts which may incorporate journal bearings, screw and nut mechanisms, ball and socket joints, etc., which are either oil- or grease- lubricated as directed in the applicable technical manual. On account of the length of time between lubrication operations, with the resulting chance for deterioration of the lubricant, these lubrication points are inclosed when possible. Flexible leather or rubber boots or covers are used to keep dust away from ball and socket mechanisms.

b. Condensation and Lubrication. If instruments are brought indoors after having been outside at low temperatures, the moisture from the warm air will condense on the cold metal, and if the instruments are operated in this condition, the grease and moisture will come into contact. Such a condition will necessitate removing all the grease and lubricating the instrument. For this reason, anticondensation containers should be used when it is necessary to bring instruments or other such equipment from a low temperature to room temperature, and instruments when finally sealed should be in a room kept at outdoor temperature. Anti-condensation containers may be specially made boxes, G. I. water cans, barracks bags, or any other fairly airtight container with heat-conducting walls. These are kept outside so that they will remain at prevailing temperatures until it is desired to bring an instrument indoors. The instrument is put into the container, the top closed, and the whole brought inside and allowed to come to room temperature. As the air in the container warms and expands, the breathing will be outward and condensation will form on the outside of the container rather than on the instrument.

74. Worm and Worm Wheel Measuring Movements

Many of the measuring movements incorporated in fire control materiel are accomplished through worm and worm wheel mechanisms. These mechanisms, while varying widely in physical adaptation, are all practically alike as far as basic principle and friction surfaces are concerned. In nearly all cases the bearing surfaces including the contact between the worm and worm wheel are lubricated sparingly with aircraft and instrument grease in accordance with instructions in the applicable lubrication order and technical manual. A felt seal is used to prevent entrance of dust at the point where the wormshaft comes out of its housing. This felt must be kept oiled or it may harden, and the friction at this point may cause the felt fibers to bunch up rendering the mechanism inoperative. In some cases it may be necessary to partially disassemble the mechanisms to get oil onto the felts. Only authorized maintenance personnel will disassemble to clean and lubricate the internal mechanisms of telescope mounts and range quadrants. Bearings, sliding surfaces (grooves in shell guide), hinge joints, and other movable parts should be clean and lubricated with a light coat of grease. The pawls should be coated with a light oil. Internal parts such as ball bearings, gears, and the working parts of the setting crank assembly should be lightly greased.

75. Computers

a. General. Computers, which continuously calculate firing data for use against moving targets, are very complicated assemblies containing large numbers of both mechanical and electrical parts of various types and descriptions. As a result there are a correspondingly large number and variety of friction points to be lubricated, including plain friction bearings, antifriction bearings, thrust bearings, slide bearings, pins, levers, cams, springs, variable speed drives, worms and worm gears, all types of spur and bevel gears, spiral drives, torque amplifiers, motors, etc. A great majority of these parts are comparatively small, bearing fits are close, back lash has to be eliminated to a great extent, and the parts still have to operate over a wide range of temperature and over long periods of time between rebuilds. The construction of various items of materiel varies so greatly that it will be necessary to refer to the pertinent technical manual for lubrication instructions for any specific item. Whenever a unit is taken in for maintenance, and it is necessary to remove the cover plates, the unit should be inspected for necessary lubrication. All bearings and points of sliding friction that are accessible should be checked. Ball bearings are greased at the time of assembly and ordinarily require no attention until the time of general rebuild, but if the grease does show any signs of hardening or other deterioration, the bearing should be removed by authorized maintenance personnel, cleaned with solvent, dried, and immediately lubricated with aircraft and instrument grease. Units showing sluggish operation at temperatures below 32° F. should be lubricated sparingly. Units which have been in storage for a considerable length of time must be completely disassembled, cleaned, and lubricated. All lubricating operations should be done in dustfree rooms.

b. Variable resistors. surfaces to be lubricated in variable resistors include not only the sliding contact between the brushes and the wires of the resistance cards or coils, but the gear teeth and bearings of the driving mechanisms as well. Thes parts generally are installed in an oiltight housing and submerged in oil, which serves as both a lubricant and an insulating medium.

c. Variable Speed Drives. Variable speed drives are made in a number of forms. The conical roller type (fig. 74) incorporates various types of friction surfaces to be lubricated including antifriction bearings, ball and socket, journal bearings, guide bearings, gears, etc. The mechanism is inclosed in a housing, however, and a supply of oil lubricates all of the surfaces by the dip method. Another and more common type of variable speed device uses a flat circular plate and a cylinder or roller connected by two balls. It is known as the disk and cylinder type. The balls are held in a cage and a line through their centers and the axis of the cylinder is perpendicular to the surface of the disk. The balls may be moved radially across the disk, thus changing either the direction of rotation of the cylinder or its speed for a given movement of the disk. Both oil and grease are used for lubricating drives of this type depending upon the speed of the disk, temperatures, etc. Refer to the pertinent technical manual and lubrication order for specific insturctions.

76. Fuze Setters

Fuze setters are used to adjust or set the movable rings of a fuze before the projectile is inserted into the gun. They may be hand-operated or completely automatic devices built onto the breech end of the cannon and controlled by a director. As far as lubrication is concerned, the smaller setters consist essentially of two concentric rings held in a housing in which they can be turned or adjusted by means of knob-operated worms meshing with teeth cut in the outside edges of the rings. Lubrication generally is accomplished by inserting oil into the hollow body of the housing through oil screw holes. Larger setters are fixed in the desired position and projectiles are put into them for setting the fuze. This necessitates a socket to hold and rotate the projectiles and the mechanisms to rotate it. The mechanism customarily includes a gear drive giving the necessary mechanical advantage, and the parts turn on friction- or antifriction-type bearings, depending on size. The bearings are lubricated as directed in the pertinent technical manual. Other setters include a fuze indicator which operates as part of the data transmission system to keep the gun crew

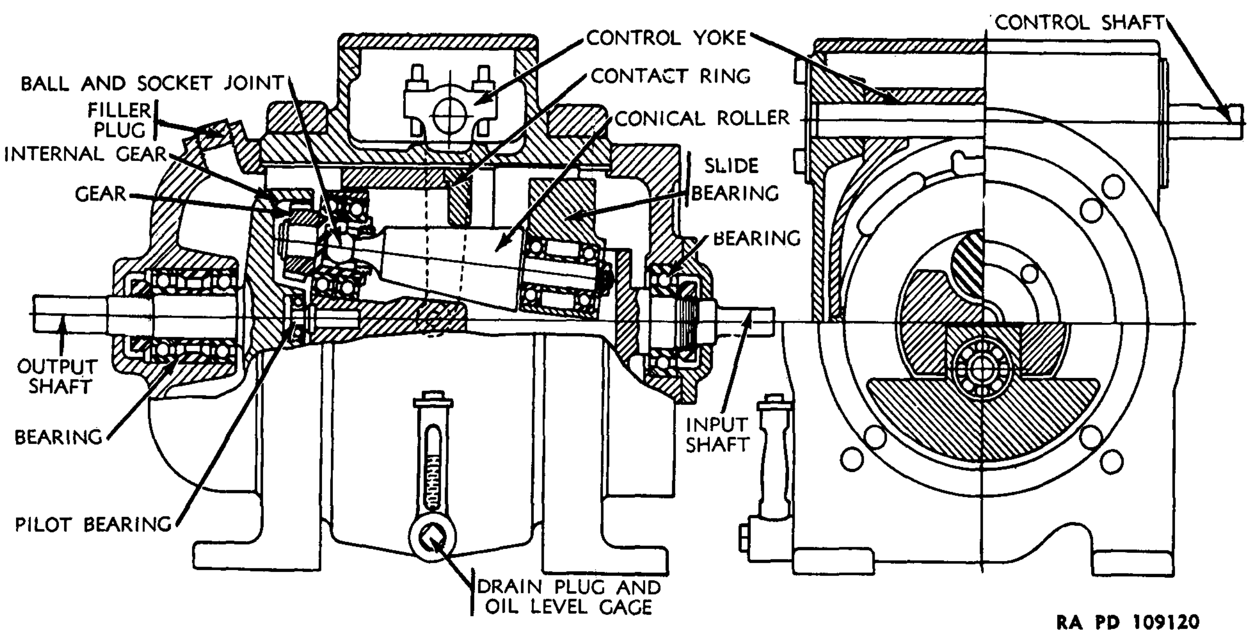


Figure 74. Variable speed drive of the conical roller type.

constantly informed as to the correct fuze setting, and some setters on anticraft guns are controlled entirely by the data transmission system.

77. Generating Units

a. Engines. The greater part of the lubrication of generator units applies to the engines which constitute the source of power. These engines generally are quite similar to the power plants of automotive vehicles, and the lubrication instructions given in chapters 6 and 13 therefore are applicable.

b. Generators. Generator bearings may be either of the plain journal or antifriction type and may be either grease- or oil-lubricated as directed in pertinent lubrication orders or technical manuals.

c. Cold Weather Conditions. If a generating unit is winterized properly and is in good mechanical condition, it will operate down to the lowest sub-zero temperature encountered.

(1) Refer to paragraph 89*b* for instructions on engine lubrication in extreme cold weather.

(2) All linkages should be lubricated very lightly with oil or grease so that they will operate easily at low temperatures.

(3) Assemblies on starters must be kept clean and free of ice and snow. They will not be lubricated.

(4) The governor linkage should be lubricated lightly and the joints kept free of ice and snow, or the governors may not function, causing the engine to "run away" when it is first operated.

(5) Choke and throttle control wires and knobs may become hard to operate at low temperatures. The wires will be removed from their casings and smoothed down with aluminum-oxide abrasive cloth or crocus cloth. The wires and inside of the casings then should be cleaned with dry-cleaning solvent and lightly lubricated before assembly.

(6) Tachometer drive cables will be removed from their sheaths and the cable and the inside of the sheath cleaned with dry-cleaning solvent. The cables will be lubricated lightly with oil or grease.

(7) When operating generating units at low temperatures, they must be run for at least 30 minutes. A shorter operating period will cause condensation of moisture in the crankcase. Some of this moisture will combine with carbon and dirt to form sludge in the crankcase. This sludge may clog oil lines, the oil filter, or oil holes so that lubrication will be insufficient and bearings may fail. During the period of warmup, the radiator should be covered to give rapid warmup.

78. Radar Equipment

a. General. Motors, servomechanisms, gear trains, instruments, support cables, turntables, and hydraulic systems are some of the elements in radar equipment that require careful lubrication. Wide coverage of lubrication is presented in technical manuals for this type of materiel. While general areas of importance are discussed here, the specific technical manuals and lubrication orders must be followed for correct servicing of these equipments. Figure 75 shows various parts of this equipment requiring lubrication.

b. Motors. The bearings of most motors in radar service are permanently lubricated and sealed. They should be checked, however, when periodic lubrication of other pieces of equipment takes place. Motors or bearings running hot, evidence of odors or smoke, and leaking seals require immediate maintenance. When motors are repaired for electrical failures, bearings should be cleaned, examined, and replaced if necessary. Proper lubrication of the bearings takes place at this time. Some motors require periodic oiling. Small amounts of light lubricating oil on the shaft bearings at monthly intervals is a general requirement. Specified maintenance instructions are prescribed in lubrication orders.

c. Servomechanisms. These devices are manufactured to tolerances of tenths of thousandths because ideal accuracy is required in

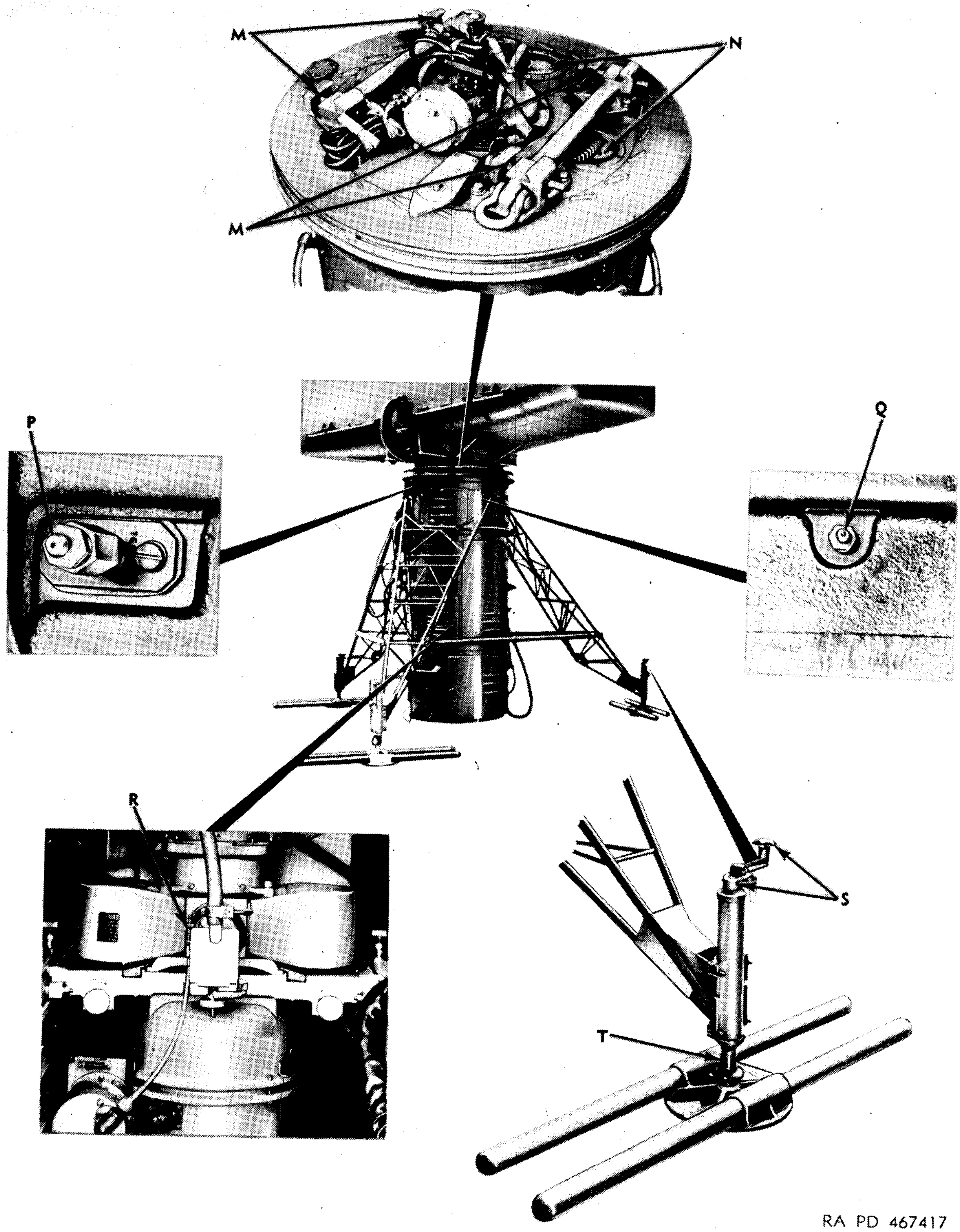


Figure 75. Lubrication points acquisition antenna.

their function. Backlash and clearances of the gears are very low. Bearing fits are close. Lubrication of such mechanisms is precise and specialized. Light instrument oil, sparingly applied, is enough lubrication. Too much oil will cause binding of moving parts. Excessive oil might penetrate electrical insulation or components and create serious malfunctioning. Some servomechanisms have components made of metals which form oxides. This bond between moving parts interferes with accurate motion. In severe cases the oxide will "feeeze" parts together making them inoperable. To prevent oxidation, special lubricating materials are prescribed. Whenever servomechanisms are involved in lubrication, the specific technical manuals and lubrication orders must be accurately followed.

d. Gear Trains. Rotating antennae are heavy pieces of equipment. Their broad surfaces, exposed to wind and snow add to the load that must be supported by operating gears and bearings. Lubrication of these parts is generally made on a quàrterly basis. Liberal use of aircraft and instrument grease is prescribed. This grease is not effected by high or low temperatures and is quite resistant to water.

e. Instruments. This class of equipment, like servomechanisms, requires correct lubrication. Special lubricants (G-611) aircraft and instrument type, lightly applied on fine gears, small bearings, and switches are necessary. These lubricants contain antioxidizing compounds. Lubrication, as well as general maintenance of this specialized equipment, is usually done by instrument experts.

f. Cable and Chains. The maintenance of support members in radar groups depends upon lubrication. Their guy wires are lightly swabbed with general OA1 type oil. The properties of the lubricant are such that it will seep through to all the strands. Because it has low evaporating qualities, it will remain as a protective seal against weather for long periods of time. Working ropes and chains require heavier lubricants such as CW II. This viscous, tacky petroleum based lubricant will cling to the surfaces needing protection. Immersions in water and bad weather conditions will not destroy or remove the compound. To make its application easy, the oil can be heated and swabbed on liberally with a paint brush.

g. Turntables. Bearing plates and the heavy rollers that move on them take grease of the GL type. Pressure-type fittings are pointed out in the technical manuals where these lubrication areas apply. A dust seal is created by the grease to protect the inner mechanisms.

h. Hydraulic Equipment. Certain elements requiring smooth motion use hydraulics. Maintenance of hydraulic systems in radar equipment is the same as in other equipments. Leaking seals or irregular consumption of the hydraulic liquids require immediate maintenance. A fluid of the OHC type containing a petroleum base with special additives is used. These fluids have different color dyes added so they may be used where they are required. Th filler caps on the hydraulic reservoirs are painted an identifying color as specified in TB ORD 586 to indicate the specific fluid to be used. The fluids have a color corresponding to the filler cap.

i. Types of Items. Lubrication instructions and references in this manual prescribing lubricants to be used on fire control materiel and method of application apply to the following types of such materiel:

(1) Boards (correction, deflection, plotting, etc.).
(2) Compasses.
(3) Computing sights.
(4) Directors and computers (mechanical and electrical except fire control systems T33C, M33C, T33D, and M33D and fire control system T38).
(5) Fuze setters (all types, except combination fuze setter-rammer M20).
(6) Motor drives.
(7) Mounts (all types, including adapters and holders).
(8) Optical instruments (all types).
(9) Quadrants (all types, including clinometers).
(10) Remote and local control system (all components except oil gears M3, M6, and M6A1).
(11) Sighting systems.
(12) Sights (all types).
(13) Training instruments (for example,

stereoscopic trainer M7, machine gun trainer M9).

(14) Tripods.

j. Aircraft and Instruments Lubricants.

(1) All fire control items listed in *i* above will be lubricated with aircraft and instruments lubricating grease. Refer to Department of the Army Supply Manual 10–1–C4–1 (Federal Supply Catalog, Department of Defense Section, C4–1, all items in FSC group 91, fuels, lubricants, oils, and waxes). The lubricant will be applied sparingly to provide smooth and reasonably free movement, particularly during periods of extreme cold. Lubricate when necessary and at time of repair or rebuild.

(2) Lubrication of fire control materiel will be performed only by ordnance personnel, with the following exceptions which may be lubricated by the using organizations.

(*a*) External parts not readily lubricated with grease, such as handwheel knobs or cranks, hinges, stay brackets, cover fastening devices, felt washers, and drawer rollers. Lubricate as required with aircraft instrument lubricating oil.

(*b*) Exposed bearing surfaces such as segments, worms, and lead screws. Lubricate with a thin film of aircraft and instruments lubricating grease. This grease provides for both lubrication and protection against corrosion.

k. Lubrication Fittings no Longer Required. Remove all external oil and grease lubricating fittings which have not previously been removed from the items listed in *i* above. Do this at the time of major repair or rebuild.

Note. Do not remove fittings used for filling or draining of insulating, recoil, hydraulic, or variable resistor oils.

l. Procedure for Removal of Lubrication Fittings and Plugging of Holes.

(1) Unscrew threaded-type fittings and remove drive-type fittings.

(2) Plug the holes from which fittings have been removed in the following manner:

(*a*) *Threaded-type fittings.* Select the proper size pipe plug which, if possible, is of the same material as the material being plugged. Apply white lead pigment to the threads of the *plug only. Do not apply pigment to the tapped hole.* Screw in the plug, cut off flush, and stake in place. When a pipe plug is not available, drill and tap the hole to the next larger size (fine thread series) and fabricate a threaded plug. Apply pigment as prescribed above, screw in the plug, cut off flush, and stake in place.

Caution: **Drilling, tapping, and plugging must be performed when the instrument is disassembled. Resultant chips and other foreign matter can then be removed. Do not permit the plug to project into the instrument. It may interfere and cause damage after assembly.**

(*b*) *Drive-type fittings.* Tap hole to accommodate either pipe or straight plug, and proceed as prescribed for plugging threaded-type fittings ((*a*) above).

(*c*) *Oil holes.* Plug in the same manner as prescribed for drive-type fittings ((*b*) above).

m. General Maintenance. For general maintenance procedures for fire control materiel, refer to TM 9–254.

CHAPTER 12
SMALL ARMS MATERIEL

79. General

The problem of the lubrication of small arms is rather peculiar because cleaning, preserving, and lubricating are so closely related. Most of the friction surfaces fall into two general classes: (1) slide bearings, reversing intermittent motion; (2) journal bearings, slow, less than 360 degree motion. The result is that lubrication problems are not severe as long as the friction surfaces are free from dust, dirt, water, etc. Although oil is used in the bores and chambers of small arms weapons, it is for preservative purposes only when the weapon is not in use. It is always removed before the weapon is fired because it will cause hazardous chamber pressure. Experience has proved that more small arms become unserviceable through lack of proper maintenance than for any other reason. Lubrication and preservation are very important parts of complete maintenance. Refer to pertinent lubrication orders and technical manuals for details.

80. Rifles

The rifle must be cleaned after firing because substances from the primer cause a deposit of ash, carbon, and corrosive salts. The bore should be swabbed with bore cleaner or soapy water followed by drying and light oiling. The gas cylinder and chamber should be oiled lightly using a preservative-type lubricant. Oil the face of the bolt and piston of the operating rod after cleaning. After removing sand, dirt, etc., from all other parts with a stiff brush, they should be oiled lightly. Linseed oil should be rubbed into the wooden parts. Rifle grease should be applied to the lip of the receiver and locking recesses. The camming lugs of the bolt and the camming surface in the hump of the operating rod should be greased. Daily examination for rust and the removal, if any, is important to the maintenance of the rifle. The rifle should always be protected with a light coat of preservative oil. FM 23–5 covers maintenance details for caliber .30 rifles M1.

81. Machineguns

Care of machineguns in the lubrication and preservative areas is similar to that of rifles. Temperature rise due to firing may cause more persistent residues than those encountered with rifles. A bore brush is used before swabbing with bore cleaner patches. The gas cylinder on some models does not require daily maintenance because of a built-in cleaning action. In hot and dusty areas, lubrication should be minimized in order that dust and grit will not adhere to parts.

82. Revolvers, Pistols

The revolver should be cleaned after use with bore cleaner or warm soapy water and dried. Moving parts then should be lightly oiled. The stationary metal parts should always be protected with a rubbed-in oil film.

CHAPTER 13
WEATHER CONDITIONS

83. General

a. Military vehicles may be used in almost any area on the face of the globe. They are designed and manufactured for certain average conditions, and special maintenance operations are used to cover extreme conditions. Aside from vehicle casualties in combat and normal wear, maintenance problems arise chiefly from the type of service (driver control, engine speeds, and engine loads) and the operating conditions (climate, atmospheric contamination and terrain).

b. Preventive-maintenance procedures are prescribed in order to secure continuous efficient engine operation and to prolong periods between rebuilds. In some areas, conditions such as relatively high or low temperatures, high humidity, dusty air, steep grades, etc., cause engine malfunctions and harmful crankcase contamination. The maintenance of proper engine adjustments; the regular cleaning and servicing of air cleaners, ventilation systems, cooling systems, oil filters, etc.; and the following of prescribed engine oil draining procedures are important elements in dependable engine service.

c. Lubrication is a most important factor in engine operation. Operating factors that cause lubricant deterioration and contamination may be divided into five general classifications—high engine temperatures, low engine temperatures, contamination by dust from the atmosphere, contamination by water from cooling system leaks or from condensation, and contamination by products of improper fuel combustion (soots and unburned fuel). These factors may develop either from the severity of type of service (driver control, speed, and loads) or the inadequacy of preventive maintenance measures taken. Adequate preventive-maintenance measures will compensate for the harmful effects of adverse operating conditions (weather and terrain).

d. Recorded world atmospheric temperatures vary from a low of –90° F. to a high of +136° F. within the limits of continental United States, temperatures of –66° to +135° F. are on record. There is also sufficiently wide variation in rainfall, relative humidity, terrain, and dust conditions to enable a fairly direct comparison with almost any area on the globe, with the exception of the extremely cold arctic regions. Experience obtained from military vehicle operation in the various areas throughout continental United States can be related to almost any set of operating conditions that may be encountered in any area throughout the world. The influence of climate upon engine operation may be considered under the following temperature ranges:

(1) *Temperatures below 0° F.* Severe cold, requiring special equipment for engine starting and operation.

(2) *Temperatures between 0° and +32° F.* Winterization kits not prescribed; however, certain precautionary and engine warming steps essential.

(3) *Temperatures between +32° and +50° F.* Moderate cold, requiring precautionary and engine warming steps for vehicles in intermittent service.

(4) *Temperatures between +50° and +85° F.* Ideal operating tempertures.

(5) *Temperatures above +85° F.* High temperature problems.

84. Engine Operation at High Atmospheric Temperatures

a. Cooling System Maintenance. As two thirds or more of the available energy in a fuel consumed in an internal combustion engine is unused and must be dissipated as heat, crankcase oil temperatures are dependent upon the proper frunction of the engine and the engine cooling system. Hence, wherever temperatures are high or loads are heavy, oil temperatures may become excessive if the engine functions poorly or improperly. For this reason, it is especially important that emphasis be placed on the maintenance of clean deposit-free water jackets and radiator cores, as well as on the efficient operation of the fan, water pump, thermostat, oil cooler, and manifold heat control.

b. Engine Adjustments. Improper adjustment of ignition or valve timing or improper carburetor fuel mixtures will cause excessive local temperatures in the upper cylinder area of the engine. Results of excessive temperatures in these areas frequently are piston ring sticking, varnish deposits on piston skirts and valve stem, piston scuffing, burned valves, breakdown of the lubricating oil to form deposits of carbon on the under side of the piston head, and general engine sludging.

c. Engine Loads and Speeds. Excessive speeds or engine lugging (operation in too high a gear) rapidly will increase oil and engine temperatures. As higher engine speeds also place increased loads on bearings and other working surfaces, greater demands are placed upon the lubricant for adequate lubrication. The higher temperatures obtained will result in reduced load carrying ability of the lubricant. Hence, excessive speed or engine lugging are particularly dangerous when atmospheric temperatures are high or loads are heavy, and should be avoided.

d. Lubricant Deterioration. The most immediate result of heat is the temporary thinning of the oil. Continued exposure to high temperatures, however, will result in the evaporation of the more volatile fractions of the oil, leaving the oil more viscous in body. Also, in the presence of air and particularly where the oil is in contact with metals, oxidation of the oil occurs. This also results in thickening of the lubricant and in the formation of sludges, lacquers, varnishes, and other objectionable oil oxidation products. Oils have been refined from stable base stocks and processed to retard oxidation and also to prevent the deposition of decomposition products, fuel soots, and sludge in the oil passages, ring grooves, and engine parts. However, all petroleum oils will break down if the temperatures are extreme. Consequently it is important that engine adjustment and temperature control equipment be maintained properly and that proper oil drain procedures at specified intervals be followed. As the film of the lubricant becomes thinner, any abrasive material that may have entered the engine from the atmosphere, or from the engine itself, will be more damaging due to the lack of sufficiently protective layers of oil.

85. Accelerated Wear From Dust

a. Dust. Wear from dust will depend upon the character of the dust particles as well as the quantity of dust in the air. Military vehicle operation includes a great deal of travel over open fields in dusty areas which makes the problem of control of wear from abrasives a very important one. Abrasives from dusty air enter the engine through several channels—the air intake system, engine breathers, and through contamination of the lubricant during storage or in the process of adding oil to the crankcase from contaminated filling receptacles.

b. Effect of Thinned Lubricant. Wear from abrasive particles is accelerated whenever the lubricant film becomes thin, either through the thinning effect of high engine temperatures or through fuel dilution.

c. Air Cleaner Maintenance. If air cleaner elements become dirty or the oil level in the element becomes low, dust particles will be sucked directly into the combustion chamber. Large accumulations of dirt in the air cleaner elements will lower filtering efficiency and also will reduce the air supply for combustion with a resulting loss of engine power. Leaky joints in connections or deterioration of the flexible air hose connections between the air cleaner and the carburetor will provide a direct channel for abrasives into the combustion chamber. Dirt accumulation on the piston head will accelerate carbon deposits and reduce heat transfer. Products of abrasions, metal particles, and pulverized dirt will be washed down into the crankcase to further circulate and result in abrasion of bearings and journals and the clogging of oil passages. Dust entering the crankcase through the air induction or breather system causes initial damage by abrasion of the cylinder walls, pistons, and piston rings. That which is absorbed by the crankcase oil is circulated to the other bearing surfaces.

d. Dirty Oil-Handling Receptacle. Loose or unserviced breather caps, loose or missing oil filler pipe caps or bayonet-gage sticks, or the use of dirty filling receptacles are responsible for a high percentage of engine damage in dusty or sandy areas. Sand or dirt entering the crankcase through these channels will be composed of both large and small particles. The large particles will be removed by the oil pump strainers and probably do no appreciable damage. The fine particles, however, circulate through the lubrication system and are a serious threat to bearings and other working surfaces. While the large sand particles found in the crankcase oil pan do not themselves directly indicate engine abrasion, they are evidence that fine particles probably have been circulating and causing serious wear. Do not expect the oil filters to offer complete protection from abrasives for the engine, as most filters operate on a bypass system and only part of the oil passes through the filter on each circulation, the balance going directly through the engine lubricating system to bearings, cylinder walls, etc.

86. Cold Weather Problems

a. General. When engine crankcase temperatures are low (below 140° F.), engine efficiency is very poor and wear and engine deterioration occurs at a faster rate. Atmospheric temperatures below 0° F. make these problems acute and require special provisions in the form of winterization kits for the starting and operation of vehicles. Where operation of a vehicle is intermittent (frequent starts and stops), engine temperatures will not be high enough when atmospheric temperatures are below +55° F. unless steps are taken to provide adequate engine temperatures.

b. Wear Accelerated By Cold Sluggish Lubrication. A distinctive characteristic of all petroleum lubricating oils is that they become thick (heavier in viscosity) as their temperature is reduced, and this means that oil will be pumped more slowly through oil passages and will penetrate less readily through small clearances. Sufficiently low temperatures are experienced in many parts of the world to cause oil to congeal. A cold sluggish lubricant places a heavy drag on the movement of engine working parts and this places a heavy load on the battery, the efficiency of which is very poor at low temperatures. The sluggish flow of the lubricant to bearings and cylinder regions means that lubrication must come from whatever lubricant has remained clinging to these parts until further supply is furnished by the oil pumped through the lubricating system. Consequently lubricant films are apt to be inadequate and actual metal-to-metal scuffing may occur during the starting of a cold engine.

c. Water Emulsion Sludges. For every gallon of gasoline burned in an engine, more than a gallon of water is formed which, at normal operating temperatures, will pass off through the exhaust and the engine ventilation system in the form of vapor. However, when cylinder walls are cold, this water vapor will condense and run down past the pistons and rings to contaminate the crankcase lubricant and to form a back sludge. Crankcase oil pans may become loaded and oil screens plugged (fig. 76). Valves (fig. 77), valve chambers, and timing gear cases may become coated to the extent that the lubricant cannot reach the working parts. Water will absorb acid gases formed by combustion and cause corrosion and rust.

d. Engine Oil Filters. Filters are connected in the oil system with a bypass, this construction continuously passing to the filter only a small percentage of the oil being pumped. Oil

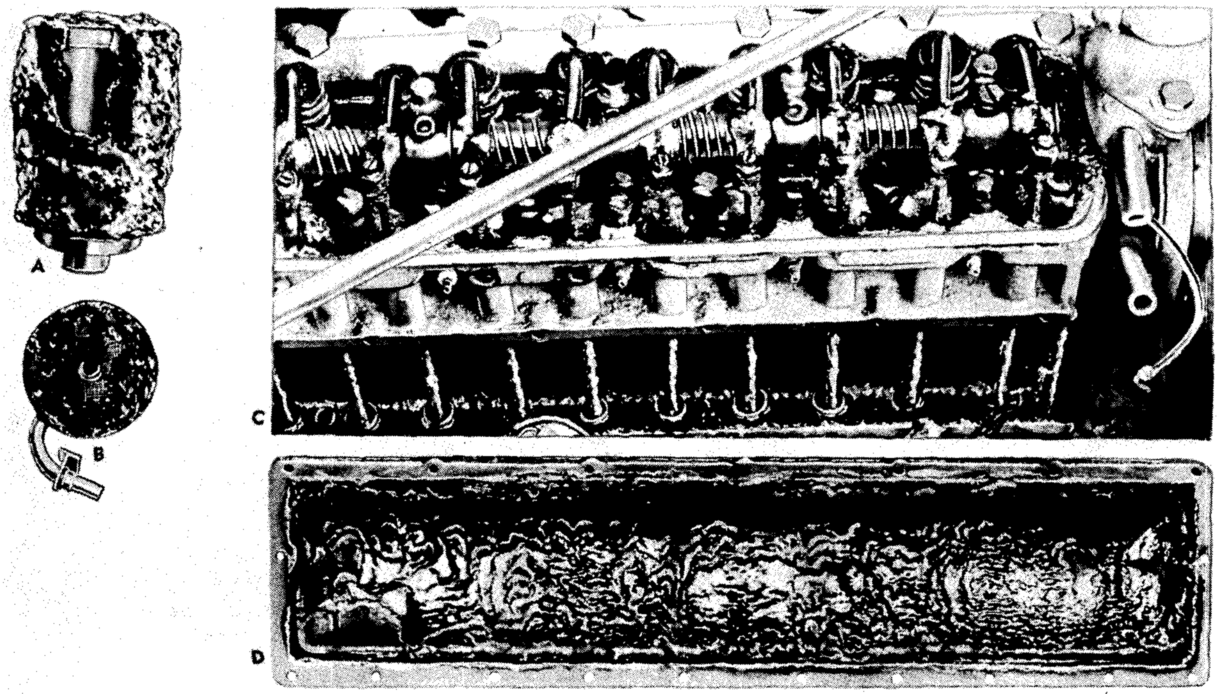


Figure 76. Sludge accumulation on (A) oil filter, (B) oil pump strainer, (C) valve mechanism, and (D) valve cover plate.

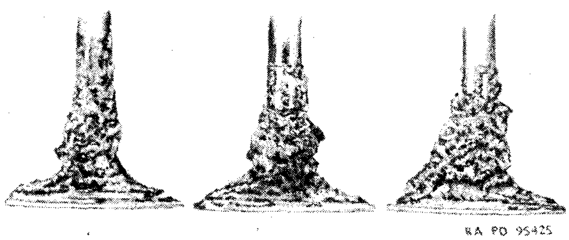


Figure 77. Gum deposits on valve stems.

filters become more loaded or clogged from cold weather type sludges than from abrasives. For this reason, filters do not become loaded as quickly during warm dusty operations as they do in cold humid areas when cold weather type sludges are more apt to occur. As the resistance to oil flow through the filter elements is increased by the oil becoming thicker at low temperatures, very little filtration occurs when engine oil temperatures are low. Consequently the oil filter cannot be expected to help in keeping the oil clean unless engine operating temperatures permit appreciable oil passage through the filter elements.

e. Combustion Problems. Combustion of fuel in an internal combustion engine is similar to the burning of kerosene in a lamp or stove. If the mixture of fuel and air is too rich (too large a portion of fuel for air), some of the fuel will be burned only partially to form soot such as may be formed on a lamp chimney or on the bottom of a pan. If the fuel is not vaporized properly, some of it will not burn at all but will drip off the burner. Unburned fuel is the source of fuel dilution of oil in the crankcase of an engine. Where engine temperatures are inadequate, it is difficult to get proper atomization of the fuel and, consequently, choking the carburetor for a richer mixture is necessary. This results in abnormal amounts of soot being formed which increases carbon deposits on piston heads and permits blowby of soot into the ring area and down into the crankcase lubricant. Fuel striking the cold cylinder walls condenses and washes down past the rings, carrying the cylinder wall lubricant with it, contaminating and thinning the crankcase lubricant.

f. Prevention of Sludge. In order to reduce cold weather sludge and resulting engine wear in automotive engines, it is absolutely essential that the cooling system temperature be raised to a minimum of +140° F. as soon as possible after starting and, so far as practicable, be maintained at +160° to +180° F. at all times while the engine is operating. The action prescribed below is applicable for all atmospheric operating temperatures below +32° F. and also for more moderate temperatures, if difficulty is experienced in raising cooling systems to +140° F. and maintaining such temperatures at +160° F. while the engine is operating.

(1) Inspect and test the cooling system thermostats to insure that the valves open and close at specified temperatures. These can be checked by removing and immersing elements in water heated to the specified temperatures.

(2) Cover hood louvers with heavy cardboard or other suitable material. This is done best from the inside of the hood.

(3) Cover radiator cores wholly or partially in accordance with atmospheric temperatures. The amount of the radiator core which must be covered in order to obtain the temperatures referred to in *f* above will vary with different vehicles and will have to be determined by trial. For temperatures of +32° to 0° F., the lower half of the core may need to be covered unless operation at high speed or under severe load is expected. For operations between +32° and +50° F. where operation is intermittent (frequent stops and starts, excessive idling, or infrequency of use), covering of the lower quarter of the core may be necessary. Radiator core covering applied for intermittent operation protection should be removed whenever high speed or heavy load operation is anticipated.

(4) Check and tighten cylinder head studs with torque indicating wrench as prescribed in applicable technical manuals to prevent liquid leaking past the gaskets.

(5) Many engines cannot be warmed up by idling. Therefore, the parctice of running engines for prolonged periods at idling speeds to warm them will be covered by operating personnel technical manuals. Start engines with clutch disengaged and maintain engine speed at fast idle until the engine is firing evenly on all cylinders and running smoothly. As soon as engine will accept a load without faltering and oil pressure has reached normal operating range, the vehicle will be operated using low gear ratios and low speeds. At no time (except in emergency conditions) will the engine be operated at high speeds or under heavy load until the dash thermometer indicates the engine has reached the normal operating temperature.

(6) The practice of running engines to charge batteries or to provide current to operate radios, turrets, guns, etc. is authorized. Pertinent technical manuals point out these cases.

(7) Each crankcase oil change will be scheduled so as to be performed *immediately* after engine operation and while the oil is still hot. Care will be taken to drain the oil completely.

(8) Oil filter cases will be drained at reduced intervals when equipped with drain cocks (or plugs) to remove sediment. It may be necessary to drain filters daily under unusually severe conditions.

(9) When it is known that an engine is badly sludged, the crankcase pan will be dropped and sludge removed from pan, valve mechanism, and exposed parts. At the same time, clean oil pump screen thoroughly.

(10) When an engine has been operated for an extended period under conditions where cold engine sludge accumulations are being experienced and

a change to high speeds or heavy loads is anticipated, it is advisable to flush with an engine conditioning oil to reduce sludge accumulation before the vehicle is placed in severe service where warm engine temperatures are expected. The procedures outlined in paragraph 45*b* will be used in flushing:

Note. Such flushing will not prevent further sludge accumulation but will reduce the hazard of screen clogging and lubrication failure from sludge that may be dislodged and put in circulation by warm oil.

g. Progressive Development of Engine Depreciation. Figure 78 shows how engine depreciation develops progressively when preventive maintenance operations are not performed or are ineffective for any reason.

87. Wet Conditions

In prolonged wet weather, particularly when traveling over soggy terrain and whenever fording takes place, water will seep into lubricated parts. This will cause sludge, corrosion, and accelerated wear. It is imperative that complete lubrication is made as soon as practicable. This involves draining and drying gear housings, crankcases, and bearings where water may have collected. Complete lubrication of the parts, in accordance with lubrication orders, must then be done. Unpainted metal surfaces should be wiped dry and preservative type lubricants applied.

88. Effect of Variation in Climate Upon Engine Conditions

a. General. In order to compare the influence of weather and operating conditions on vehicle engines, several hundred thousand tests were conducted on military vehicles in training areas throughout the continental United States. The results of these tests have been broken down and related to prevailing conditions of climate, and figures 79 to 83 inclusive show average results of operation under varying cli-

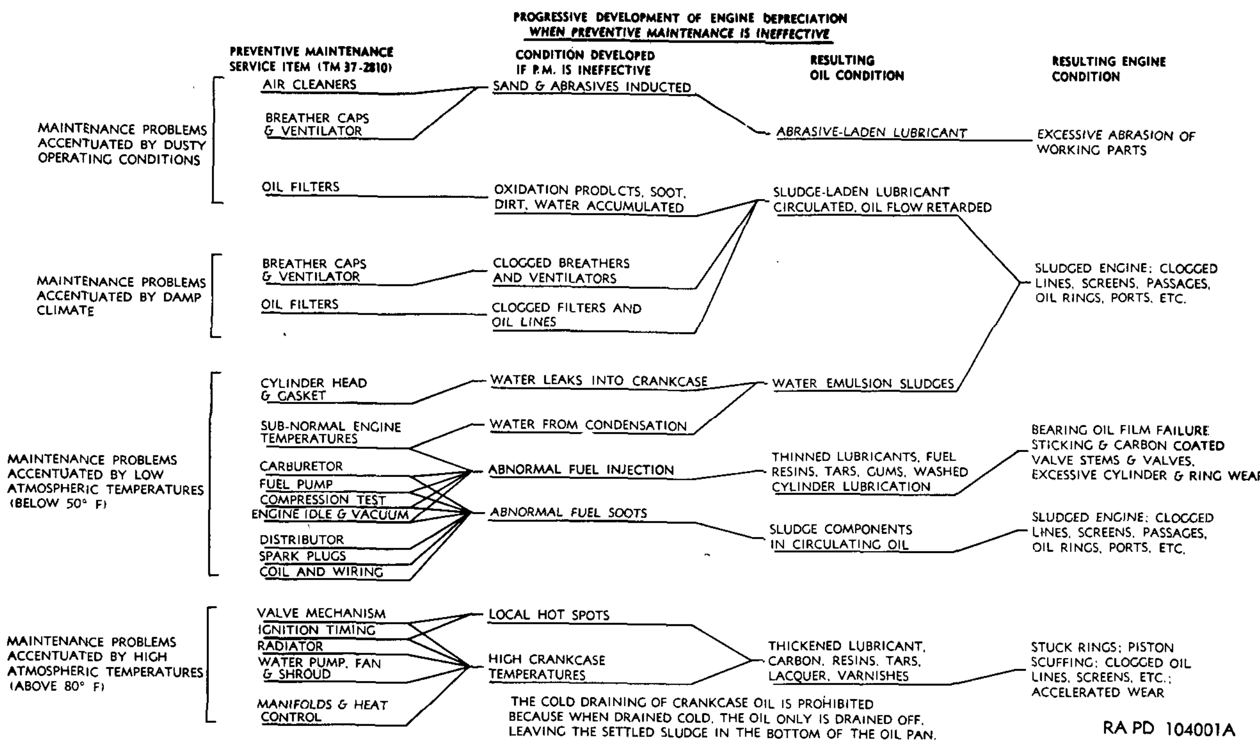


Figure 78. Progressive development of engine depreciation when preventive maintenance is ineffective.

matic conditions with respect to water contamination, engine sludging, filter loading, combustion difficulties, and accelerated wear. The purpose of these charts is to enable maintenance personnel to anticipate problems in maintenance and operation in order to minimize harmful effects from unfavorable operating conditions.

b. Water Accumulation in Crankcase (fig. 79). The accumulation of water in appreciable quantities (in excess of 1 percent of the crankcase contents) depends chiefly upon the temperature in the crankcase. Temperatures in the crankcase in excess of +160° F. will prevent condensation of water. From figure 79 it will be noted that only a very moderate percentage of vehicles experience water contamination of the lubricant at air temperatures above +50° F. However, below this temperature the percent of engines experiencing water contamination of the crankcase oil approximately doubles for each 20 degrees decrease in temperature.

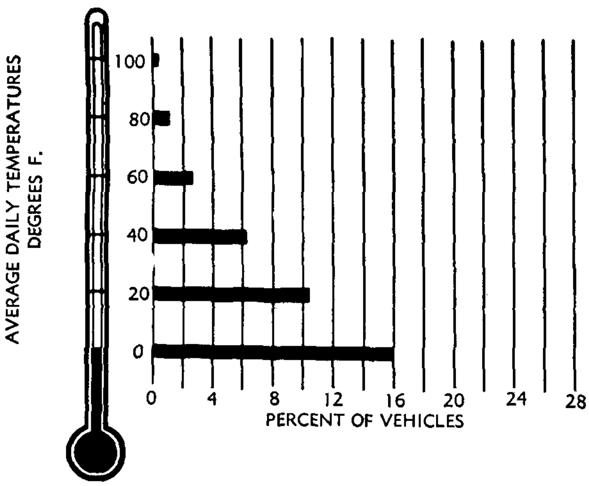


Figure 79. Prevalence of water emulsion in crankcase oil.

c. Engine Sludge. From figure 80 it will be noted that both temperature and relative humidity are important factors in engine sludging. By far the greatest percentage of sludged engines experienced in military operation are of the cold weather sludge type. Prescribed military crankcase lubricants are exceptionally stable to high temperature oxidation and decomposition. The dispersing properties of these lubricants prevent the deposition at normal temperatures of sludge-forming constituents. However, if crankcase temperatures become cool, water, fuel dilution, and other products of combustion tend to promote precipitation of contamination to form engine sludges. In damp humid climates the vapor-laden air tends to accelerate the deposition of such sludges. It will be noted that the percent of engines experiencing sludge accumulations is about twice as great in humid areas as in dry areas of corresponding temperature conditions.

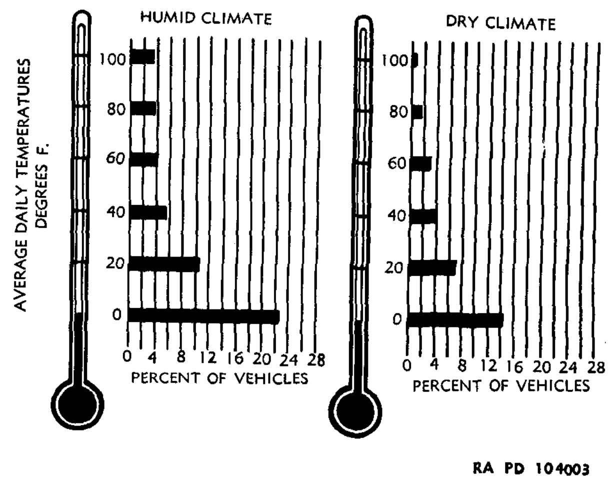


Figure 80. Prevalence of sludge in crankcase oil.

d. Ineffective Filtration. It will be noted from figure 81 that the increase in rate of filter loading or the decrease in filtering effectiveness closely parallels the formation of sludge (fig. 80). A primary function of the oil filter is to remove from the crankcase oil sludge-forming constituents. Therefore, it is natural that the rate of filter loading would correspond very closely to the rate of occurrence of sludge-forming material. It also will be noted that relative humidity, as well as temperatures, is an important element in the rate of filter loading.

e. Combustion Difficulties. Poor vaporization of the fuel attends vehicle operation at temperatures below +50° F. Consequently, difficulties in obtaining efficient combustion of the fuel below this temperature increase rapidly as the temperature is lowered. Concurrent contamination of the lubricating oil by fuel

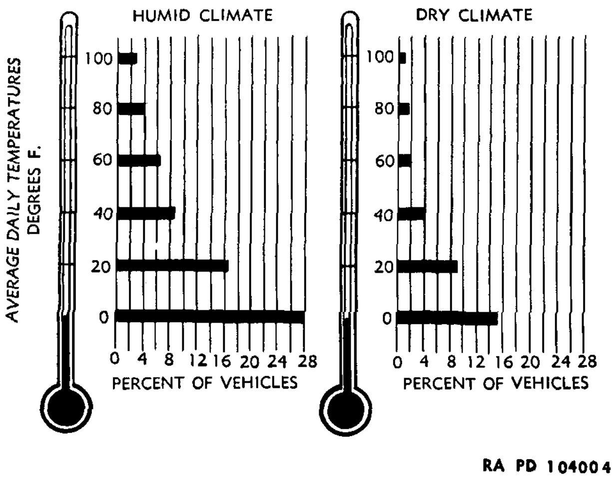


Figure 81. Prevalence of ineffective filtration.

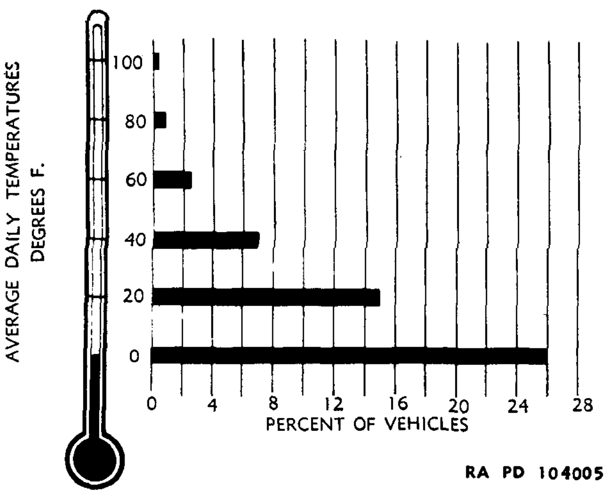


Figure 82. Prevalence of poor combustion.

soot and unburned fuel (fuel dilution) increases at corresponding rates (fig. 82).

f. Accelerated Wear. Two prime causes for abnormal wear of military vehicle engines are cold weather starting and dusty operating conditions.

(1) Figure 83 shows the relative rate of increase in abnormal wear chiefly due to cold starting of engines in relation to the prevailing air temperature. In this connection it can be pointed out that even +80° F. is cold for an engine. The rate of accelerated wear during the starting period increases very rapidly below 32° F. and it is of extreme importance that proper warmup procedures be followed for operation at temperatures below this point.

(2) Figures 84 and 85 show the effect of dusty conditions. Abrasives from dusty air enter engines through the air intake system, engine breathers, and from contaminated oils or oil containers. If air cleaner elements become dirty or the oil level in the element becomes low, dust particles will be sucked directly into the cylinders. Large accumulations of dirt in the air cleaner elements will lower filtering efficiency and will also reduce the air supply for combustion, resulting in a lowered fuel efficiency. Products of abrasion, metal particles, and pulverized dirt will be washed down the cylinder walls into the crankcase to result in abrasion of bearings and journals and clogging of oil passages. Dust and dirt that enters the crankcase directly through loose or missing breather caps, contaminated oils, or misuse of containers, dipsticks, etc., will pass through the oil circulating system, causing accelerated wear to parts. While the large particles will be filtered out, and seen on strainers and filters, the smaller particles are passed through to do damage to all surfaces on which oil is used.

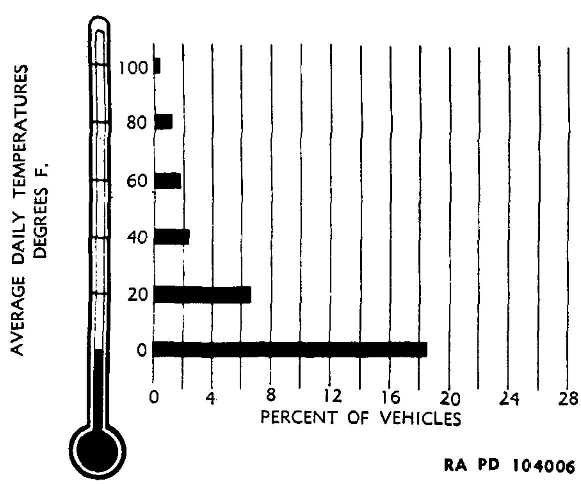


Figure 83. Prevalence of abnormal wear due to low atmospheric temperatures.

g. Results of Tests. Charts showing average results of tests from vehicles of training organizations within continental United States are shown in figures 84 and 85. The locations of installations from which tests were taken are indicated on the outline map (fig. 86) on which zones of average temperatures are shown. A world outline map (fig. 87) showing corresponding temperature zones is provided in order to assist in relating experiences of vehicle operation in United States to that to be anticipated for similar climate in foreign theaters. Table III gives climatic data for representative points throughout the world.

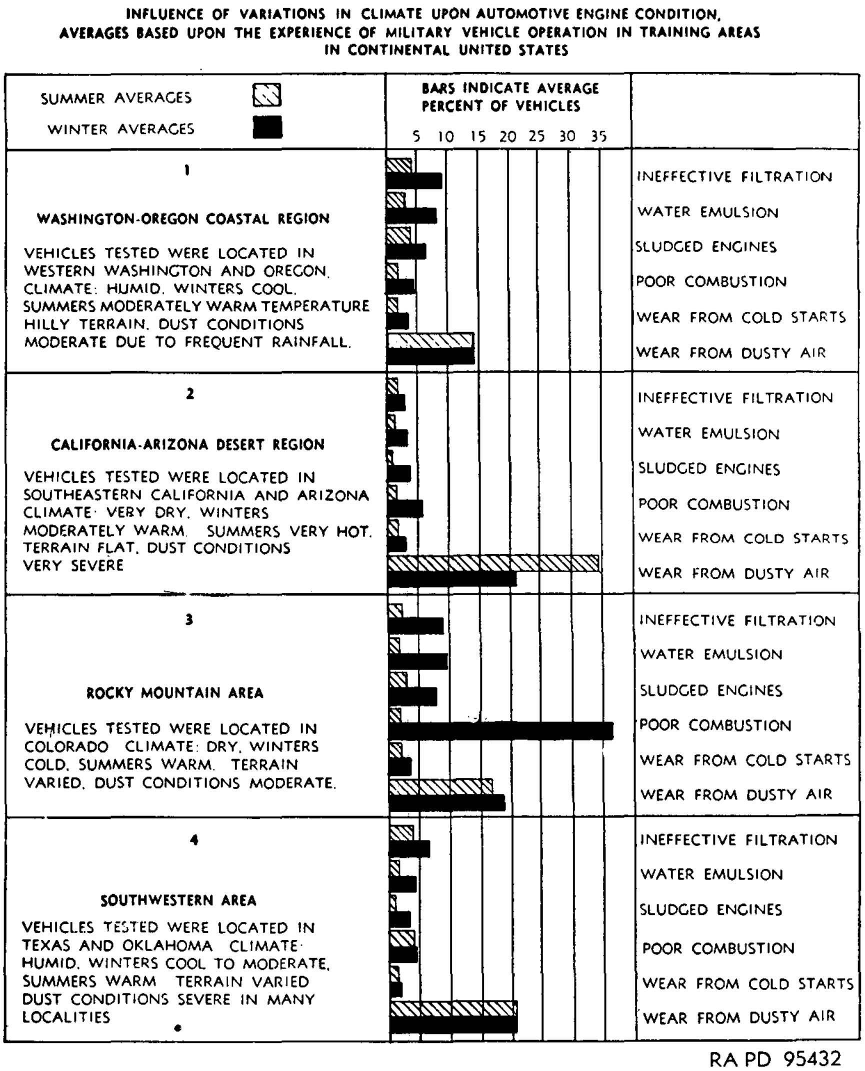


Figure 84. Influence of variation in climate upon atomotive engine condition.

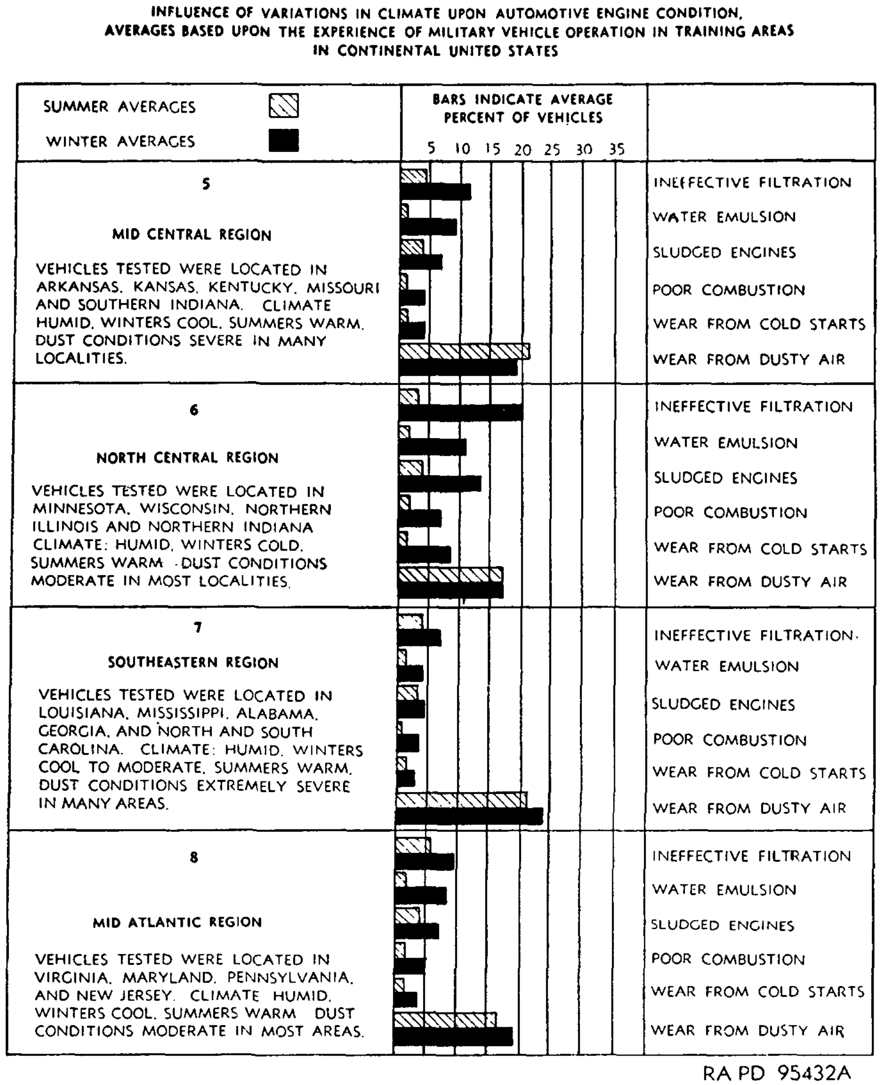


Figure 85. Influence of variations in climate upon automotive engine condition.

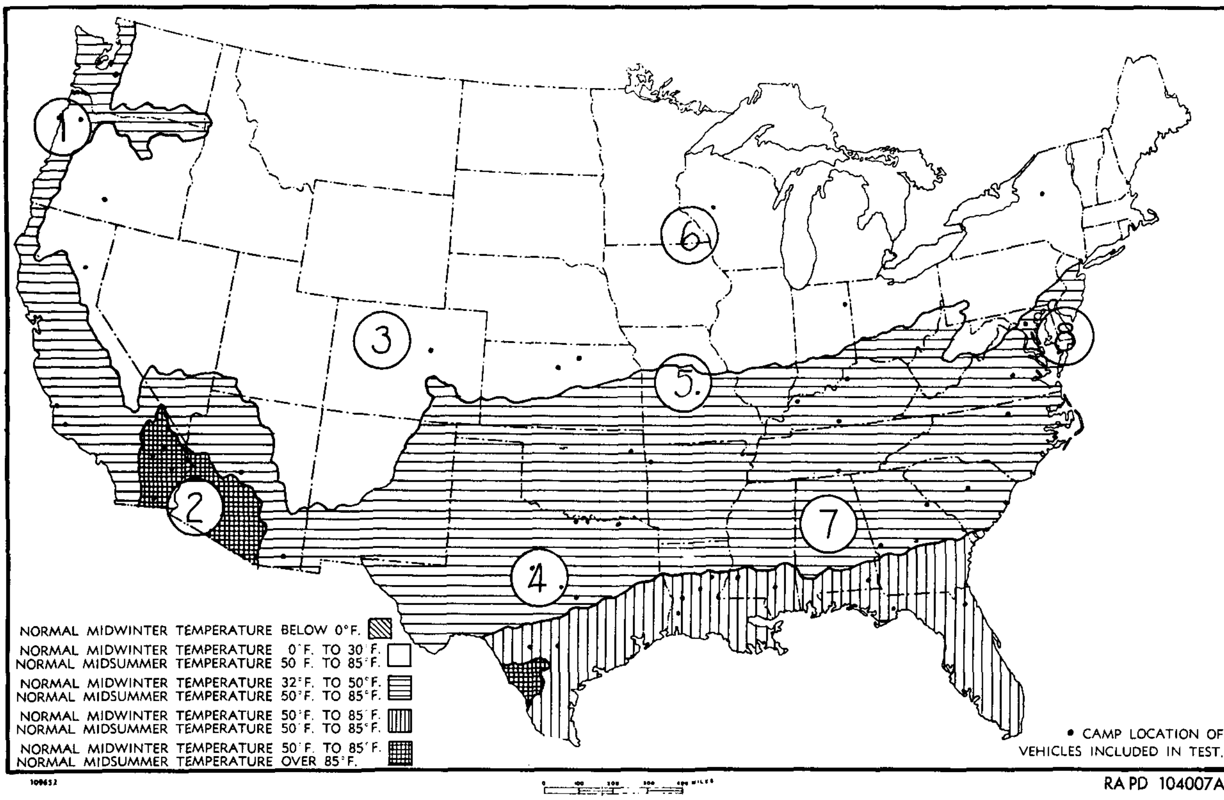


Figure 86. Map of the United States showing test points and temperatures zones. Figures in circles indicate areas discussed in figures 84 and 85.

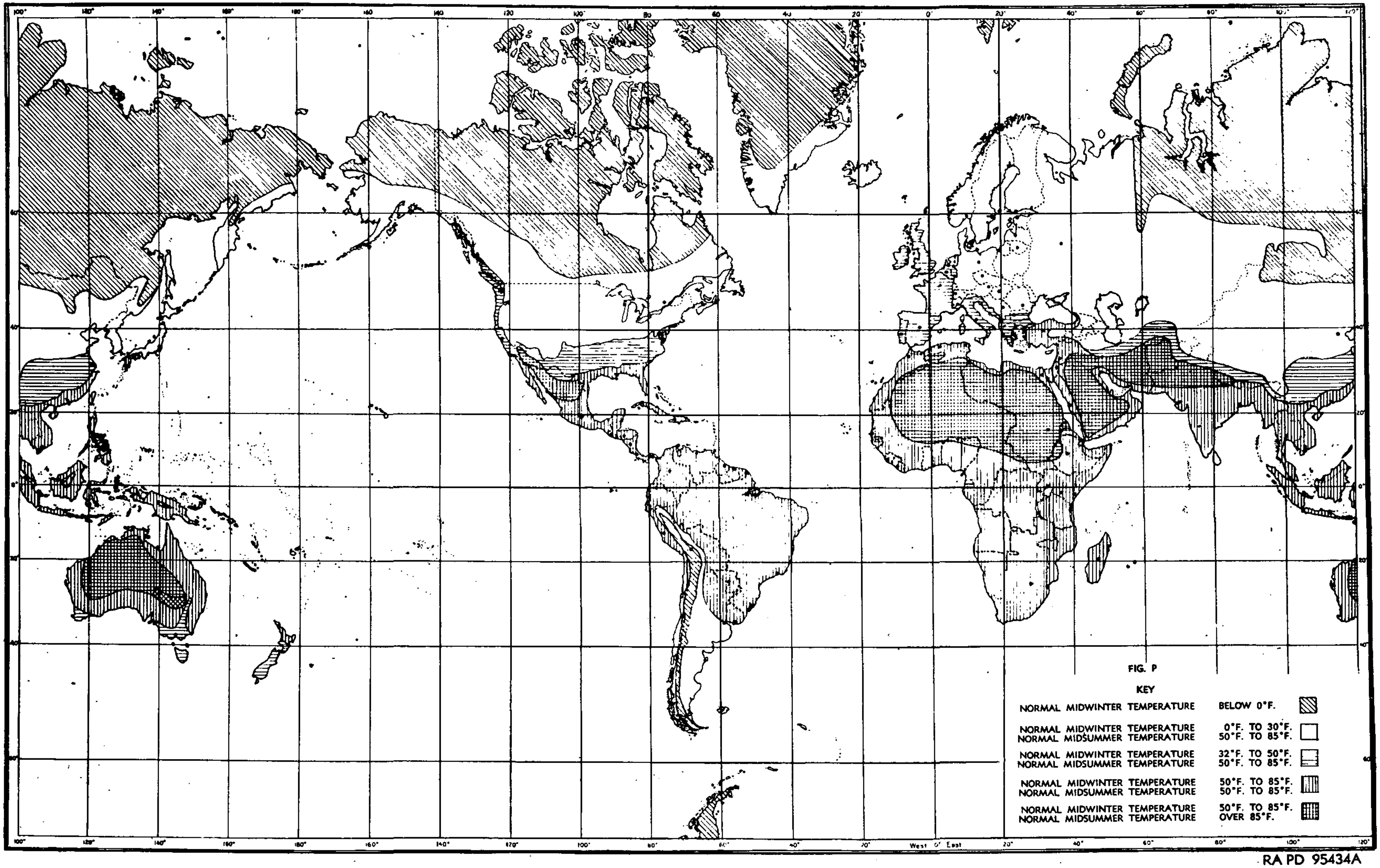


Figure 87. Map of the world showing temperature zones corresponding to those of the United States shown in figure 86.

Table III. Climatic Data for Representative Points Throughout the World

	Normal temperatures (degrees F.)		Extremes (degrees F.)		Annual rainfall (inches)
	January	July	Max	Min	
North America:					
Alaska:					
Fairbanks	–11.6	60.0	99	–66	11.87
Nome	3.4	49.8	84	–47	17.82
Sitka	32.4	54.9	87	–5	87.13
Canada:					
Fort Good Hope	–22.9	59.6	95	–79	10.45
Halifax	23.0	64.8	99	–21	55.52
Vancouver	35.6	63.3	92	2	58.65
Winnipeg	–3.4	66.6	103	–46	20.37
Central America:					
Guatemala	63.0	69.2	90	41	51.84
Greenland:					
Invigtut	18.5	49.8	86	–21	44.85
Upernivik	–7.6	41.0	69	–44	9.00
Iceland Vestmanno	34.5	52.5	71	–6	52.91
Mexico:					
Chihuahua	55.2	76.2	103	11	15.39
Mexico City	54.2	62.7	92	24	29.38
Vera Cruz	70.6	79.8	96	49	63.74
United States:					
Death Valley, Calif	51.6	102.0	134	15	1.49
Denver, Colo	32.0	72.6	105	–29	13.99
Key West, Fla	69.9	83.2	100	41	38.36
New Orleans, La	53.5	80.1	102	7	59.72
New York City, N. Y.	32.1	74.4	102	–14	48.63
Minneapolis, Minn	13.1	73.2	108	–34	27.31
Portland, Maine	23.4	67.8	103	–21	42.05
San Francisco, Calif	49.8	58.9	101	27	20.23
Seattle, Wash	39.5	63.1	98	3	31.80
West Indies:					
Havana, Cuba	69.8	79.2	95	50	48.08
South America:					
Argentina:					
Buenos Aires	74.4	51.2	103	28	37.86
Deseado	61.4	39.0	102	1	7.17
Bolivia, La Paz	53.2	45.3	75	27	22.18
Brazil:					
Belem	79.4	80.2	95	64	93.19
Rio de Janeiro	78.4	68.4	102	52	43.25
Chile, Santiago	69.3	48.1	99	24	14.09
Paraguay, Asuncion	82.0	65.6	109	33	54.61
Peru, Lima	73.4	61.2	90	40	1.90
Uruguay, Montivedio	72.4	50.0	109	25	37.99
Venezuela, Caracas	65.8	68.9	91	45	32.15
Europe:					
Austria, Vienna	31.9	65.8	97	–4	25.37
British Isles:					
Glasgow	48.6	58.0	85	7	37.18
London	38.5	63.5	100	4	24.47

Table III. Climatic Data for Representative Points Throughout the World—Continued

	Normal temperatures (degrees F.)		Extremes (degrees F.)		Annual rainfall (inches)
	January	July	Max	Min	
Europe—Continued					
Bulgaria, Sofia	28.4	69.1	102	–24	24.30
Czechoslovakia, Prague	30.0	66.6	95	–14	19.25
Denmark, Copenhagen	30.5	61.8	90	–13	20.75
Finland, Helsingfors	21.4	63.8	88	–23	27.75
France:					
Marseilles	44.2	72.0	100	12	22.59
Paris	37.8	65.6	101	–14	22.62
Germany:					
Berlin	30.2	64.4	99	–15	22.88
Hamburg	31.7	62.6	92	–6	28.58
Greece, Athens	47.6	81.3	109	20	15.48
Hungary, Budapest	31.6	70.4	102	–2	25.20
Italy:					
Rome	45.0	76.1	104	21	35.50
Turin	33.2	72.8	96	4	35.49
Netherlands, Amsterdam	37.5	63.0	91	4	27.95
Norway:					
Bergen	34.2	57.9	89	5	81.02
Trondheim	27.3	57.2	95	–15	31.09
Poland, Warsaw	25.7	65.4	98	–28	22.21
Portugal, Lisbon	50.9	71.2	103	30	28.87
Romania, Bucharest	26.6	73.0	105	–23	23.17
Spain, Madrid	40.4	73.8	112	10	16.48
Sweden, Stockholm	26.6	62.6	92	–22	18.64
Switzerland, Zurich	31.5	64.8	98	–11	45.17
Turkey, Istanbul	42.4	74.5	100	17	28.86
Russia:					
Archangel	58.1	59.5	94	–49	17.21
Baku	38.1	77.4	99		8.96
Leningrad	18.3	63.5	97	–39	20.44
Moscow	12.6	64.4	100	–43	23.49
Yugoslavia, Belgrade	33.0	72.2	107	–9	24.37
Asia:					
Arabia, Aden	76.2	88.1	109	61	1.93
China:					
Chungking	48.4	84.0	111	27	43.36
Hongkong	60.2	82.5	97	32	84.27
Shanghai	39.8	82.2	103	10	44.95
East Indies, Batavia	78.7	79.4	96	66	72.13
India:					
Bombay	75.5	81.4	100	56	71.88
Calcutta	66.6	83.6	111	44	61.81
Delhi	59.0	88.0	118	32	27.52
Rangoon	76.8	80.6	107	55	98.66
Irag, Bagdad	48.6	94.4	123	19	7.08
Japan:					
Nagasaki	42.8	78.8	98	22	78.55
Tokyo	37.9	76.0	98	15	57.84
Malay State, Singapore	79.8	81.4	97	66	95.06

Table III. Climatic Data for Representative Points Throughout the World—Continued

	Normal temperatures (degrees F.)		Extremes (degrees F.)		Annual rainfall (inches)
	January	July	Max	Min	
Asia—Continued					
Manchukuo:					
Hailar	–18.7	69.2	104	–57	11.99
Mukden	8.8	77.2	103	–27	25.97
Philippine Isles, Manila	77.2	81.2	101	58	79.61
Russia:					
Bulum	–40.0	52.7	85	–75	8.75
Guriev	12.2	78.2	105	–34	6.35
Krasnovodsk	37.4	84.0	108	1	4.49
Vladivostok	7.3	64.6	96	–22	22.44
Siam, Bangkok	79.2	83.8	106	52	52.36
Tibet, Gyantse	24.4	58.0	85	–20	
Turkey, Smyrna	47.0	81.3	111	12	25.65
Africa:					
Algeria, Algiers	55.5	77.2	112	28	27.43
British Somaliland, Berberia	76.8	98.0	117	52	2.38
Egypt, Cairo	55.0	82.8	113	31	1.27
Ethiopia, Adis Ababa	59.9	62.0	93	32	49.57
French West Africa:					
Dakar	70.4	82.3	104	55	19.60
Timbuctu	71.2	90.9	122	41	7.68
Libya, Bengazi	56.8	78.0	109	38	10.56
Morocco, Rabat	52.1	71.0	115	34	20.78
Northern Rhodesia:					
Livingston	75.7	64.6	103	37	33.78
Tunisia, Tunis	50.6	79.6	122	28	15.80
Union of South Africa:					
Cape Town	69.5	54.6	104	31	25.01
Australia:					
Adelaide	73.7	51.8	116	32	21.22
Brisbane	77.2	58.5	109	36	45.07
Darwin	83.4	77.8	104	56	61.37
Melbourne	67.4	48.7	111	27	25.58
Perth	73.8	55.2	108	34	34.32
New Zealand:					
Wellington	62.5	47.7	88	29	48.11

89. Cold Weather Lubrication

a. General.

(1) It is a natural tendency for lubricants to thicken in cold weather, and in extreme cold weather (0° to –65° F.) they will solidify. (Oil does not freeze hard like ice but solidifies in somewhat the manner of cold butter or lard.) Obviously, lubricants in this state cannot perform their work. Extreme care in inspection and servicing by both operating and maintenance personnel is required if poor performance or even total failure is to be avoided.

(2) Winterization kits have been developed for many vehicles to combat the added problems of extreme cold weather operation. The kits are designed primarily to overcome the three main difficulties in starting an engine (thickened engine oil, failure of storage battery to give necessary electrical energy, and failure of fuel to furnish a combustible mixture to the intake manifold) and to maintain engine temperatures while operating.

(3) Refer to applicable lubrication orders and technical manuals for prescribed lubricants and pertinent instructions for extreme cold weather operation. TM 9–207 contains specific information on the operation and maintenance of ordnance materiel in extreme cold weather.

b. Engine Lubrication Oils.

(1) *General.* Refer to paragraph 86 for cold weather problems concerning lubrication of internal combustion engines.

(2) *Starting an engine.* Before a start is attempted, the engine oil must be checked for quantity and fluidity. Cold weather, by increasing the viscosity (thickening) of an oil, will increase the fluid friction of the oil in the cylinder walls and bearings to the extent that it is not possible to crank the engine with the ordinary storage battery. The oil must be sufficiently fluid so that it can be picked up immediately and pumped by the engine oil pump. Several methods are employed to accomplish this objective ("pumpability") as indicated below.

***Caution:* Heat applied to the engine coolant will allow for an engine start, but ordinarily it will not make the oil in the lines and pan sufficiently fluid for pumpability. Pumpability must be assured before a start is attempted.**

(*a*) A heat exchanger is supplied for some vehicles, through which the engine coolant circulates, keeping the engine warm when it is not in operation. Some other vehicles are equipped with a standby heater having a hot-air duct directed at the oil pan or an engine compartment heater.

(*b*) Heat blast may be applied to the engine oil pan from an external source, such as the air heater of the auxiliary starting aid (slave) kit.

(*c*) As a last resort, the oil (while fluid after vehicle operation) may be removed from the system and subsequently warmed over a fire.

***Caution:* Do not get oil too hot. Heat to not more than 180° F. Heat only to a point where the bare hand can be inserted without burning—approximately 140° F.**

(*d*) After it has been determined that the engine oil is fluid and the necessary precautions taken to insure that the fuel and engine electrical systems are in a condition necessary for engine starting, an attempted start can be made. As soon as engine starts, observe the oil pressure gage. If oil pressure is not indicated immediately after starting, shut down engine and determine the cause.

(3) *During operation.* Vehicles must be operated with engine temperatures ranging from 140° to 180° F. Low engine operating temperatures result in undue wear and failure of engine parts because of the collection of sludge in the oil (par. 86). Consult the applicable operator's (10 series) technical manual for normal oil pressures and observe the oil pressure gage frequently during operation. Shut engine down immediately if indicator needle drops exceptionally low, and determine cause. It may be a low quantity of oil, oil thickening due to extreme cold, or failure of oil pump or lines.

c. Power Train Lubricants. Extreme cold weather will stiffen and solidify the lubricants in the gear cases and the various bearings throughout the power train. Extreme caution must be observed when placing a vehicle in motion after a shutdown period, as undue wear or failure will result if lubrication in any or all of the power train components has congealed. Before friction can develop enough heat to liquefy the lubricant and establish the film, bearing and gear teeth surfaces may score and fail. The following instructions are general. Consult pertinent technical manuals for particular vehicle operation.

(1) When starting engine, place transmission gear shift lever in neutral and depress clutch. After engine is running smoothly, release clutch cautiously and maintain engine at idle for at least 2 minutes or longer to warm up lubricant in transmission. If the vehicle is equipped with a transfer case with a selector lever, the transfer case lubricant may be warmed in the same manner by placing selector lever in neutral and transmission in low gear.

(2) The driver must be extremely careful when placing vehicle in motion; place transmission in low gear and transfer case in low range, if so equipped. Drive vehicle 100 yards, being careful not to stall the engine. This will heat the lubricants to the point where normal operation can be expected.

(3) When preparing a vehicle for a shutdown period, place transmission and transfer case selector levers in the neutral position. This will place those units in readiness for the next start by preventing them from freezing in an engaged position.

d. Other Lubrication Points. For all other lubrication points, use lubricants prescribed in pertinent applicable lubrication orders and technical manuals for subzero operation.

CHAPTER 14
OTHER USES OF LUBRICANTS

90. General

Lubricants, besides their basic purpose to lubricate, have other characteristics which maintenance programs use. Their ability to conduct heat, to repell water, and to adhere is valuable. Lubricants are generally available and wide application of these qualities is not difficult.

91. Electrical Uses

Certain electrical components use oils as heat transfer agents (transformers and resistors) while others use oils as dielectrics (capacitors). When oil is used in transformers and resistors it conducts heat away from the regions where it is generated. The oil is circulated by a gravity system or a pump system through cooling fins before it is returned to absorb more heat. Figure 88 shows the servicing of an oil-cooled resistor. The electrical components use an OT-type oil and they must be drained and refilled at intervals.

92. Preservation

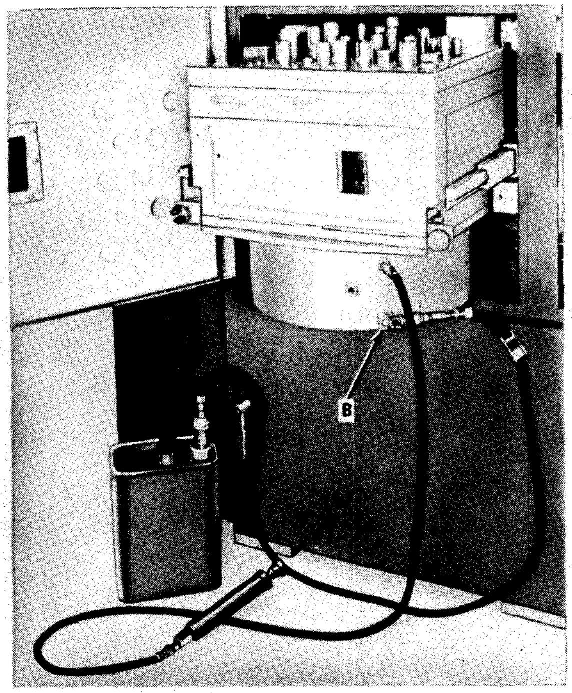
Lubricants, by nature, have water-repellent characteristics and good adhesiveness (stick to surfaces). Use is made of these properties to protect metal surfaces from weather and water. While not as permanent as paints, lubricants are easily applied (by brush or cloth) and easily removed (by soap and water or mineral spirits paint thinner). Some lubricants contain additional antioxidation compounds. These lubricants are specified in many technical manual to be used when storing or transporting materiel. Animal oil (neat's-foot and tallow) are used to preserve leather, while vegetable oils (linseed) preserve wooden articles.

93. Machine Shop Use

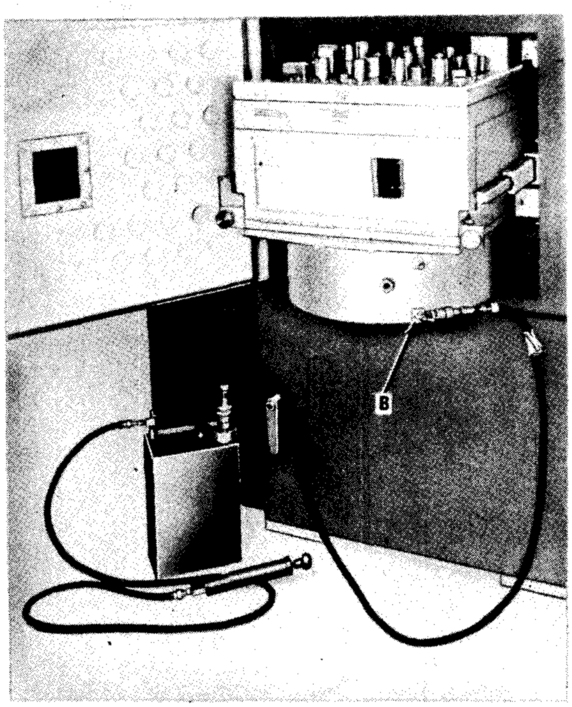
Machines, such as lathes, millers, shapers, and screw machines, use lubricants to preserve the cutting edges of tool bits. Oils, made from lard, both pure and sulfonated carry away heat from the working edges. Generous volumes of oil are applied either manually or by a force feed system. Oils are also in general use for quenching metals during heat treating and tempering processes.

94. Antiseize Compounds

Some screw threads, particularly those in light alloys (magnesium and aluminum) have a tendency to bind when tightened. To prevent this, lubricants in the silicone and fluorolube classes are used to lightly coat the threads before assembly.



A—DRAINING OIL-FILLED
VARIABLE RESISTOR



B—FILLING OIL-FILLED
VARIABLE RESISTOR

RA PD 419775

Figure 88. Draining and filling a resistor.

APPENDIX
REFERENCES

1. Publication Indexes

The following indexes should be consulted frequently for the latest changes or revisions of references given in this appendix and for new publications relating to material covered in this manual.

Index of Army Motion Pictures, Film Strips, Slides, and Phono-Recordings.	DA Pam 108–1
Military Publications:	
Index of Administrative Publications	DA Pam 310–1
Index of Blank Forms	DA Pam 310–2
Index of Graphic Training Aids and Devices	DA Pam 310–5
Index of Supply Manuals; Ordnance Corps	DA Pam 310–29
Index of Technical Manuals, Technical Bulletins, Supply Bulletins, Lubrications Orders, and Modification Work Orders.	DA Pam 310–4
Index of Training Publications	DA Pam 310–3

2. Forms

The following form pertains to this materiel:

DA Form 2028, Recommended Changes to DA Technical Manuals Parts Lists or Supply Manual 7, 8, or 9 (cut sheet).

3. Other Publications

The following explanatory publications contain information pertinent to this materiel and associated equipment:

a. General.

Federal Supply Catalog, Department of Defense Section (Petroleum, Petroleum-Base Products, and Related Materiel) (Department of the Army Supply Manual 10–1–C4–1).	C4–1
Machinegun, 7.62-mm, M60	FM 23–67
Military Symbols	FM 21–30/AFM 55–3
Military Terms, Abbreviations, and Symbols:	
Authorized Abbreviations and Brevity Codes	AR 320–50
Dictionary of United States Army Terms	AR 320–5
Military Training	FM 21–5
Safety: Accident Reporting and Records	AR 385–40
Techniques of Military Instruction	FM 21–6
U. S. Rifle, Caliber .30, M1	FM 23–5

b. Maintenance and Repair.

Description and Application of Oil Seals, Packings and Packing Materials and Gaskets and Gasket Materials.	TB 9–255
General; Fluids for Hydraulic Equipment	TM 1–42B2–1–3

General Maintenance Procedures for Fire Control Materiel	TM 9–254
General Supply; Winterization Equipment for Automotive Materiel	SB 9–16
General Use of Aircraft and Electronic Lubricants	TM 1–42B–1–7
Grease, Automotive and Artillery, MIL–G–10924 (ORD), Amendments 1, 2, and 3, and MIL–G–10924A.	SB 725–9150–1
Inspection, Care and Maintenance of Antifriction Bearings	TM 9–214
Inspection and Disposition of lubricants, Specification MIL–L–7808	TM 1–42B2–1–507
Lubricant Fittings	TB 34–9–70
Lubricants, Corrosion Prevention and Antiseize Compounds	TM 1–42B–1–6
Lubricants for Use with Automobiles and Commercial Type Administration Vehicles.	TB ORD 2300–10/3
Lubrication of Aircraft Parts Requiring Molybdenum Disulphide Lubricant.	TM 1–42B3–1–2
Maintenance Instructions and Procedures for Administrative Vehicles.	TM 38–660–2
Materials Used For Cleaning, Preserving, Abrading, and Cementing Ordnance Materiel, and Related Materials Including Chemicals.	TM 9–247
Operation and Maintenance Ordnance Materiel in Extreme Cold Weather, 0° to –65° F.	TM 9–207
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BY ORDER OF THE SECRETARY OF THE ARMY:

G. H. DECKER,
General, United States Army,
Chief of Staff.

Official:
J. C. LAMBERT,
Major General, United States Army,
The Adjutant General.

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NG: State AG (3); units — same as active Army except allowance is one copy to each unit.

USAR: Same as Active Army except allowance is one copy to each unit.

For explanations of abbreviations used, see AR 320-50.