TM 9-2835

DEPARTMENT OF THE ARMY TECHNICAL MANUAL

LUBRICATION

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This manual supersedes TB 9–850–14, 6 July 1944; OFSTB 2835–2, 13 November 1943; TB 9–2835–4, 30 December 1943; TB 9–2835–5, 18 February 1944; TB 9–2835–9, 21 February 1945; TB 9–2835–10, 22 March 1945; TB ORD 274, 27 March 1945, and OFSB 6–4, 22 November 1943

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Section I
INTRODUCTION

1. Purpose and Scope

a. This manual is intended to give the reader a general understanding of the subject of lubrication as it applies to military matériel. No attempt has been made to give definite lubrication procedure for specific items. Lubrication instructions for specific items of matériel may be found in pertinent lubrication orders and technical manuals.

b. This manual explains the fundamental principles of lubrication; lists the lubricants, lubrication publications, and lubricating equipment available to personnel; and analyzes the basic types of surfaces or bearings which must be lubricated. Lubrication of types of matériel also is discussed.

Section II
FUNDAMENTALS OF LUBRICATION

2. 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.

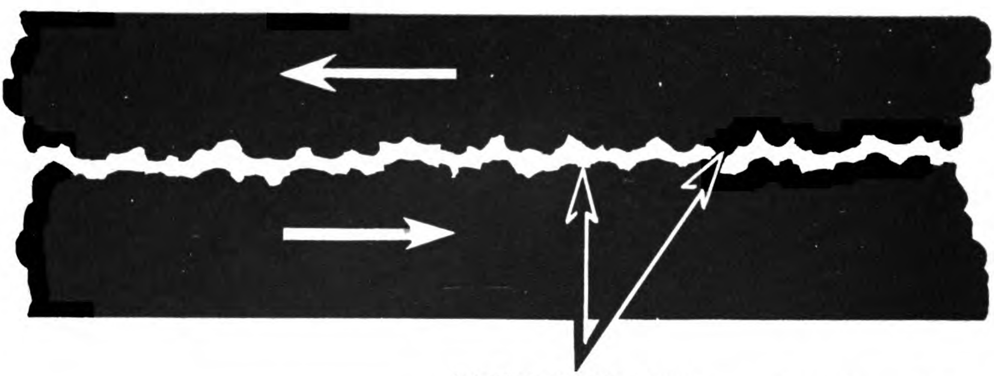

Figure 1. Magnified view of two surfaces in contact.

3. Definition of Friction

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.

4. 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 kinetic friction, which must be overcome to keep the body in motion after it is started. This fact is illustrated in figure 2 which shows

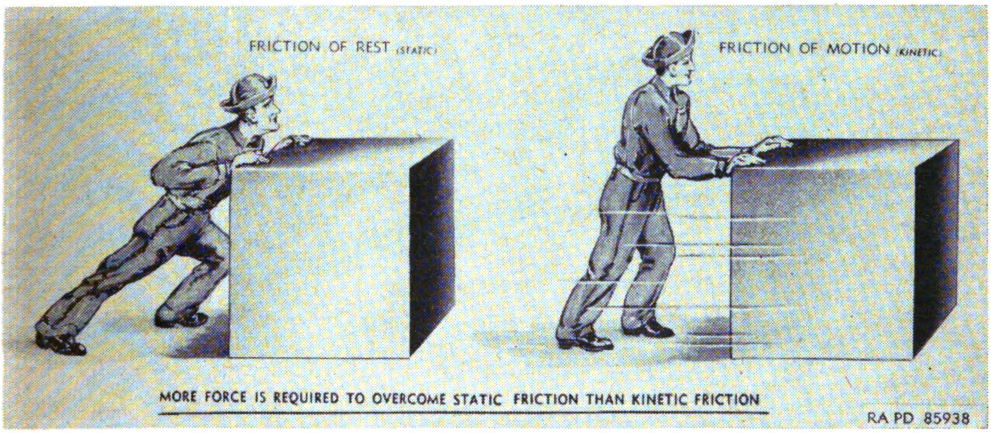

Figure 2. Friction of rest and friction of motion.

a man exerting himself to start a body in motion, but another man pushing it easily after it is once in motion.

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

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 overcome. Fluid friction is the resistance to motion

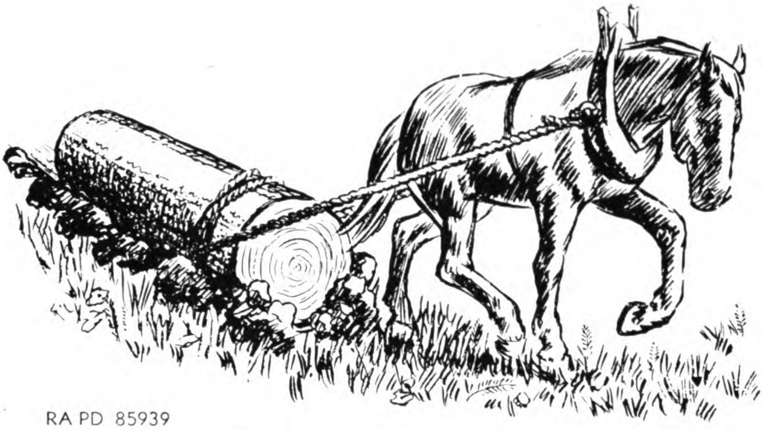

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Figure 3. Sliding friction.

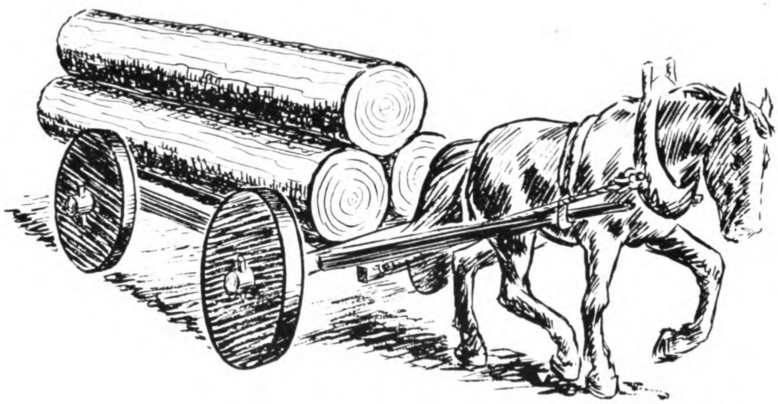

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Figure 4. Rolling friction.

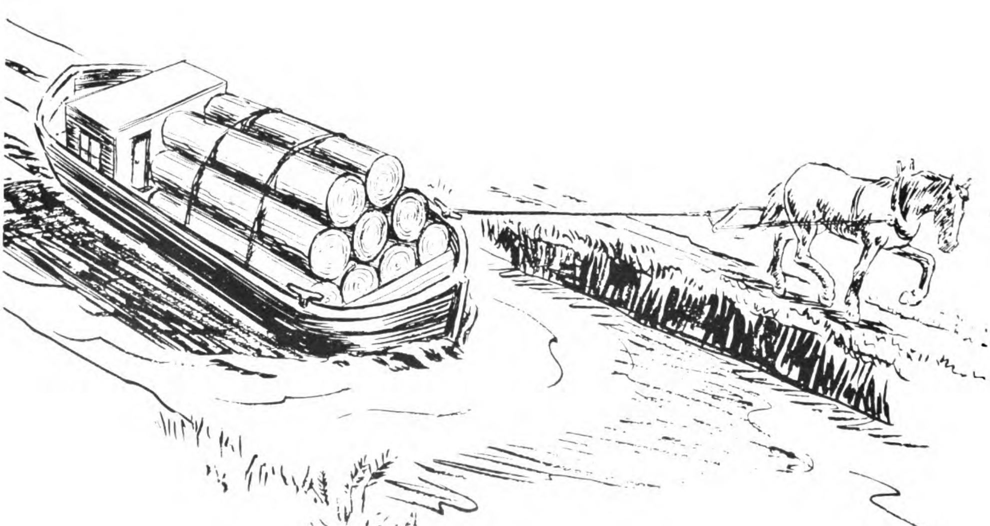

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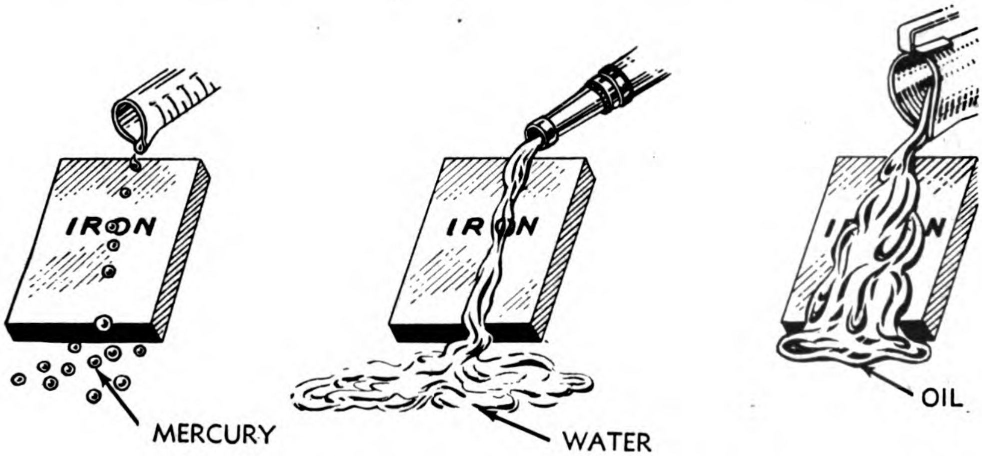
Figure 5. Fluid friction.

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 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.

5. 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



Mercury will not adhere to iron because of its low adhesive and high cohesive properties. Water will adhere to metal, but has relatively low adhesive and cohesive properties. Oil will adhere to metal more than either mercury or water, because it possesses relatively higher adhesive as well as cohesive properties.

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Figure 6. Adhesive properties of fluids vary greatly.

attraction existing between surfaces of bodies in contact or the force which causes unlike materials to stick together. From the standpoint of lubrication, adhesion is the property of a lubricant that causes it to stick or adhere to the parts lubricated, while 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 ahere to the plate, spread out over it to a considerable extent, and will run off slowly.

6. 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. To overcome sliding friction consumes the greatest amount of power and produces the greatest amount of heat. To overcome rolling friction consumes a lesser amount of power and produces a lesser amount of heat. To overcome fluid friction consumes the least amount of power and produces the least amount of heat.

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. 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.

7. 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

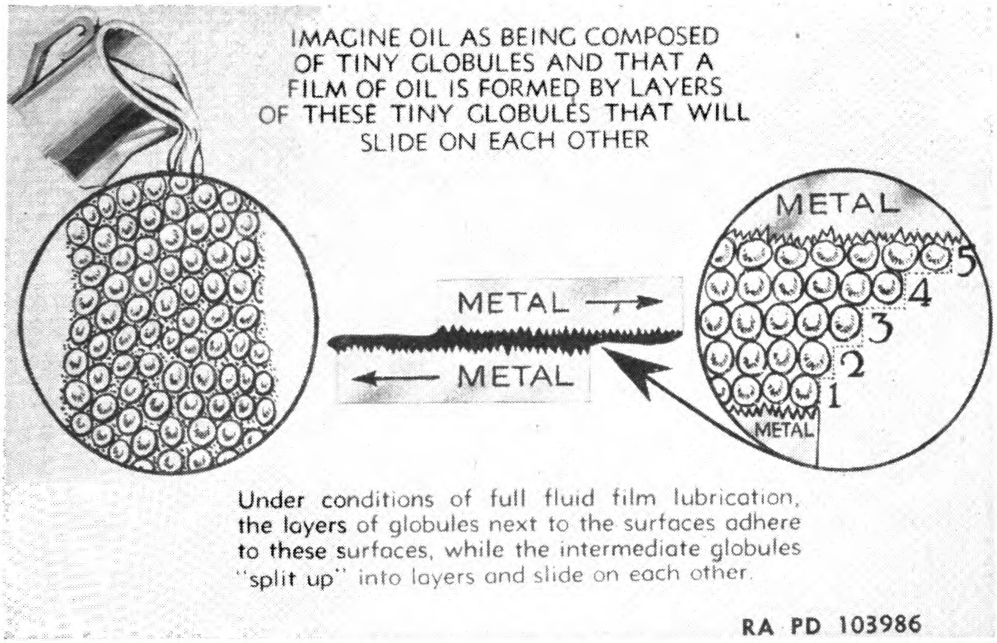

Figure 7. Theory of an oil film.

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).

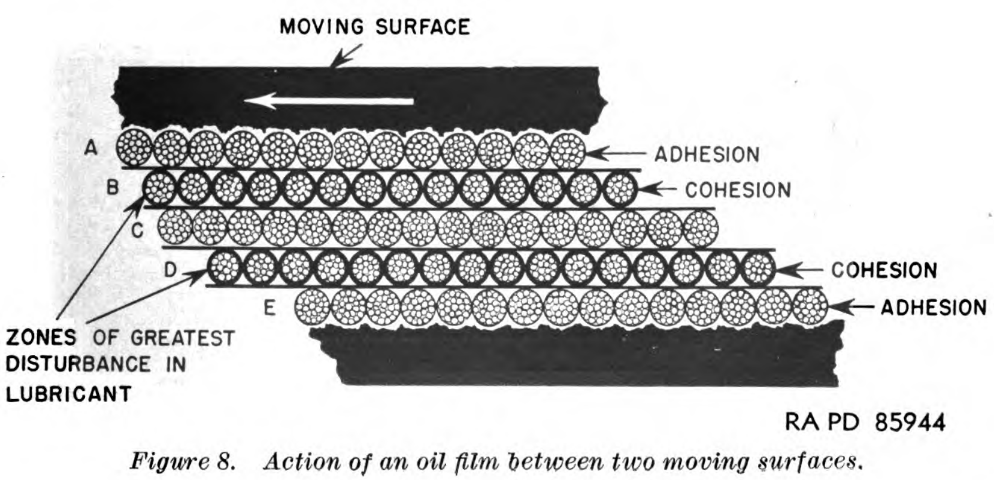

Figure 8. Action of an oil film between two moving surfaces.

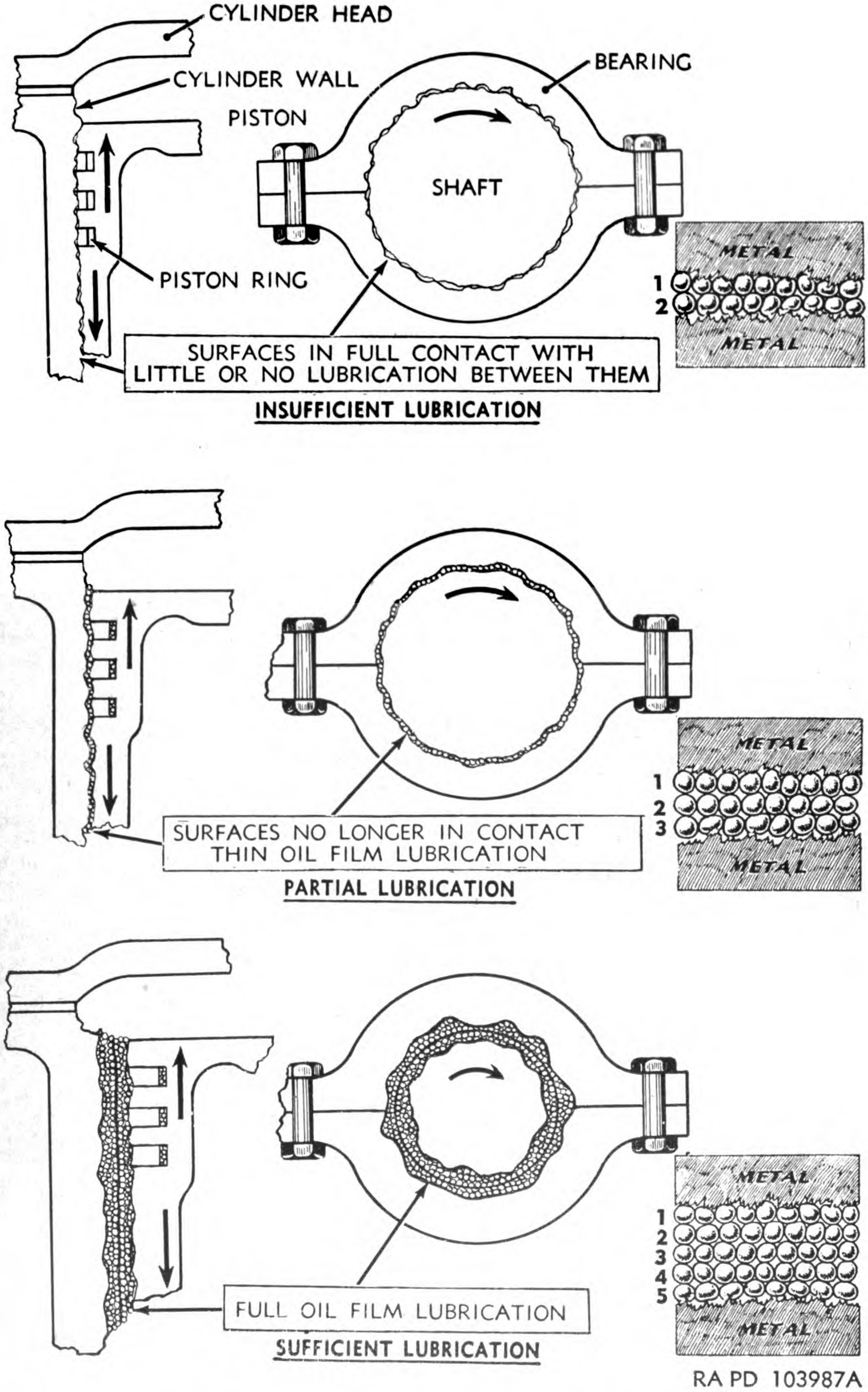

Figure 9. Insufficient, partial, and sufficient lubrication.

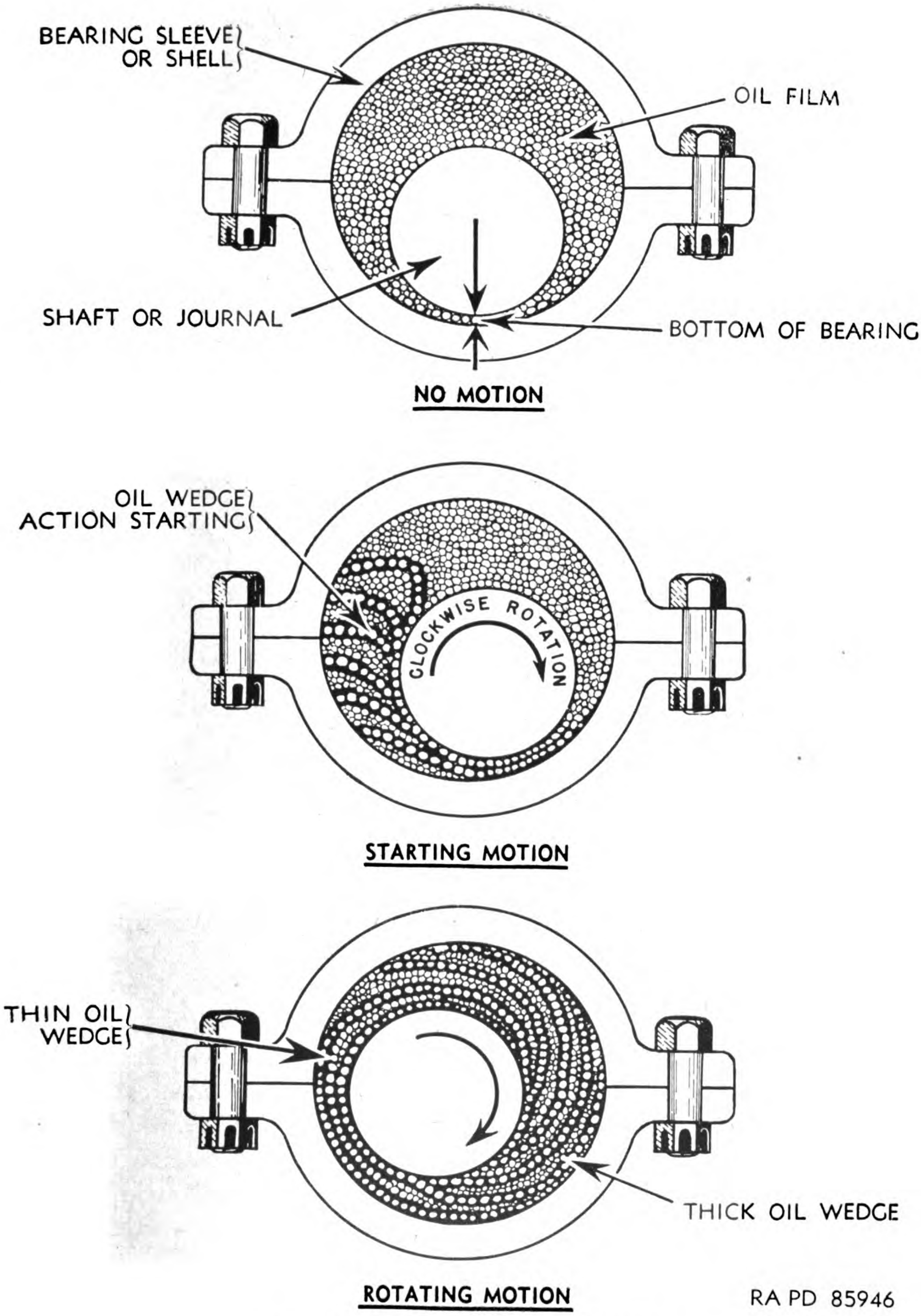

Figure 10. Oil film and wedge theory.

8. Oil Film and Wedge Theory

The oil film and wedge theory affects 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 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

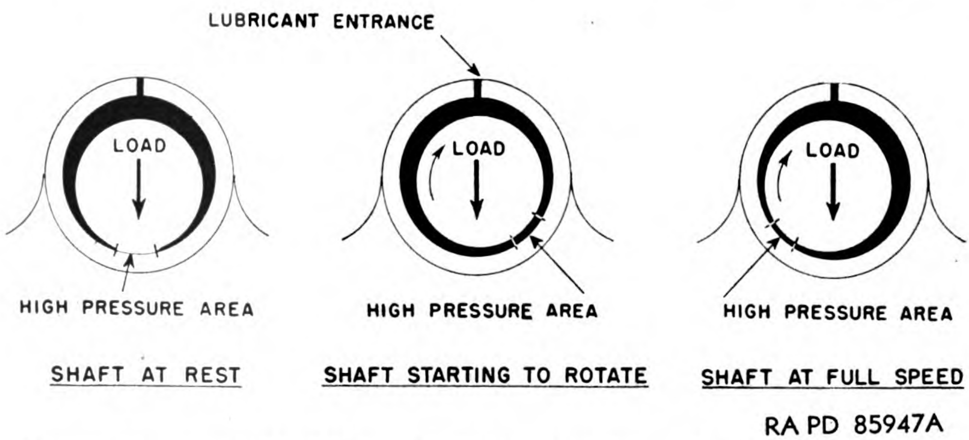

Figure 11. Speed of rotation determines the high- and low-pressure areas.

of the low- and high-pressure areas vary somewhat with the speed of rotation.

9. Viscosity

The degree of cohesion between 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 behavior 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).

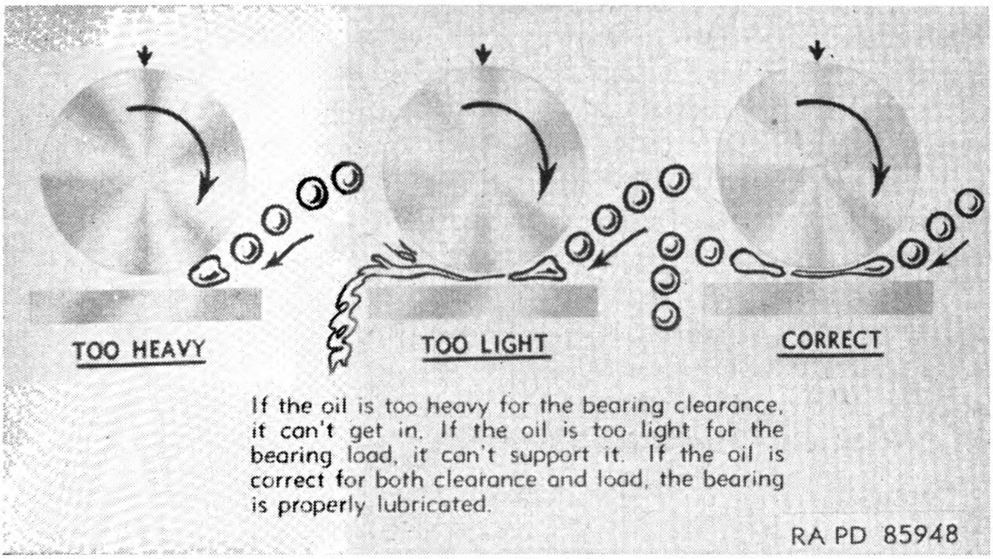

Figure 12. Effect of viscosity.

10. Fundamental Factors Influencing Selection of Proper Grade of Lubricant

There are three fundamental factors which influence the selection of the proper grade of lubricant for any normal bearing operated under normal conditions: First, the rubbing speed (generally in linear feet per minute); second, the clearance between bearing surfaces; third, 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 three 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 break-down 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.

11. Additional Functions of Lubricants

In addition to reducing friction a lubricant usually has one or several of the following functions: To cool machine parts by conduction of generated heat, to remove contaminants, to prevent rust, to absorb or reject air or water, to resist the actions of solvents, to prevent corrosion or solution of certain sensitive metals, to transmit power by hydraulic means, and to prevent scuffing or welding of rubbing surfaces during momentary failure of lubricant supply. In many cases, lubricants are used solely for their ability to prevent rust, to transmit power hydraulically, etc.

Section III
BEARINGS AND BEARING SURFACES

12. 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 anti-friction-type bearings.

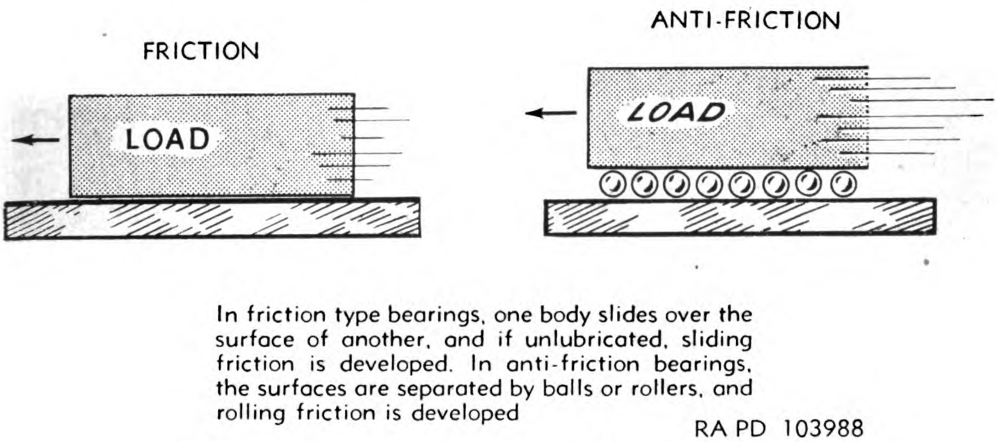

Figure 13. Friction- and anti-friction-type bearings.

a. 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.

b. Anti-friction-type Bearings. Anti-friction-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.

13. Friction-type Bearings

a. GENERAL. Friction-type bearings (those which have sliding contact between their surfaces) (fig. 14) 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

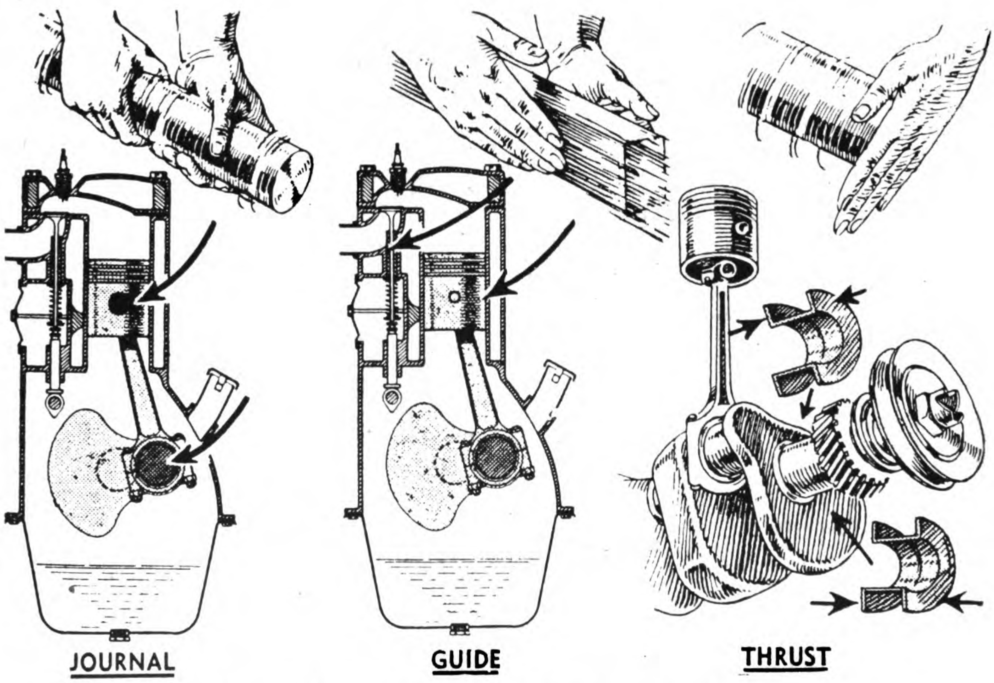

Figure 14. Three classifications of friction-type bearings.

solid bearings, half bearings, two-part or split bearings, and multipart bearings.

(1) *Solid bearings.* A typical solid style journal bearing application is the piston pin bearing (A, fig. 15), 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

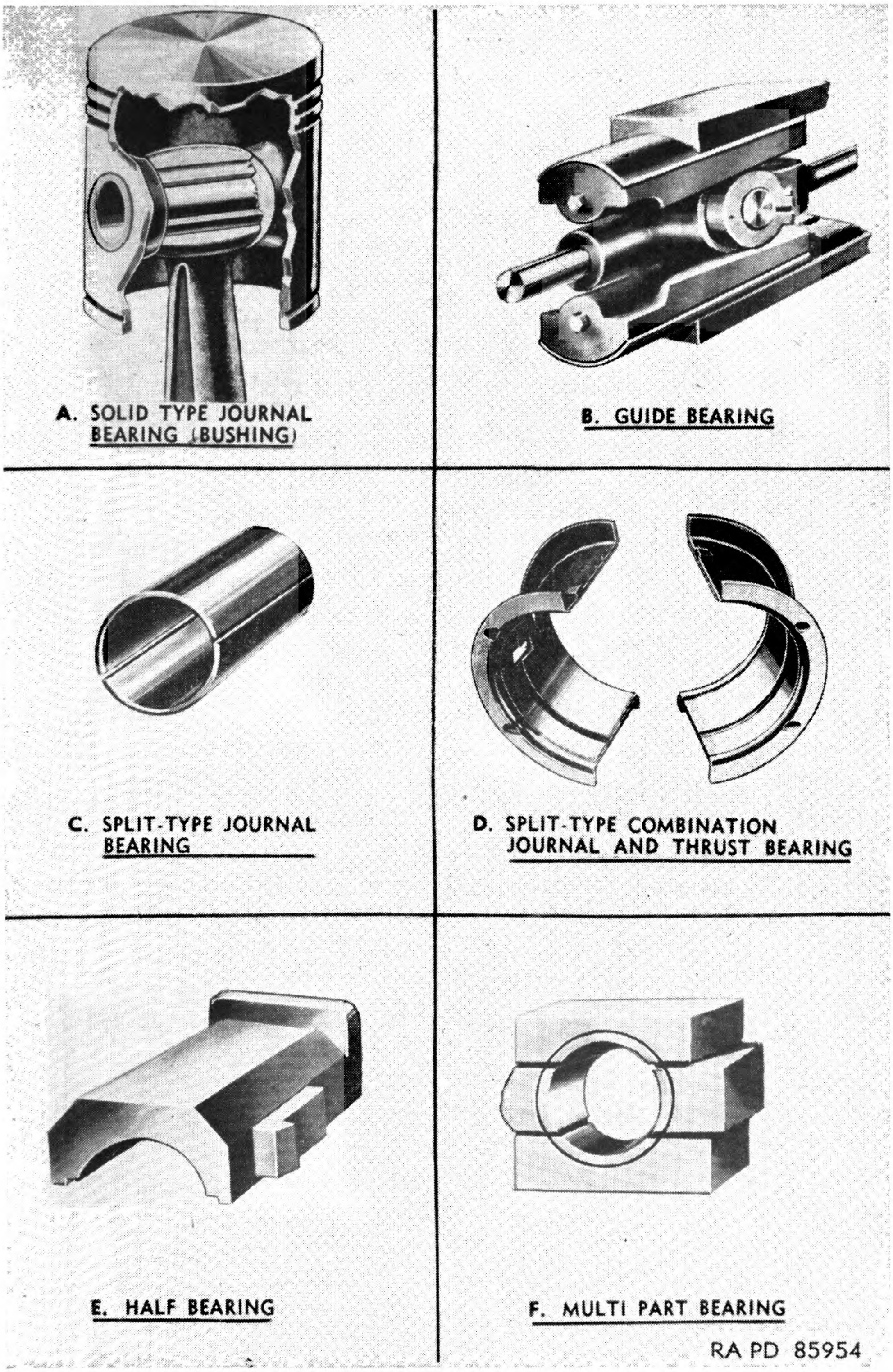

Figure 15. Various friction-type bearings.

danger of interrupting the oil film. Solid bearings also can be made quite rigid, due to the absence of either bolts or clamps which may either work loose or permit flexing.

(2) *Half bearings.* Perhaps the most common application of the half bearing (E, fig. 15) 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 bearings (C, fig. 15) 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.

(4) *Multipart bearings.* Multipart bearings of the friction type (F, fig. 15) 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. 15), 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 cross head 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. 15). 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.

c. Lubrication of Friction Bearings. 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.

(1) *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 can be used as an aid in carrying the oil down onto the rotating journal.

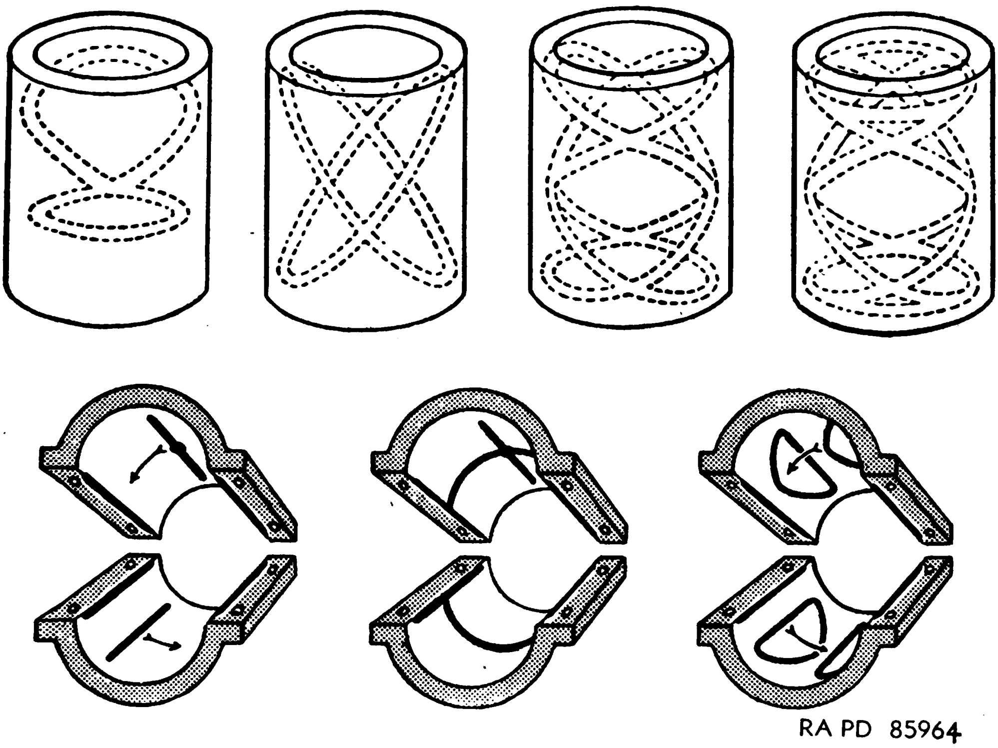

Figure 16. Oil-groove patterns in friction-type bearings.

(2) *Oil grooves.* Oil grooves (fig. 16) are simply reservoirs which trap some of the oil supplied to the bearing. 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 speeds 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 edges. Even when grooves are placed advantageously and are of the correct size, grooves with sharp corners facing the direction of rotation will tend

Proper chamfering of oil grooves removes sharp edges that may tend to rupture the oil film on the journal. The direction of journal rotation determines the side of the groove that should be chamfered, as shown.

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Figure 17. Properly shaped oil grooves.

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 (fig. 17). If the journal reverses its direction of rotation, the grooves must be chamfered on both edges.

(3) *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 graphite 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 a number of different trade names.

14. Antifriction-type Bearings

a. General. Anti-friction-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. 18).

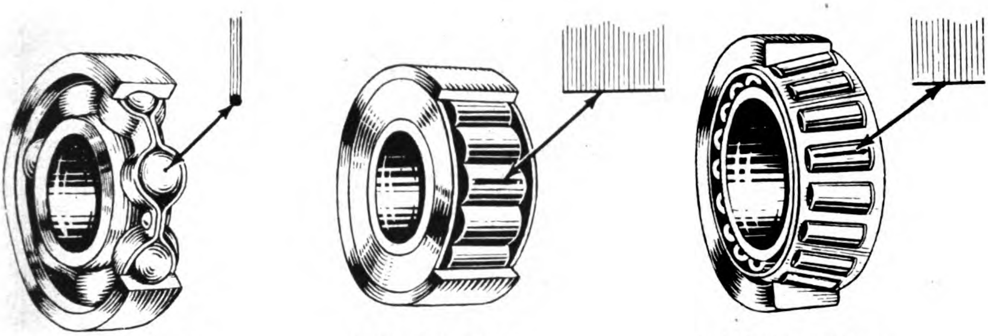


Figure 18. Load carrying areas of ball and roller bearings.

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. Roller bearings are of three general types—straight, tapered, and spherical. A straight roller bearing can sustain loads in one direction only, a tapered roller bearing can sustain both radial and thrust loads simultaneously, and a spherical roller bearing can sustain both radial and thrust loads and is self-alining.

c. Ball Bearings. Due to their varied application, complete ball bearings are manufactured in a considerable number of standard assemblies. Generally they are classified according to the type of load they carry—radial, thrust, and combined radial and thrust load. In some bearings a separator or cage is used to separate or space the balls, while in others adjacent balls are in contact. Lubrication is required on the flat or curved surfaces of the races and on the spherical surfaces of the balls.

d. Lubrication of Antifriction Bearings.

(1) Fundamentals covering the lubrication of antifriction bearings, particularly of the ball type, vary considerably from those involved in the lubrication of friction-type bearings. In the friction-type bearing, the journal load is supported by a lubricating film. The maintenance of this film under the various speed, load, and temperature conditions influences the selection of the type of lubricant and the method of which it is to be applied. In other words, these factors must be considered when determining whether or not a grease or an oil will be the best lubricant for a given bearing.

(2) Unit contact pressure in excess of 300,000 psi 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.

(3) When antifriction bearings are under radial load, a number of the balls or rollers on the unloaded side of the bearings will not be in full pressure contact with both the inner and outer races. A cage or separator is used to maintain correct spacing between the adjacent rolling members and prevent high-velocity rubbing which would occur between adjacent balls or rollers, the surfaces of which are moving in opposite direc-

tions. Obviously there is motion between the balls or rollers and the surfaces of their cages or separators, and this creates a sliding friction rather than a rolling friction at these points of contact. In order to maintain rolling friction in radial or combination radial-thrust antifriction bearing and prevent excessive wear, the outer race must be free to "creep" in the bearing housing. Creep is due to the difference between the external diameter of the rolling element channel in the inner race and the internal diameter of the outer race. If no slippage occurs between the rolling elements and the faces, the outer race will be dragged or will "creep" a distance equal

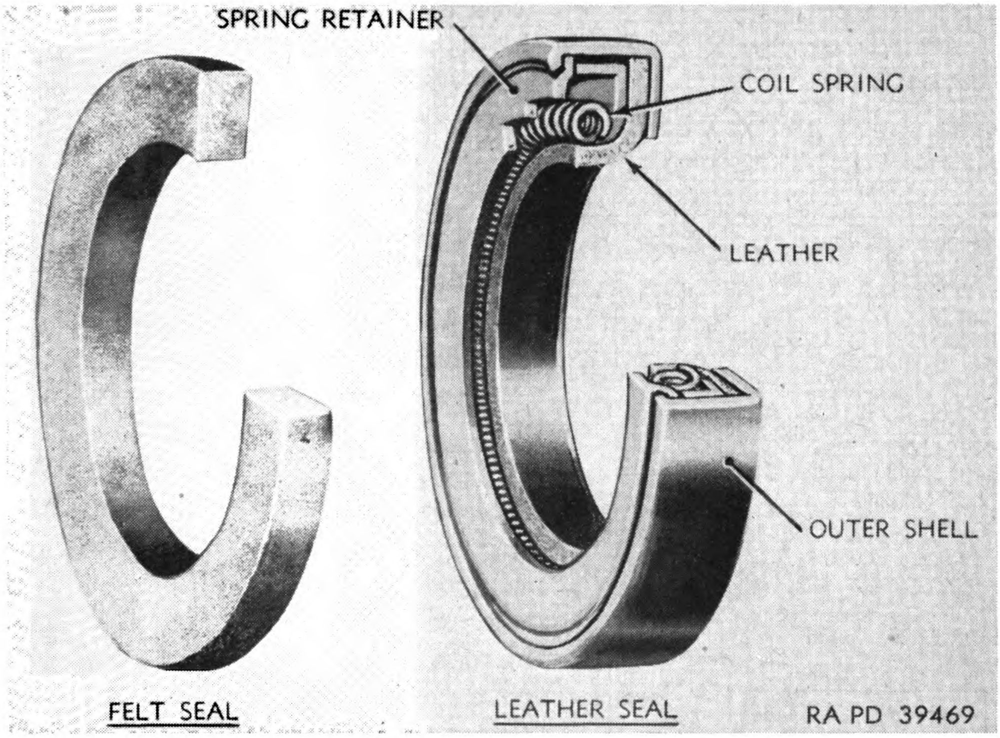


Figure 19. Two types of grease or oil seals.

to the difference in these circumferences. The lubricant used in the bearing also must form a lubrication and corrosion-resisting film between the outer race of the bearing and the bearing housing.

(4) Under different conditions, either fluid oils or greases may be used for ball- or roler-bearing lubrication. In machines where oils may be supplied readily to the bearing without excessive leakage, they are preferred because of their cooling action. Where it is impractical to provide full automatic lubrication, or where excessive leakage of oil would result, grease is prescribed.

15. Oil and Grease Seals

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 (fig. 19). The plain felt seal generally is installed in a counterbore in the end of the bearing and held in place by a snap ring. 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.

Section IV
LUBRICANTS

16. General

a. Standardization of Materials. The present lubrication program of the United States Army has been set up for the preservation of the life of matériel. Several all-purpose lubricants have been developed to reduce the number of products necessary. The approved lubricants are limited to those grades and types deemed essential to provide proper lubrication under all anticipated operating conditions. Definite names and symbols result in uniformity of products, containers, and marking when supplied by different refiners or manufacturers. All branches of the Army now are using these standardized lubricants. All standardized lubricants are listed in later paragraphs together with their characteristics and uses.

b. Instructions. Proper application of lubricants and servicing materials is just as important as quality and availability. Therefore, published instructions are revised or 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 use the latest instructions issued.

c. Lubrication Orders. Lubrication orders are numbered serially and dated cards or decalcomania labels which prescribe lubrication instructions for mechanical equipment issued by the Department of the Army. They are to be carried with or attached to the equipment to which they pertain. Instructions contained therein are mandatory to using troops and supersede all conflicting lubrication orders of prior date. Unit commanders are responsible for obtaining, installing, and fully complying with all current lubrication orders that are applicable to equipment within their commands. Difficulties experienced in the performance of these responsibilities will be reported through technical channels to the Chief of the Service—Attention: Maintenance.

(1) Some of the older lubrication orders are classed as equipment and are stocked and issued by each of the technical services of the Army. Their physical form may be either a 10 x 15-inch steel-bound waterproof card, a temporary-type

cardboard, or a decalcomania transfer label. This type of lubrication order may be identified by serial number, which is a number of three or four digits and contains no prefix. Examples are: 151, 1026, 3040, 6001, 6009, and 7003. The responsible technical service may be determined by referring the serial number to FM 21–6. These lubrication orders usually are not issued automatically and must be requisitioned from the technical service depots indicated in FM 21–6. Informal letters that list the serial number, issue date, and quantity desired will be honored by issuing agencies.

(2) All lubrication orders are classed as expendable publications which are prepared by the responsible technical services, but are published and automatically distributed by The Adjutant General. Their physical form will be either a simple card or a decalcomania transfer label. They may be identified readily by means of their distinctive serial numbers which are preceded by the letters "LO" and a number which identifies the technical service. The numbers which follow the "LO" and the technical service number usually are the same as the number of the corresponding technical manual. For example, LO 9–772 indicates that the matériel is a responsibility of Ordnance (9-series are ordnance publications—see FM 21–6) and the technical manual for the matériel is TM 9–772. Other examples of serial numbers are LO 5–3112 (Engineer), LO 8–626 (Medical), and LO 3–360 (Chemical). Since automatic distribution never can be complete, necessary additional quantities of these lubrication orders should be requisitioned in conformance with instructions in SR 310–90–1. Refer to the latest issue of FM 21–6, List and Index of Department of the Army Publications, for a listing of current lubrication orders.

d. LUBRICATION INTERVALS.

(1) Each lubrication order and technical manual specifies the intervals at which every part of the matériel is to be serviced and/or lubricated. Such intervals are for normal operating conditions. For extreme conditions, the periods between servicing shall be reduced by one-third or one-half, or more if conditions warrant. Unusual conditions are excessively high or low operating temperatures, 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.

(2) Determining the extent of reduction of prescribed intervals is a matter of exercising judgment. Lubrication is intended

to provide maximum performance and prevent excessive wear by maintaining an adequate lubricating film between moving parts. When it becomes evident that malfunctioning or excessive wear is being caused by contamination of the lubricants or lack of lubrication, the matériel should be serviced or lubricated immediately, regardless of the period since it was last serviced.

e. ATMOSPHERIC TEMPERATURES.

(1) Summer and winter (seasonal) grades of lubricants no longer are prescribed because of the wide variation in temperatures experienced in domestic and oversea areas. For example, since winter mean temperatures in Florida are higher than those in Alaska, the same winter lubricant specification cannot be applied to both areas. During the summer months the same corresponding variable in temperatures is experienced in the different areas.

(2) Lubrication orders and technical manuals specify grades of lubricants for their air temperature ranges, above +32° F., or normal summer atmospheric conditions for most areas; +32° F. to 0° F., or normal winter temperature for most regions; 0° F. to −40° F.; and below −40° F. for arctic temperatures.

(3) The time to change lubricants is determined by maintaining a close check on climatic conditions and the operation of the matériel during the approach to change-over periods. Lubricants thicken as the temperature drops until they become sluggish or solidify to such an extent that they no longer provide lubrication protection. The point at which a lubricant becomes too heavy depends upon its normal temperature consistency or viscosity, the type of lubricant (grease thickens faster than oil), and the rate that viscosity increases as the temperature drops.

(4) As the temperature increases, lubricants become thinner and finally reach the point where they are not retained by the seal, whether it be the piston rings, valve guides, bearings, or actual oil seals. Failure occurs from lack of lubricant on the working surfaces resulting in metal-to-metal contact and rapid destruction of the parts. Therefore, it is important to use the exact grades of lubricants prescribed by lubrication orders and technical manuals.

(5) United States Army lubricant specifications provide a margin of safety for borderline cases where air temperatures vary between two ranges. For example, during the fall in some areas night air temperature may drop to +25° F., whereas day temperatures remain consistently above +32° F. In

such cases, lubricants specified for average summer (above +32° F.) should not be replaced with lighter grades until the average air temperature is consistently below +32° F. However, when temperatures below 0° F., are encountered lubricants must be changed in accordance with current lubrication orders. The major factor is ease of starting for automotive matériel or ease of initial action for artillery. Slow engine start, sluggish gear action, subnormal gun recoil, or similar malfunctioning are indications that the lubricants are thickening and should be changed for the next lower temperature range. In cases where the air temperatures are consistently in the next higher range, change to heavier lubricants regardless of the period since the last lubrication or service was performed. (This is essential especially for initial action.)

f. Recoil Oils.

(1) *Use.* The greatest care must be taken not to use any oil in a recoil mechanism except the grade and kind prescribed for it. The specific recoil oil to be used with a given weapon is specified in the current applicable lubrication order and technical manual provided for the matériel.

(2) *Care (foreign matter).*

(*a*) 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 Department of the Army Supply Catalog pamphlet ORD 3 SNL K–1. Great care must be taken to maintain correct labels on all oil containers so that the oils will be put to their proper use.

(*b*) Recoil oils should never be left in open containers.

(*c*) Recoil oils must not be subjected to excessive heat.

(*d*) The greatest care must be taken to exclude moisture and dirt.

(3) *Water or moisture.*

(*a*) It is important that no water be introduced into a recoil mechanism that uses recoil oil, as the water greatly increases the rate of corrosion and may result in pitting of the finished surfaces, interfering with the functions of the recuperator, and reducing its normal serviceable life.

(*b*) In spite of the great care taken in the preparation and shipping of recoil oils, water often is 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. Condensation in a container partly filled with oil, or pouring from one container to another which has moisture on its inner walls, results in the moisture being carried along with the oil into recoil mechanisms.

(*c*) It is advisable that organization commanders test the recoil oil on hand, before use, for water content. If a clean, dry, glass bottle of about 1-pint capacity is filled with the recoil oil after agitation in the original container and then capped and allowed to settle, the water being heavier than the oil will sink to the bottom. With the bottle slightly tilted, drops or bubbles of water will form in the lower corner of the bottle. If the bottle then is inverted with this corner uppermost and held to the light, such drops or bubbles may be seen sinking slowly in the oil. If the oil has a cloudy appearance, the cloudiness may be ascribed to minute particles of water in suspension.

(*d*) Should any of the tests show water in the oil, all oil that was handled or stored the same as the test portion should be turned in for exchange, as there is no practical way of extracting the water or dehydrating the oil except at a depot equipped with special machinery for that purpose.

(*e*) Settling alone is insufficient to remove water, and boiling should not be attempted as it affects the characteristics of the oil.

g. CLEANLINESS. Cleanliness of lubricant at the point of use is dependent upon cleanliness in storage and handling, and this is a point which cannot be overemphasized. When dispensing lubricant, wipe all dirt, moisture, or dust from around the opening before unscrewing or removing the plug or cap. All containers must be kept closed tight when not in use. Some oils and greases will absorb water to such an extent that their physical characteristics will change so as to definitely reduce their lubricating value. Water contamination will cause corrosion of the friction surfaces of the matériel and of parts of lubricating equipment such as check valves, plunger shafts, plunger leathers, etc. It also will cause grease to run out of a bearing, readily leaving the surfaces insufficiently lubricated. Engine oil that has absorbed water will promote the formation of sludge in the crankcase. In cold weather the water may freeze before changing to sludge, thus preventing the oil circulation. Oils in use at the present time will dissolve sludge to a certain extent but the presence of water still will have a corrosive effect. Closing of partially filled containers is particularly important in arctic or cold-weather operation because condensation, due to the "breathing" of a partially filled container, or moisture condensed from warm air if the container is removed from inside temperature, will be introduced into the lubricant. All drum or container openings, plugs, pumps, funnels, guns, or other lubricating utensils or equipment must be protected from sand, dirt, rain, sleet, flame, and heat, and must be kept as clean as possible. Never lay lubricating guns, couplers, or other equipment on the ground.

h. CONTAINERS.

(1) *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 drum. The standard sizes 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- and 400-pound drums. Sizes of the containers in which any given variety of lubricant is available vary with the type of lubricant and the amount normally used. For example, clock and watch oil is furnished only in 5-cc bottles, while engine oil is furnished in 1-quart, 5-quart and 5-gallon cans, and 55-gallon drums.

(2) *Storage and handling.* Whenever possible, lubricant containers should be stored where they will not be exposed to the weather. This is desirable particularly in the case of cans packed in other containers. Where it becomes necessary to store in the open, containers should be covered with a tarpaulin and sheltered from sand, dirt, rain, sleet, heat, etc., as well as possible. Containers should be packed with the opening up to prevent leakage. Drums should not be rolled over rocks or uneven surfaces where a puncture might result and, when rolled on grades, the speed should be controlled by ropes or pieces of wood. Cans should be handled with both hands, not thrown or rolled. Containers and 55-gallon drums must not be dropped from vehicles to the ground. The shock damages seams and permits minute air leaks which may cause water contamination. Drum skids or hoists always should be used. If a leaking container is found, the contents should be transferred to another container known to be tight and clean, the identifying marks being placed on the new container. Before removing the plug or cap from any opening, all adjacent surfaces should be cleaned carefully of any dirt or other contaminating material. Do not open more containers than can be used promptly.

(3) *Symbols.* Symbols are used on packages as a means of abbreviated nomenclature of a product. They correspond to the symbols indicated under the lubricant column on lubrication orders. Such symbols are indicated after product nomenclature of lubricants authorized for ordnance matériel listed in paragraphs 17 through 21.

i. CHANGE FROM STRAIGHT MINERAL OIL TO ENGINE OIL (USA 2–104, latest revision).

(1) *General.* Instructions which follow apply only to engines which have been operated with straight mineral oil when engine oil is prescribed by current applicable lubrication orders. The procedures also will apply when preparing engines in captured equipment for service with United States Army troops. These instructions do not affect certain engines for which straight mineral oil is prescribed. In instructions which follow, engine oil will be referred to as heavy-duty engine oil.

(2) *Heavy-duty engine oil.*

(*a*) Engine oils supplied under Specification USA 2-104 are the heavy-duty type and possess two characteristics which are not inherent in straight mineral oils, namely: detergency and high resistance to oxidation. These qualities are obtained by blending chemical additives in the finished engine oil. Detergency prevents the formation of acid, varnish, and sludge deposits in new or clean engines and cleans or dissolves deposits previously formed from the use of straight mineral oil. This cleaning action dissolves the varnish or gums which act as carbon binders and carries them in suspension in the oil. Large particles of carbon and sludge are removed by the oil filter or cleaner. Fine particles carried in suspension and not removed by the oil filter are too small to cause any harmful effects. Detergency likewise enables the heavy-duty engine oils to carry in suspension fuel blow-by and oil oxidation products which might eventually result in engine deposits. This is why heavy-duty engine oils usually turn black within the first few hours of operation.

(*b*) Amount of carbon and sludge accumulations in an engine operated with straight mineral oil depends on the time or distance operated, operating conditions, and quality of the oil. Therefore, procedures herein must be followed without deviation when changing to heavy-duty engine oil. Otherwise, the cleaning action may cause excessive accumulations of carbon and sludge to clog the oil screen or circulating system and result in engine failure due to lack of lubrication.

(3) *In-line or V-type engines.*

(*a*) Fill new and rebuilt engines with heavy-duty engine oil, either at the start or finish of the run-in period. If necessary during the run-in period, add heavy-duty oil as required to maintain the proper oil level. At the end of the run-in period, inspect filter element. If coated with sludge, clean inside of case and install new element. Fasten a tag to the oil pressure gage so that it is plainly visible at all times. The following statement should appear on the tag: "Oil in this engine has been changed to engine oil (Specification USA 2–104)." Service the engine as normally precribed by the current applicable lubrication order.

(*b*) Oil in new or rebuilt engines low in mileage or hours of operation and in engines reasonably free from sludge will be changed at the next crankcase drain period as follows:

1. Drain crankcase when engine and oil are thoroughly heated. Do this immediately after operation. Otherwise, start the engine and run at fast idle for about 15 minutes, until engine and oil are at operating temperature. Temporarily blanket the radiator, if necessary, in cold weather.

2. Inspect filter element. If heavily coated with sludge, clean inside of case and install new element.

3. Fill the crankcase with heavy-duty engine oil and tag as per (*a*) above.

4. Operate the engine in the normal manner for approximately 250 miles or 25 hours. Watch the oil pressure gage carefully to see that normal pressure is maintained, indicating that oil lines and screens have not become clogged by loosened sludge and carbon. If oil pressure drops below normal (a gradual drop if oil supply is restricted or a sudden drop if oil supply is interrupted), stop the engine immediately. Check all oil lines and clean if restricted. Remove the oil pan. Remove and clean the oil screen. Inspect and clean the pan, interior of the engine, and oil pressure relief valve. If, at the end of 250 miles or 25 hours, there has been no pressure drop and operation of the engine has been normal in every way, drain the crankcase while the engine is hot. Refill with heavy-duty engine oil. Change filter element if coated with sludge. Service engine as normally prescribed.

(*c*) Oil in engines not meeting the conditions outlined in (*a*) and (*b*) above will be changed as follows:

1. Drain crankcase while hot, immediately after operation, if possible. Otherwise, operate as prescribed in (*b*) *1*, above. Remove old filter element, clean inside of case, and install new filter element.

2. Fill the crankcase half-full with heavy-duty engine oil for engines with force feed lubricating systems; or to the "FULL" mark for engines with splash systems. Run the engine at fast idle for one-half hour, watching the oil pressure gage continually. If oil pressure drops below normal, proceed to clean oil screen, lines, and pan as in (*b*) *4* above. If oil pressure remains normal, drain crankcase. Inspect filter element. If heavily sludged, clean inside of case and install new element. Again fill crankcase half-full with heavy-duty engine oil and operate at fast idle for one-half hour. Inspect filter element again. If second inspection shows heavy sludge deposits or if oil pressure drops, proceed as in (*b*) *4* above. After engine reassembly, install new filter element. Fill crankcase with heavy-duty engine oil and tag as per (3) (*a*) above. Operate in the normal manner for approximately 250 miles or 25 hours. Watch the oil pressure gage carefully. If oil pressure and engine operation are normal, drain crankcase while hot and refill with heavy-duty engine oil. The vehicle then will be serviced as normally prescribed.

3. If it is not necessary to mechanically clean the engine, fill crankcase to the normal oil level and mark unit as per (*b*) *4* above. During the first 100 miles or 10 hours of operation, watch the oil gage carefully to check pressure. At the end of this period, drain crankcase. Remove and inspect filter element. If coated with sludge, clean inside of case and replace element. If element and engine are reasonably clean, they may be put into regular service after refilling crankcase. Watch oil pressure gage to see that no further accumulations of sludge become dislodged, thereby retarding the oil supply as indicated by a drop in oil pressure.

(4) *Radial engines in new vehicles.* At start or finish of run-in and first draining periods, fill new engines in new vehicles with heavy-duty engine oil if the oil cooler and oil tank are clean. If necessary during run-in period, add heavy-duty engine oil to maintain proper oil level. Until the oil in all vehicles has been changed, fasten a tag to the oil pressure gage so that it is plainly visible. The following statement should appear on this tag: "Oil in this vehicle has been changed to engine oil (Specifications USA 2–104)." Service the vehicle as normally prescribed.

(5) *Radial engines in used vehicles.* Oil in new or rebuilt engines installed in used vehicles as replacement for engines previously used will be changed as follows:

(*a*) Before the engine is operated, clean the oil tank and cooler as follows:

1. *Medium tanks and medium tank chassis.* Remove oil tank and cooler from vehicle. Wash with dry-cleaning solvent and blow out with steam. Flush with an additional charge of dry-cleaning solvent and dry thoroughly. Where a steam cleaning device is not available, use dry-cleaning solvent, benzol (benzene, grade C), acetone, or mixture of these solvents in equal proportions, as available. Where installed, remove oil tank hopper from oil tank to facilitate cleaning. In all cases, rinse the cooler and tank with any of the above solvents until all foreign material is removed. Drain and blow with air. Inspect for cleanliness and replace on vehicle.

2. *Light tanks and light tank chassis.* Drain oil tank and engine oil sump. Remove and clean oil strainer and oil screens. Clean oil tank and oil cooler as directed in *1* above.

(*b*) After cleaning, refill oil tank, tag vehicle as previously specified, and operate engine in the usual manner for 1 day or approximately 8 hours. Watch oil pressure and temperature gages constantly for evidence of low pressure or overheating.

(*c*) At the end of this period, drain oil tank and engine oil sump. Remove, clean, and replace oil strainer, oil pump, and pump screens.

(*d*) Refill oil tank and operate engine in accordance with standard instructions.

(*e*) If there is evidence of low oil pressure or overheating, stop engine, drain oil tank, and inspect oil screens, oil strainer, and oil pump bypass valve for dirt and other foreign material.

(*f*) After inspecting and cleaning, fill oil tank with heavy-duty engine oil and operate the engine again as in steps (*b*), (*c*), and (*d*) above. If no difficulty develops, operate the engine in accordance with standard instructions.

(6) Disassemble and thoroughly clean radial engines operated with straight mineral oil more than 200 hours or 2,000 miles before changing over to heavy-duty engine oil. Also clean oil tank, circulating system, and oil strainer.

17. Fluids

a. Fluid, Hydraulic Brake (HB).

(1) *Characteristics.* A clear nonmineral fluid for hydraulic brake systems; it will not deteriorate rubber and thus is

suitable for lubrication of points where a petroleum oil cannot be used.

(2) *Use.*

(*a*) Hydraulic brake systems.

(*b*) Lubrication of rubber bushings and shackles to stop squeaks.

b. Fluid, Shock Absorber, Heavy (SAH).

(1) *Characteristics.* This fluid is made from a nonpetroleum base, usually castor oil with about a minus 30° F. pourpoint. Shock absorbers filled with this fluid will not function in temperatures below —20° F. and should be disconnected to prevent breakage.

(2) *Use.* This fluid is used only in Houde shock absorbers. It will not be used in brake cylinders.

c. Glycerine, U.S.P.

(1) *Characteristics.* A heavy colorless liquid which mixes readily with water.

(2) *Use.* Mixed with distilled water and sodium hydroxide pellets to serve as a recoil fluid in certain recoil mechanisms.

18. Gear Lubricants

a. Lubricant, Gear, Universal, Grade 90 and Grade 75 (GO).

(1) *Characteristics.*

(*a*) A compounded mineral oil with extreme pressure characteristics to increase load-carrying capacity, especially for hypoid and other gears which operate at extremely high gear tooth pressures.

(*b*) Universal gear lubricants manufactured by different refiners in accordance with Specification USA 2–105 are completely miscible and if mixed in any proportions will not react chemically in an objectionable manner.

(2) *Use.*

(*a*) Automotive gear case lubrication where prescribed by lubrication orders.

(*b*) Other bearings and gears which operate under extremely high gear tooth or bearing pressures where prescribed in the current applicable lubrication order.

(*c*) Grade 90 generally is specified for above 0° F. and grade 75 for below 0° F. Grade 75 may be used to −40° F.

Note. Gear cases on matériel received from manufacturing facilities, or other sources, may contain universal gear lubricant (grade 80). These gear cases will not be drained in order to substitute grade 90 unless draining is necessary due to period of service or condition of the lubricant. When temperatures below 0° F. are expected, universal gear lubricant (grade 80 or 90) will be drained and replaced with grade 75. Universal gear lubricant (grade 75) provides a

margin of safety for operation above 0° F. and need not be drained prior to the regular drain period unless air temperatures exceed +32° F. Grade 90 will be used to maintain gear case levels between +32° F. and 0° F. provided temperatures are not expected to drop below 0° F. again, in which event grade 75 will be used.

b. LUBRICANT, CHAIN, EXPOSED GEARS, AND WIRE ROPE, GRADE 2 (CW).

(1) *Characteristics.* A viscous black oil selected for its ability to adhere to metal surfaces and thus act as a protective coating against rust. It is not a satisfactory lubricant for close fitting mechanisms or gears.

(2) *Use.* Protective coating for chain and some wire cables and slow moving exposed gears, such as found on draglines.

19. Greases

a. GREASE, ALUMINUM BASE.

(1) *Characteristics.* A transparent grease containing a metallic soap (aluminum stearate) which is very stable over a wide range of temperatures. It also is waterproof and is not broken down by water like sodium soap greases. In use, aluminum soap base grease becomes more adhesive and cohesive as the temperature increases to about the melting point of the grease.

(2) *Use.* For rebuild of recoil mechanisms where prescribed.

b. GREASE, BALL AND ROLLER BEARING (BR).

(1) *Characteristics.* A heavy high melting point grease for antifriction bearings which operate at high temperatures and under heavy loads, especially when lubrication is performed at infrequent intervals.

(2) *Use.*

(*a*) Clutch pilot and hub bearings in radial tank engines.

(*b*) Pilot bearings in other heavy-duty engines when prescribed by technical manuals or lubrication orders.

(*c*) Some generator bearings which are packed at assembly.

c. GREASE, GENERAL PURPOSE, NO. 0 AND NO. 1 (CG).

(1) *Characteristics.* These are semisolid low melting point greases used primarily for lubrication of chassis points equipped with lubrication fittings. They are not suitable for lubricating packed antifriction bearings or other points that operate at high speeds and temperatures. The soap content of some of the No. 1 greases is soluble in water and should be relied upon for protection against rain or other moisture conditions.

(2) *Use.*

(*a*) General automotive chassis lubrication.

(*b*) Grease lubrication of large artillery matériel when prescribed by lubrication orders.
(*c*) No. 1 generally is prescribed for above +32° F., and No. 0 is used for below +32° F.

d. Grease, General Purpose, No. 2 (WB).

(1) *Characteristics.* This type of lubricant is fibrous in consistency, has a fairly high melting point, and the soap content is soluble in water. It is intended primarily for lubricating antifriction bearings which do not operate at excessively high temperatures.

(2) *Use.*
(*a*) Wheel bearings at all temperatures above −30° F.
(*b*) Clutch pilot and release bearings on general purpose vehicles.
(*c*) Grease lubricated distributor shafts.
(*d*) Some generator and starter bearings.

e. Grease, Graphited, Soft (GG).

(1) *Characteristics.* A light grease compounded with graphite which provides increased resistance to removal from lubricated surfaces under conditions of very high pressure, particularly at low speeds and when lubrication is performed at extended intervals. This grease will not be used on antifriction bearings or between other rubbing surfaces for which it is not prescribed.

(2) *Use.* For coating springs in recoil mechanisms and equilibrators and other large springs on artilllery, when prescribed.

f. Grease, Lubricating, Mineral, Gear (GLG).

(1) *Characteristics.* This is a special high temperature grease. It becomes more adhesive at moderately elevated temperatures, therefore, being more serviceable as a result of superior retention on moving surfaces.

(2) *Use.* To lubricate metallizing guns.

g. Grease, Lubricating, Primer Seat. An antiseize compound to prevent galling of metal surfaces after exposure to high temperatures.

h. Grease, Lubricating, Special (GL).

(1) *Characteristics.* A grease especially compounded to offer maximum resistance to congealing at extremely low temperatures and also to maintain normal consistency at fairly high temperatures.

(2) *Use.*
(*a*) Grease lubrication of sighting and fire control equipment at all temperatures.

(*b*) Bearings where a special low temperature grease is required.

i. GREASE, LUBRICATING, RIFLE (RG).

(1) *Characteristics.* A special grease which offers maximum resistance to the washing action of rain and sea water spray for certain surfaces of the rifle, cal. .30, M1 (series) and the carbine, cal. .30.

(2) *Container.* A special plastic container (container, grease, M1).

(3) *Use.* To lubricate the actuating cam on the operating rod; bolt locking recess in the receiver; hammer actuating cam on the rear bolt; upper and lower circular surfaces on the rear of the bolt; and the upper and lower circular surfaces forming the receiver bridge at the rear end of the bolt.

j. GREASE, ORD. DEPT., NO. 0 AND NO. 00 (OG).

(1) *Characteristics.* These are light consistency greases, especially compounded to meet the requirements of artillery carriages, mounts, and automotive matériel.

(2) *Use.*

(*a*) Grease lubrication of automotive matériel, artillery carriages and mounts, and some machine gun mounts where prescribed by lubrication orders.

(*b*) No. 0 is generally recommended for operation above +32° F.; No. 00 for below +32° F.

k. GREASE, SPECIAL, HIGH TEMPERATURE (GM).

(1) *Characteristics.* A special high melting point grease for antifriction bearings and other parts that operate at extremely high speeds and temperatures.

(2) *Use.* Ball and roller bearings operating at extremely high speeds and temperatures.

l. GREASE, WATER PUMP (WP).

(1) *Characteristics.* A waterproof grease of No. 4 consistency highly resistant to dissolving or melting by hot water in engine cooling systems. It is not satisfactory for temperatures above +212° F.

(2) *Use.* Some grease-lubricated water pumps, as prescribed. Do not use this grease in wheel bearings, universal joints, or other points that operate at high speeds and temperatures as the oil will separate from the soap base.

20. Oils

a. OIL, CASTOR, TECHNICAL GRADE (CASTOR).

(1) *Characteristics.* A white, transparent, sluggish vegetable oil, chemically stabilized against rancidity.

(2) *Use.* Lubrication of the rubber or synthetic rubber packings of some hydropneumatic recoil mechanisms of 155-mm and 240-mm howitzers. Also presently prescribed for preservation of hydraulic brake cylinders in packages and vehicle brake systems on vehicles for stand-by storage.

b. OIL, CLOCK AND WATCH (OCW).

(1) *Characteristics.* A clear synthetic oil possessing extremely low coefficient of friction; high resistance to gumming, evaporation, and protection against development of corrosiveness over long periods of time; and has high fluidity at low temperatures.

(2) *Use.* Lubrication of clocks, watches, transits, and chronometers.

c. OIL, CUTTING, MINERAL-LARD (ML).

(1) *Characteristics.* A mineral-oil compounded with lard. It is not emulsive with water.

(2) *Use.* A cutting tool lubricant and coolant. It also flushes away metal chips and keeps the tools clean.

d. OIL, CUTTING, SOLUBLE (OS).

(1) *Characteristics.* A compound cutting oil emulsive with water.

(2) *Use.* A cutting tool lubricant and coolant used especially when a large volume is required to reduce tool temperatures and to flush away chips.

(3) *Preparation for use.* Usually mixed with water in the proportions of about 1 part oil to from 20 to 40 parts water, depending on the nature of the work.

e. OIL, ENGINE CONDITIONING.

(1) *Characteristics.* This is a mineral lubricating oil containing additives which have gum and varnish solvent action. The oil also is compounded to neutralize acids which cause corrosion of the internal surfaces of the engine.

(2) *Use.* The oil can be fed through the carburetor or sprayed into the combustion chamber by removing spark plugs. It also may be used to flush the crankcase to purge some of the acids, gums, varnishes, sludge, and other deleterious foreign matter.

f. OIL, ENGINE, USA 2–104.

(1) *Characteristics.*

(*a*) Oil, engine, USA 2–104, is supplied only in the SAE 10, 30, and 50 grades, since field experience has shown that intermediate grades are not necessary to meet the requirements of gasoline or Diesel engines as used in United States Army vehicles.

(*b*) Oil, engine, USA 2–104, is a heavy-duty type oil containing additives used to eliminate or reduce the objectionable characteristics of straight mineral oils when used in engines operated under the severe conditions of military service.

(*c*) One of the chemical additives in engine oil dissolves the carbon binders (gum or varnish) and holds them in suspension. This is referred to as washing, as the oil affectively cleans the surfaces with which it comes in contact and prevents new carbon and gum formations. This is why the oil turns black soon after it is placed into service. The change in color does not affect the lubricating qualities of the oil but indicates that cleaning action is taking place. Larger foreign particles are removed by the oil filter. The particles which are carried in suspension are so small that they will not damage bearings, cylinders, gears, or other surfaces, and are removed when the oil is drained. To take full advantage of this cleaning action and to insure that all carbon, sludge, and other contaminants carried in suspension are removed, crankcases and gear cases must be drained completely while the oil is hot.

(*d*) The cleaning action of the oil will maintain a clean engine under normal temperature conditions but is not a "cure-all" especially against low temperature sludge. When operating vehicles at low temperatures care must be taken to assure properly operating coolant thermostats. Radiator and hood blankets must be used if air temperature is in the sub-zero range to maintain proper engine operating temperatures above +140° F.

(*e*) The high resistance of this oil to oxidation prevents formation of corrosive acids and therefore insures longer bearing life for all types of engines, especially those equipped with alloy bearings.

(2) *Use.*

(*a*) All internal combustion engines.

(*b*) Tank and some tractor gear cases.

g. Oil, Engine, Preservative, SAE 10 (Grade 1), SAE 30 (Grade 2) (PE).

(1) *Characteristics.* A highly refined mineral oil similar to specification USA 2–104 heavy-duty type but containing rust inhibitors to prevent rust on internal parts of engines and other metal surfaces. It is not intended for heavy-duty service but will perform satisfactorily as an engine lubricating oil and may be used for 500 miles.

(2) *Use.*

(*a*) Preservation of internal parts of engines during shipment and limited storage.

(*b*) Lubrication of other mechanisms only when prescribed by current applicable lubrication orders and technical manuals.

h. OIL, HYDRAULIC (OH).

(1) *Characteristics.* A special, low pour-point oil, with particularly high resistance to viscosity changes under high pressures, and to thickening at low temperatures, and oxidation or sludging in service. It thus serves as an ideal lubricant for mechanisms which are affected by any tendency of the hydraulic medium to form gums on valves, gears, and other parts, or which become sluggish or inoperative at low temperatures due to oil thickening or congealing. This oil contains rust preventives for storage protection in equipment for which it is specified.

(2) *Use.*

(*a*) Tank hydraulic systems.

(*b*) Artillery remote control systems.

(*c*) Other hydraulic systems.

i. OIL, LARD, (OL).

(1) *Characteristics.* An oil made from lard and having necessary high lubricating properties for use in thread cutting and machining operations. It is not emulsive with water.

(2) *Use.* A lubricant and coolant for dies and tools for cutting and threading pipe, and similar operations.

j. OIL, LUBRICATING, GENERAL PURPOSE.

(1) *Characteristics.* This is a highly refined petroleum oil used in equipment where high pressures and temperatures are not a factor.

(2) *Use.* It is used in sleeve bearings, frictional surfaces of machines, motors, etc.

k. OIL, LUBRICATING, LIGHT (LO)

(1) *Characteristics.* A light highly refined mineral oil with practically no rust-preventive properties.

(2) *Use.* Oil lubrication of sighting and fire control instruments in all shock absorbers except Houde and for lubrication of brake vacuum and Hydrovac cylinders.

l. OIL, LUBRICATING, STEAM CYLINDER, MINERAL.

(1) *Characteristics.* A heavy straight mineral cylinder oil suitable for use at high temperatures, such as in the presence of dry or superheated steam and in heavily loaded industrial-type gears.

(2) *Use.* Lubrication of steam engine cylinders and valves where operating with dry or superheated steam. Also used for lubrication of some industrial gears.

m. OIL, LUBRICATING, PRESERVATIVE, MEDIUM (PL-MEDIUM).

(1) *Characteristics.* A medium viscosity mineral oil containing a rust inhibitor. The heavier body provides better protection against moisture and salt water spray than the special grade.

(2) *Use.* Lubrication and preservation of artillery, small arms, and machine guns, above +32° F. when prescribed by the current applicable lubrication order.

n. OIL, LUBRICATING, PRESERVATIVE, SPECIAL (PL-SPECIAL).

(1) *Characteristics.* A light very low pourpoint mineral oil containing a rust inhibitor. It should be depended upon only for day-to-day preservation of matériel.

(2) *Use.*

(*a*) Lubrication and preservation of artillery, small arms, and machine guns, below 32° F. when prescribed by the current applicable lubrication order.

(*b*) Oilcan lubrication of automotive matériel where prescribed.

(*c*) Penetrating oil.

o. OIL POTENTIOMETER (OP).

(1) *Characteristics.* A very light highly refined petroleum fluid comparable in viscosity to kerosene.

(2) *Use.* For potentiometers of AA directors, computers, and radar matériel.

21. Recoil Oils

a. OIL, RECOIL, LIGHT (RL).

(1) *Characteristics.* A special low pourpoint oil which is satisfactory for use at all temperatures in the recoil mechanisms for which it is specified.

(2) *Use.* A recoil fluid for use in recoil mechanisms when prescribed by current applicable lubrication orders and technical manuals.

b. OIL, RECOIL, SPECIAL (RS).

(1) *Characteristics.* A specially refined oil with an unusually high viscosity index which results in minimum tendency to become thinner at high temperatures and pressures or to congeal at extremely low temperatures. It has a clear bright green color for easy identification.

(2) *Use.*

(*a*) A recoil fluid for recoil mechanisms where prescribed by lubrication orders and technical manuals.

(*b*) Replaces recoil oil (heavy) below 0° F.; also above 0° F. when stocks of heavy are depleted.

(*c*) Replaces hydraulic oil below 0° F. in hydraulic mechanisms if sluggish action develops.

22. Miscellaneous

a. GRAPHITE.

(1) *Grades and characteristics.*

(*a*) *Graphite, amorphous.* A noncrystalline, powered graphite.

(*b*) *Graphite, lubricating, flake grade, small* (GFS). A fine grade of flaked graphite.

(2) *Use.*

(*a*) The powered amorphous grade is mainly for use on gaskets, etc., where high temperatures develop and high grade lubricating qualities are not required.

(*b*) Flake grade—small is for lubrication only when prescribed by technical manuals.

b. GUN, GRAPHITE, HAND-OPERATED (FILLED).

(1) *Characteristics.* A bellows type gun filled with lubricating graphite (very fine). (Issue until stock is exhausted.)

(2) *Use.* Lubrication of locks.

Section V
LUBRICATION EQUIPMENT

23. General

a. GENERAL. Standardization of lubricants not only reduced 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 matériel 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 oilcans, 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 cause malfunctioning of the matériel 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.

24. Oil Pumps

a. OIL BARREL PUMP. An oil barrel pump (fig. 20) 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 fre-

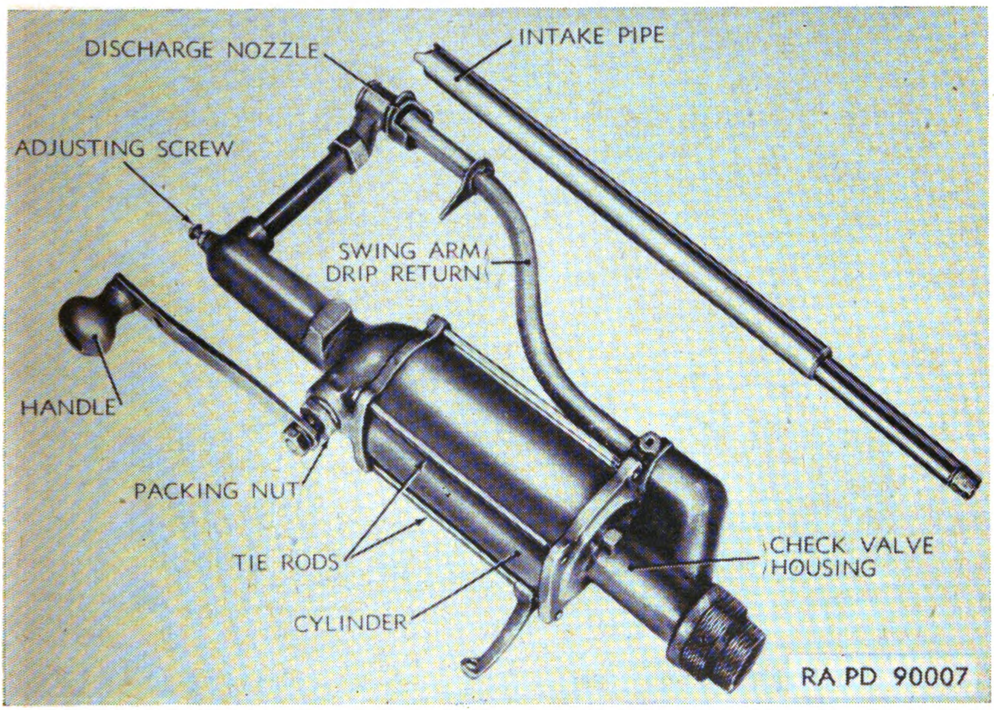


Figure 20. Oil Barrel Pump.

quent 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 nozzle. 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. 21) 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.

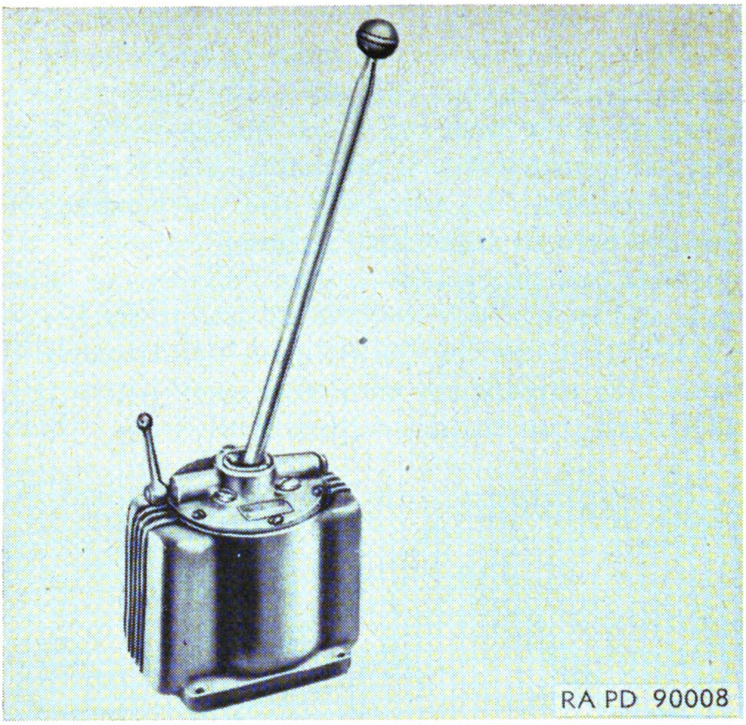


Figure 21. Recoil oil pump.

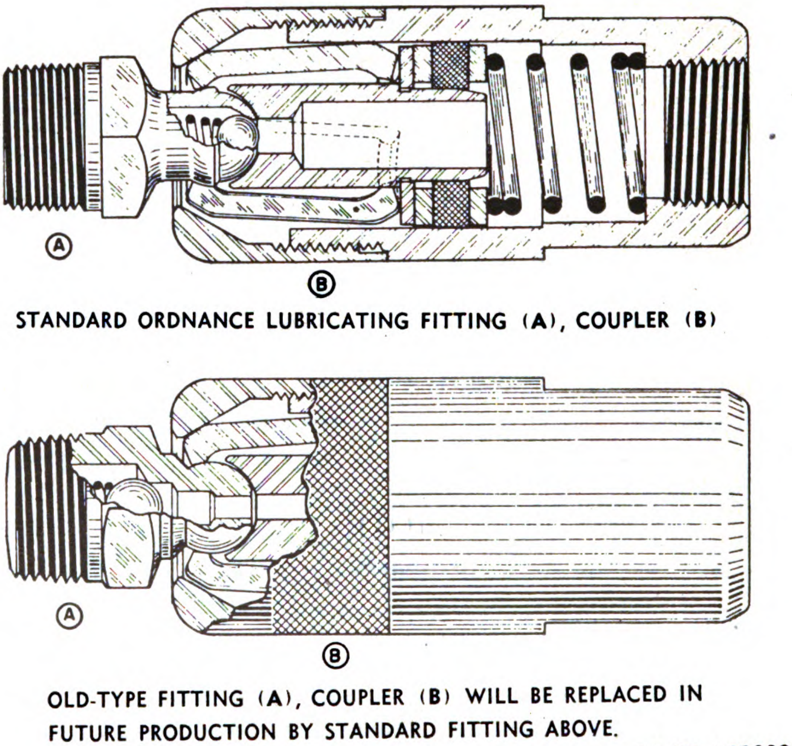


Figure 22. Old and new type lubricating fittings and couplers.

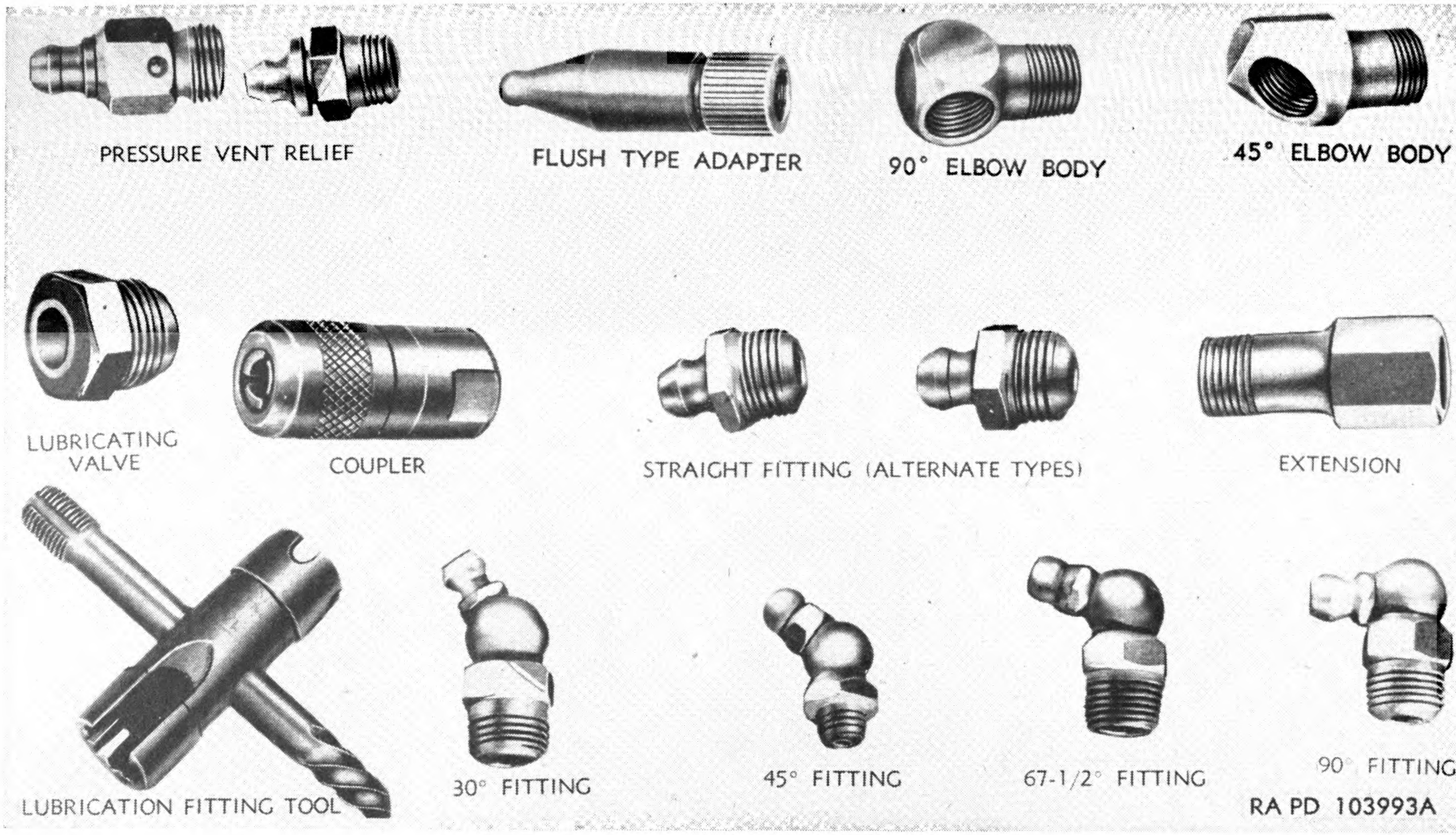


Figure 23. Grease lubrication fittings and appliances.

25. Lubricating Devices

a. Lubricating Fittings and Couplers. Matériel 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 matériel. The new type of fitting (fig. 22) 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 (fig. 23) 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. 24).

26. 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. 25) used for dispensing potentiometer 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.

27. 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

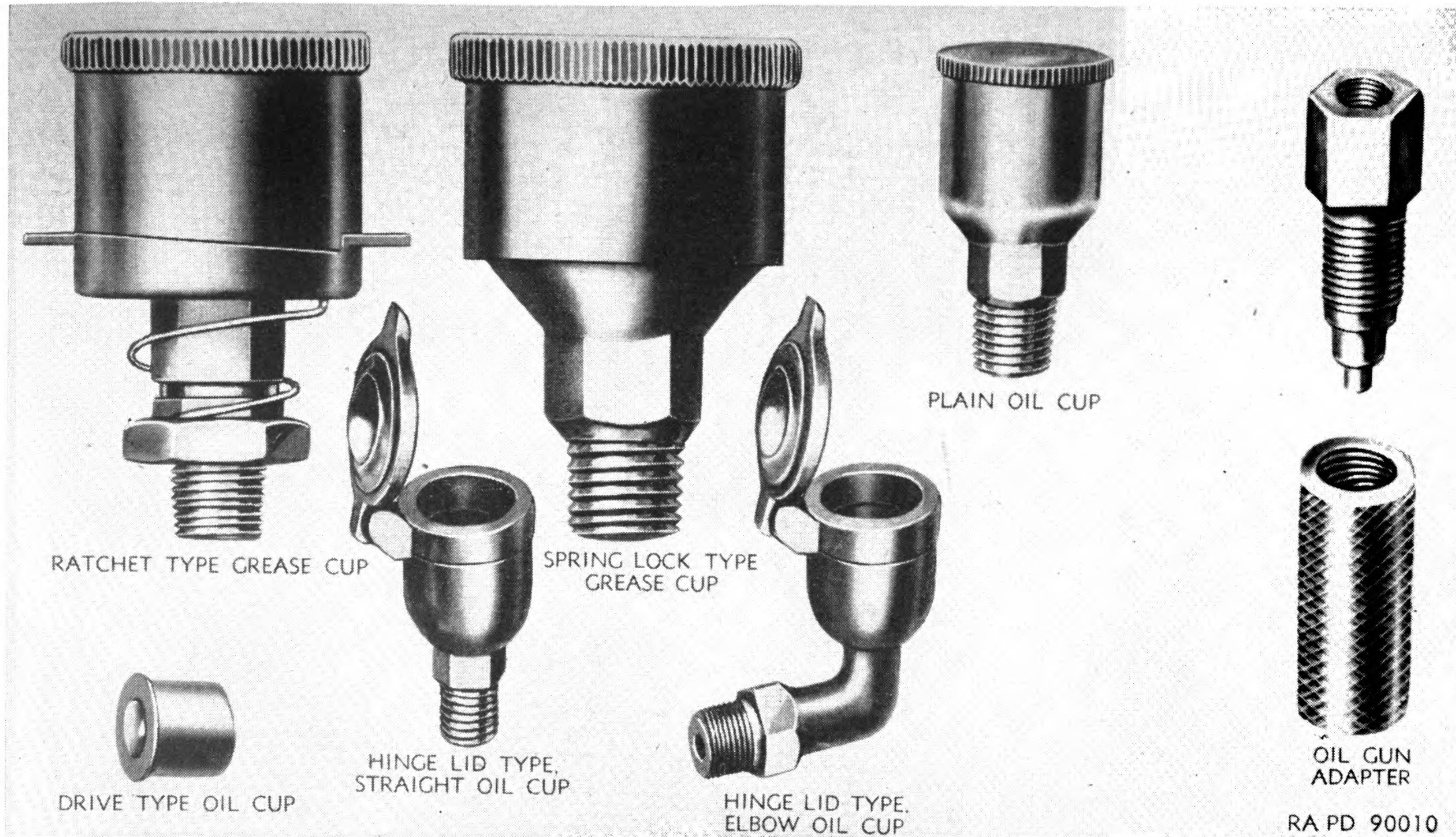


Figure 24. Oil and grease cups.

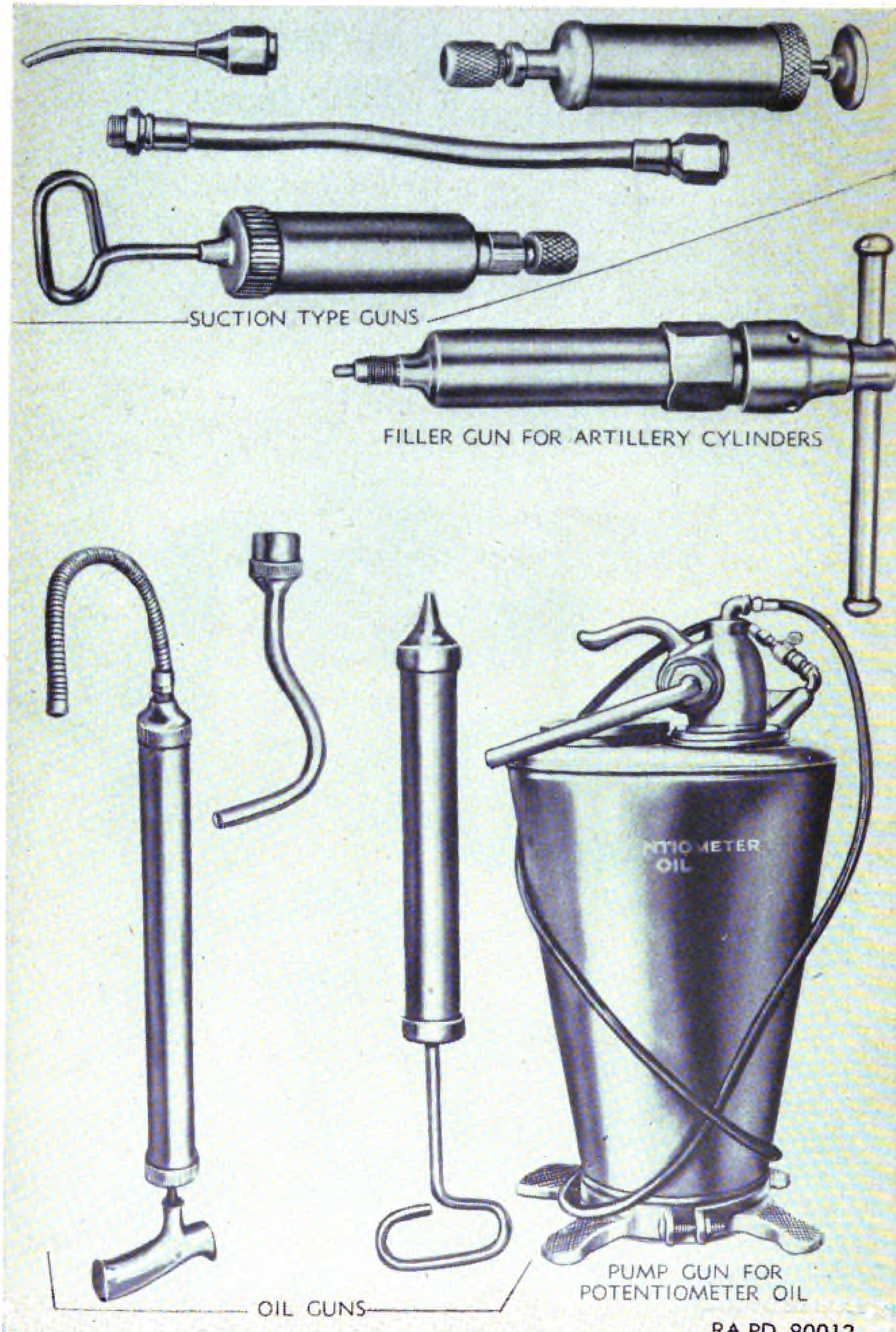


Figure 25. Typical oil guns.

lubricating fittings are installed are lubricated with high-pressure guns of either the hand-operated or air-operated types.

b. Low-pressure Guns. Figure 26 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 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

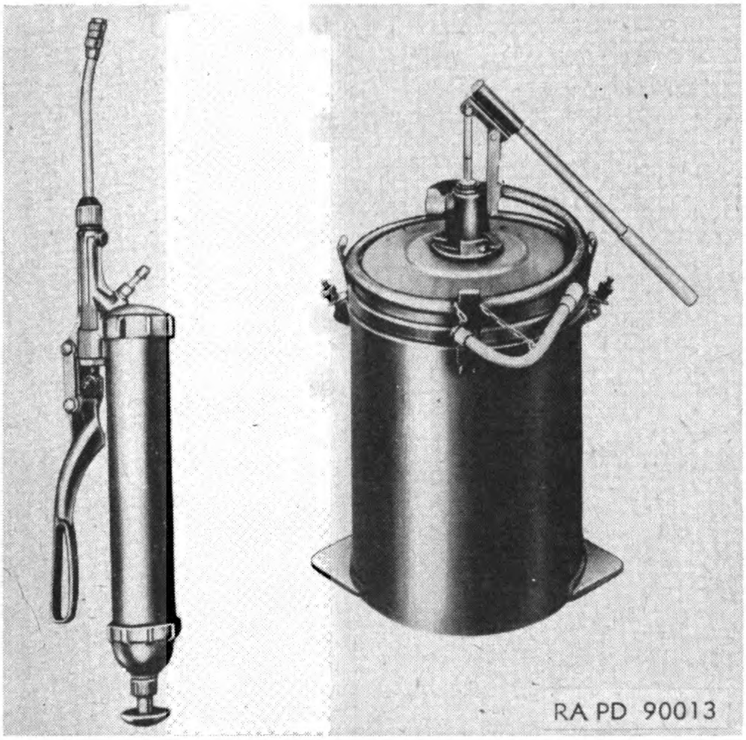


Figure 26. Low-pressure, hand-operated lubricating guns.

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. 27) are used in the lubrication of artillery, fire control instruments, motorcycles, and automotive vehicles. Although made in various styles, they

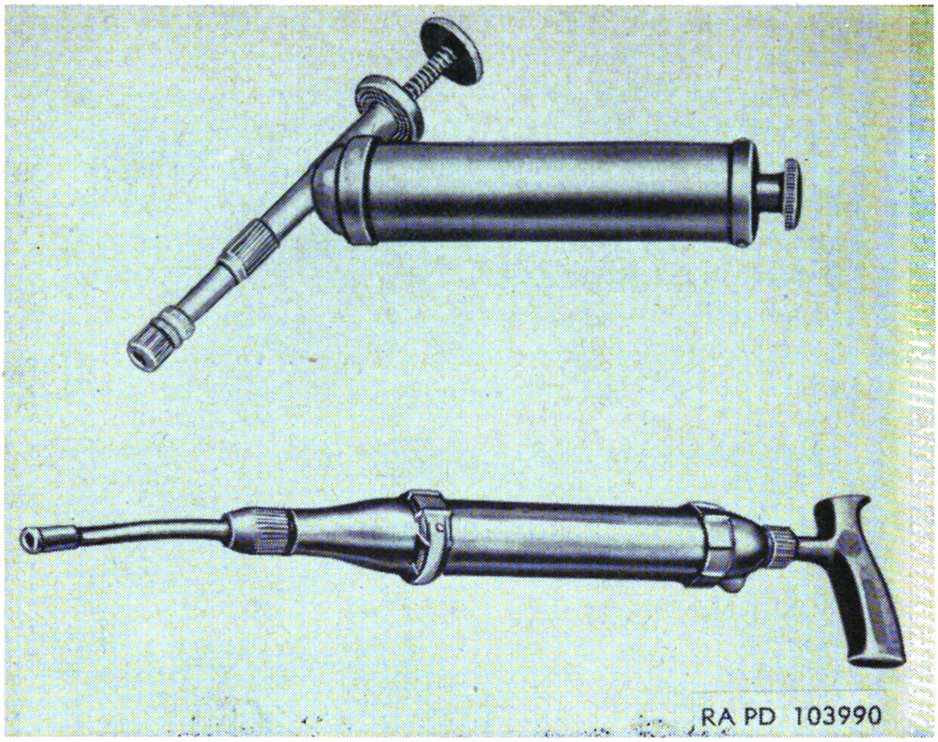


Figure 27. Typical push-type lubricating guns.

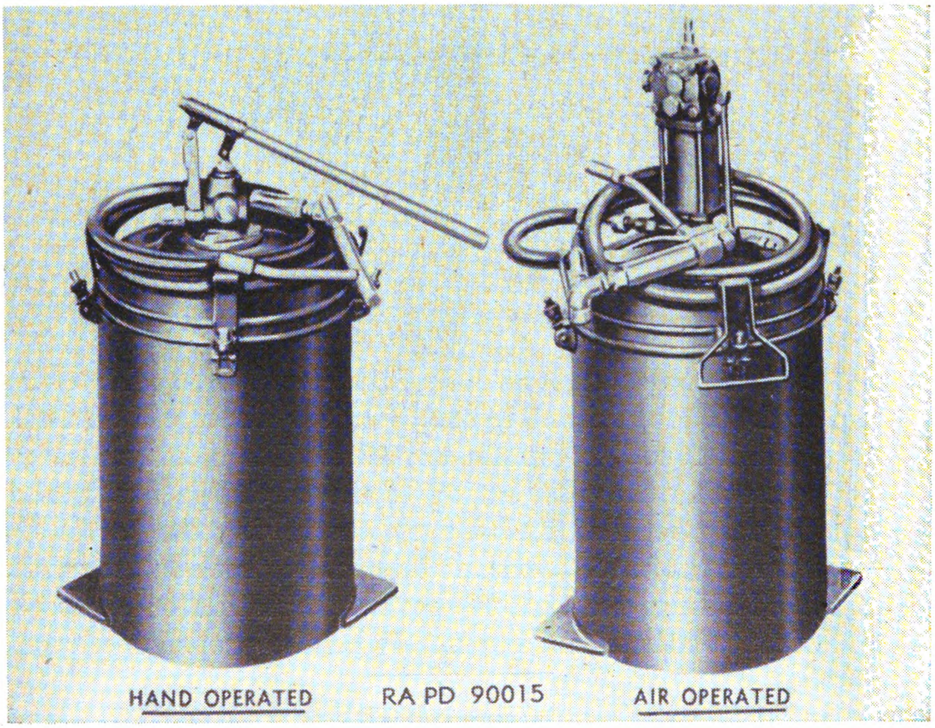


Figure 28. Pressure lubricating guns.

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 plunger or pumping piston forward in 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 these cause irregular action. If a 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-pressure lubrication guns (fig. 28) 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 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 a compressed air motor 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.

28. Miscellaneous Equipment

a. GENERAL. Aside from the various types of lubricating equipment previously covered, there also is 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. 30) 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

Figure 29. Typical miscellaneous lubricating equipment.

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.

c. Spray Oiler. The spray oiler (fig. 29) 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. 29) 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. 29 and 30). Pressure to eject the oil is secured either by a push-bottom 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. 29). 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. 30) 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,

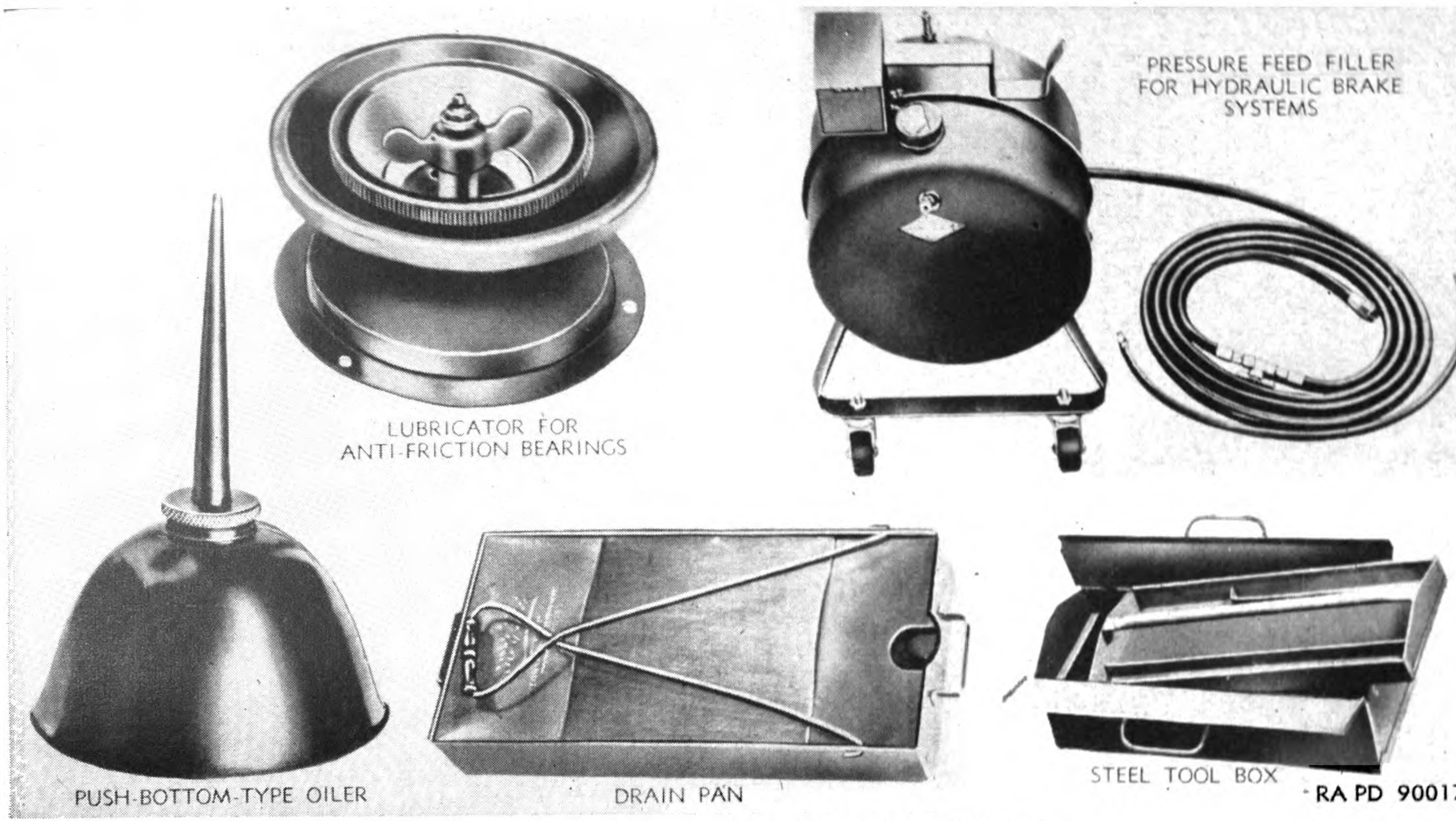


Figure 30. Typical miscellaneous lubricating equipment.

and tin plate; with and without strainers; and with various types of fixed or removable spouts.

i. Can Spout. The spout (fig. 29) 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. 30) 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. 23) 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. 30) 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.

Section VI
LUBRICATION PUBLICATIONS

29. General

a. Early in 1944 the Ordnance Field Service system of publications was revised and a new series known as War Department publications was instituted. In 1947 this new series was changed to Department of the Army publications. Eventually the Department of the Army publications will supersede completely the earlier series of publications, but at the present time lubrication directives are to be found in both series. Information on lubrication may be found in the following publications: lubrication orders (formerly War Department lubrication orders or War Department lubrication guides), technical manuals, and technical bulletins.

b. A complete index of these publications may be found in the current issue of FM 21–6.

30. Lubrication Orders

Lubrication orders (formerly known as guides) (figs. 31 and 32) are illustrated, numbered, dated cards or decalcomania labels which prescribe lubrication instructions for mechanical equipment issued by the technical services of the Army. They are to be carried with, or attached to, the equipment to which they pertain. Instructions contained thereon are mandatory. Orders are identified by a number, printed in the upper right corner, and date. They should be requisitioned by this number (not by name of the matériel) and date. Lubrication orders consist of a diagrammatic sketch of the matériel with arrows leading to lubrication points. Arrows with dotted shafts indicate that there are lubrication points on both sides of the item. At the tail end of each arrow the lubrication interval, the lubricant symbol, the name of the part to be lubricated, and in some cases, additional information is given. Also included on the lubrication orders are keys to all lubricant and lubrication period symbols used on the arrows; a table of capacities of such items as engine crankcases, gear housings, rear axles, etc. are shown at the diagram points; lubricants specified for use at various operating temperatures; and such other lengthy notes as are referred to on the diagram. At the present time lubrication orders are being supplied for most small arms in the form of small decalcomanias. Lubrication orders published at a later date than the applicable technical manual supersede the instructions given in the manual in case of conflict of instructions.

31. Technical Manuals (TM)

Pertinent lubrication order or orders are reproduced in technical manuals. Technical manuals generally include additional information on lubrication and illustrations made from actual photographs, thus enabling personnel to identify the lubrication points more readily than is possible from the diagrammatic illustration of the lubrication order.

32. Technical Bulletins (TB)

Technical bulletins publish new instructions or technical information which later may be incorporated in manuals or changes to manuals. Such instructions, information, or material might apply to lubrication. Such bulletins as apply to one item of matériel carry only the manual number of that item. For example, TB 9–1711–5 would translate as follows: The 9 signifies that the TB applies to the 9 group, Ordnance; the 1711 signifies that the information given applies to TM 9–1711, The White Engine 160AX; the 5 signifies that this TB is the fifth bulletin issued on this matériel. Such bulletins as apply to two or more items of matériel are identified by TB ORD followed by a number, the numbers being assigned consecutively as bulletins are published.

LUBRICATION ORDER LO 9-710-5

18 May 1948 (Supersedes WDLO 9-710-5, 12 Mar 1945)

CARRIAGE, MOTOR, MULTIPLE GUN, M16

References: ORD 7 SNL G-102; TM 9-710

Intervals are **based on normal operation.** Reduce to compensate for abnormal operation or severe conditions. During inactive periods intervals may be extended commensurate with adequate preservation.

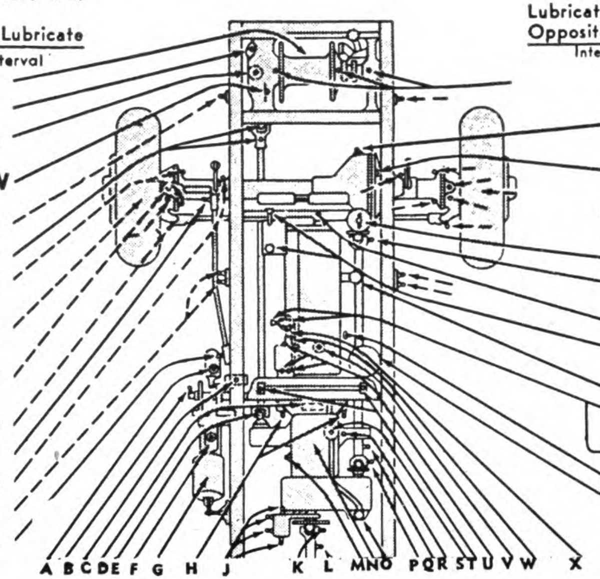
Clean fittings before lubricating. Lubricate after washing and **deep water fording.**

Clean parts with SOLVENT, dry cleaning. Dry before lubricating. (For exception, see ARMAMENT Note).

Lubricate dotted arrow points on both sides.

Opposite points are shown by short arrows.

	Lubricant	Interval
Winch Cable (See Note 14)	OE	
Winch Worm Housing Fill	GO	
Winch Worm Housing Drain Drain and refill. Cap. 2 qt. (See Note 6)		6
Winch Worm Housing Level Check level		W
Spring Bolt	CG	1
Universal and Slip Joint	CG	1
Universal Joint (See Note 13)	CG	1
Wheel Bearings Remove, clean and repack	WB	6
Steering Knuckle Bearings, Upper and Lower	CG	1
Tie Rod	CG	1
Drag Link	CG	1
Shock Absorber	SAH	6
Spring Shackle	CG	1
Drag Link	CG	1



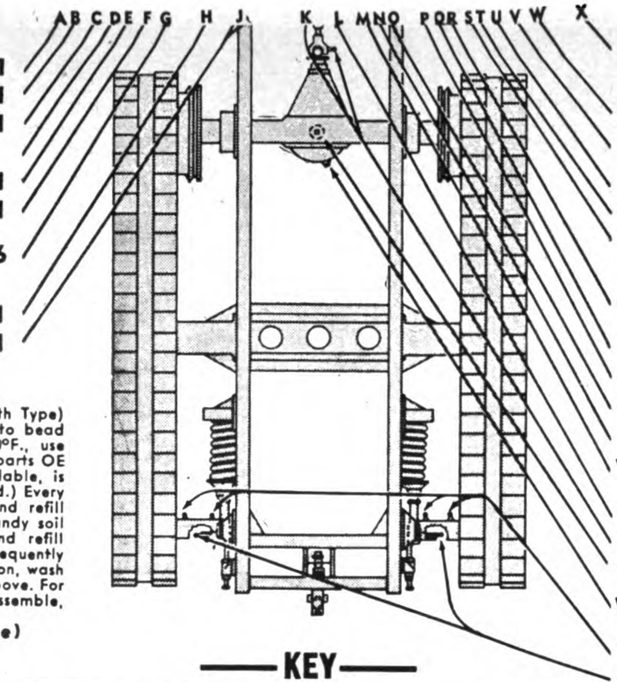
Interval	Lubricant	
1	CG	Winch Drum and Shaft Bearings
W	GO	Front Axle Diff. Fill and Level Check level
6		*Front Axle Diff. Drain* (See Note 6) Drain and refill Cap. 3½ qt.

Serviced From Under Hood

Interval	Lubricant	
1		*Oil Filter* Drain sediment (See Note 10)
1	CG	Universal Joint (Reached from under vehicle)
1	CG	Front Engine Support
1	WB	Generator Turn cup down 1 full turn, refill as required
	OE	Crankcase Fill and Breather
1	WB	Distributor Shaft Turn cup down 1 full turn, refill as required
6		Distributor (See Note 5)
D		*Crankcase Level* Check level
D	OE	Air Cleaner Check level (See Note 1)

FOLD FOLD

Steering Gear GO 1
Pedal Shaft CG 1
Clutch Relay Shaft CG 1
Clutch Pilot Bearing (See Note 2) BR
Universal Joint CG 1
Brake Master Cylinder HB 1
Fill to ½ in. from top
Brake Vacuum Cylinder LO 6
Lubricate with ½ oz. (See Note 8)
Clutch Release Shaft CG 1
Disc Brake CG 1



1 WB Tachometer Adapter
Turn cup down 1 full turn, refill as required
6 CG Tachometer Cable
Remove core and coat lightly with No. 0
1 *Crankcase Drain* Drain and refill Cap. 10½ qt. (See Notes 3 & 4)
1 OE Starter 6 to 8 drops (See Note 11)
1 OE Accelerator Cross Shaft
6 *Transmission and Transfer Case Drain* Drain and refill. Cap. 7½ qt (See Note 6)
1 CG Transfer Case Shift Levers
OE (Some models, oil hole)
1 CG Slip Joint
1 CG Universal Joint
6 CG Speedometer Cable
Remove core and coat lightly with No. 0
1 WB Clutch Release Brg.
W GO Trans. and Transfer Case Fill and Level Check level
1 CG Slip Joint
1 CG Universal Joint
6 *Rear Axle Diff. (Jackshaft) Drain* Drain and refill. Cap. 6 qt. (See Note 6)
W GO Rear Axle Diff. (Jackshaft) Fill and Level Check level
1 CG Idler Support Bearings
1 CG Idler Adjusting Screws (Some models)

— NOTES —

1. AIR CLEANERS AND BREATHERS—(Oil Bath Type) After every 8 hours of operation replenish to bead level with OE. (For temperatures above 0°F., use crankcase grade; from 0°F. to −40°F., use 4 parts OE 10 with 1 part diluent. Diesel fuel, if available, is preferred as diluent but gasoline may be used.) Every 1,000 miles, disassemble, wash all parts and refill with OE as above. For desert or similar sandy soil operation, disassemble, wash all parts, and refill with OE as above every 4 hours or more frequently if required. (Mesh Type) For normal operation, wash and reoil at indicated intervals with OE as above. For desert or similar sandy soil operation disassemble, wash all parts and reoil every 100 miles.

(Notes continued on reverse side)

—KEY—

LUBRICANTS	EXPECTED TEMPERATURES		
	above +32°F.	+32°F. to 0°F.	0°F. to −40°F.
OE—OIL, engine			
Crankcase	OE 30 or N.S. 9250	OE 10 or N.S. 9110	See Note 4
Other Points	OE 30 or N.S. 9250	OE 10 or N.S. 9110	PL—Special or Navy Spec. OS 1361
PL—OIL, lubricating, preservative			
Small Arms	PL—Medium or Navy Spec. OS 1363	PL—Medium or Navy Spec. OS 1363	PL—Special or Navy Spec. OS 1361
Buffer (Cal. .50 Machine Gun)	PL—Special or Navy Spec. OS 1361	PL—Special or Navy Spec. OS 1361	PL—Special or Navy Spec. OS 1361
GO—LUBRICANT, gear, universal	GO 90	GO 90	GO 75
CG—GREASE, general purpose	CG 1 or N.S. 14L9	CG 0	CG 0

Below −40°F., See TB ORD 126 & 193

LUBRICANTS
WB—GREASE, general purpose, No. 2 or Navy Spec. 14L10
HB—FLUID, hydraulic brake
SAH—FLUID, shock absorber, heavy
LO—OIL, lubricating, light
CW—LUBRICANT, chain, exposed gear and wire rope
CR—CLEANER, rifle bore
BR—GREASE, ball and roller bearing or Navy Spec. 14L3, Gr II

INTERVALS
25—25 Hours
D—Daily
W—Weekly
M—Monthly
S—Semiannually
¼—250 Miles
1—1,000 Miles
6—6,000 Miles

RA PD 113431

Figure 31. Lubrication order—front (sample).

Lubricant • Interval

PL M Trunnion Bearing
Elevate while lubricating

OE D Air Cleaner
Check level (See Note 1)

PL Breech and Firing Mechanism
Weekly and after firing, clean and oil

PL W Trunnion Sector Rack
Clean and oil

PL Breech and Firing Mechanism
Weekly and after firing, clean and oil

Interval • Lubricant

PL Gun Bores
(See Note 7)

M CG Seat Roller

M PL Trunnion Bearing
Elevate while lubricating

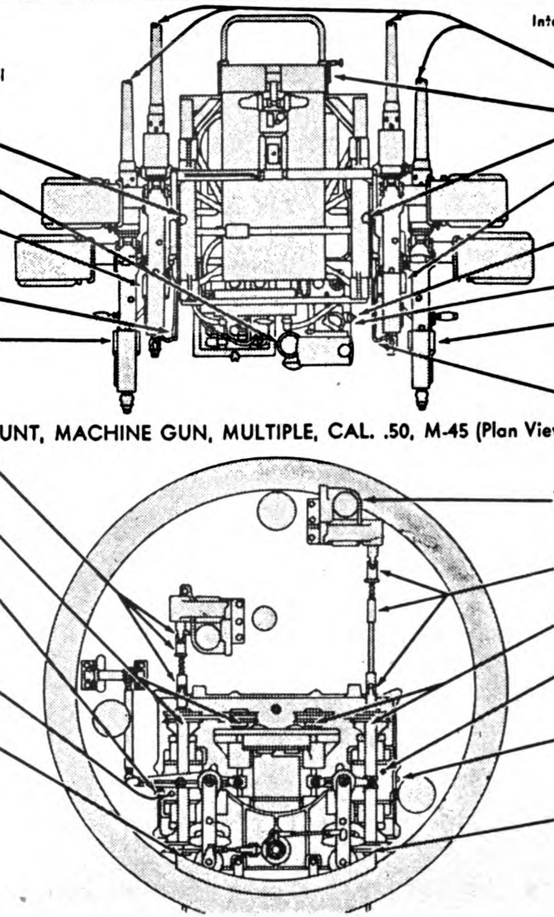
PL Breech and Firing Mechanism
Weekly and after firing, clean and oil

D OE Crankcase Fill and Level
Check level

25 *Crankcase Drain*
Drain and refill. Cap. 1 pt. (See Notes 3 & 4)

PL Breech and Firing Mechanism
Weekly and after firing, clean and oil

W PL Trunnion Sector Rack
Clean and oil



MOUNT, MACHINE GUN, MULTIPLE, CAL. .50, M-45 (Plan View)

PL W Universal Joints and Spline
(Reached through plate hole)

PL W Pulley Splined Shafts
(Reached through plate hole)

PL M Left Differential Drive Housing Fill and Level
Check level

S *Left Differential Drive Housing Drain*
Drain and refill (See Note 9)

PL W Pulley Splined Shaft
(Reached through plate hole)

W CG Turret Ring Gear and Pinion (See Note 12)

W PL Universal Joints and Spline
(Reached through plate hole)

W PL Pulley Splined Shafts
(Reached through plate hole)

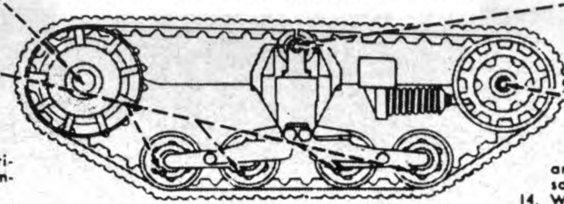
S *Right Differential Drive Housing Drain*
Drain and refill (See Note 9)

M PL Right Differential Drive Housing Fill and Level
Check level

W PL Pulley Splined Shaft
(Reached through plate hole)

FOLD

FOLD



HALF TRACK SUSPENSION SYSTEM SIDE VIEW

2. CLUTCH PILOT BEARING—Remove, clean and lubricate every 6,000 miles and when clutch is disassembled for any purpose.
3. CRANKCASES—Drain only when engine is hot. After refilling, run engine a few minutes, recheck level.
4. ENGINE OIL BELOW 0°F.—If equipment such as winterization kit, slave kit or heated storage is available, use OE 10 undiluted. If dilution is required, gasoline or Diesel fuel may be used but gasoline, if available, must be used. Therefore, fill oil reservoir with OE 10 to normal FULL mark on dipstick. Add diluent to oil reservoir in ratio of 1½ qt. to each 5 qt. of reservoir capacity—approximately 3 qt. of diluent. Run engine 5 to 10 minutes to mix lubricant and diluent thoroughly. Stop engine and note level of the diluted lubricant above the normal FULL mark on the gage or dipstick for future reference. Under operation check oil level frequently. During operation, add OE 10 if level drops below normal FULL mark. Upon shutdown of engine add OE 10 to normal FULL mark and diluent to diluent FULL mark if anticipated shutdown time will be sufficient to cool engine. (Mount Engine) If heated storage or heater are not available, drain after operation. Refill with warmed OE 10 undiluted.
5. DISTRIBUTOR—Every 6,000 miles, wipe breaker cam lightly with CG and lubricate breaker arm pivot and wick under rotor with 1 to 2 drops of OE.
6. GEAR CASES—Fill to plug levels before operation and after draining. Drain only after operation.
7. ARMAMENT—After firing, and on 2 consecutive days thereafter, thoroughly clean the bores with CLEANER, rifle bore, making sure that all surfaces, including the rifling are well coated. Do not wipe dry. On the third day after firing, clean the bores with CR, wipe dry and lightly coat with PL. Weekly, thereafter, clean with CR, wipe dry and reoil with PL. Clean all other exterior armament parts with CR before lubricating with PL. Buffer (Cal. .50 H.B.) Weekly, inject PL-Special, then rotate buffer assembly and drain excess. In humid and salt air areas, use PL Medium daily in buffer and on external surfaces of armament.
8. HYDROVAC CYLINDER (Some models)—Lubricate through plug holes in top and rear of cylinder with ½ oz. of LO in each hole. Replace plugs.
9. LEFT AND RIGHT DIFFERENTIAL DRIVE HOUSINGS—(Some models) Monthly, check oil level by removing plate on side of case. Add PL to level of plate opening. Semiannually, drain and refill with PL. Drain only after operation. Fill to level of plate opening. (Some models) Fill through fill plug to level plug opening. Drain through drain plug located in bottom of case.
10. OIL FILTER—Every 6,000 miles, while crankcase is being drained, remove element, clean inside of case, install new element.
11. STARTER—When starter is removed, lubricate outer bearing through oiler with OE. Remove plug in top of reduction gear housing and fill with CG. Replace plug.
12. TURRET RING GEAR AND PINION—Apply lubricant through handhole plate opening in side of base ring to pinion and as much of the ring gear as can be reached. Monthly, clean ring gear and pinion and relubricate.
13. UNIVERSAL JOINTS (Front Wheels)—Remove inspection plugs. Fill through rear plug hole until lubricant is level with opposite hole. Do not overfill. Every 6,000 miles, remove, clean, inspect and replace universal joints. Remove plug in spindle, insert fitting and inject 1 pound CG. Replace plugs. Refill universal joint housings.
14. WINCH CABLE—After each use, clean and oil with OE. Semiannually, if cable is not generally used, unwind entire cable and soak by means of a brush with PL-Special. Wipe off excess and coat cable with CW. Coat winch drum also with CW before rewinding cable on drum.
15. OIL CAN POINTS (Carrier)—Every 1,000 miles lubricate Throttle Rod Ends, Clevises, Hinges, Latches, Vacuum Cylinder Valve and Power Lever Linkage, Disc Brake Control Linkage (when equipped with Bumper Rollers, Bumper Roller Slides and Bushings), Pintle with OE. (Gun) Weekly, lubricate Azimuth and Elevation Control Lever Gears, Control Lever and Shifter Lever Linkage, Elevation Limit Linkage, Gun Battery and Solenoid Latches, Armor Door Hinges with PL.
16. DO NOT LUBRICATE—Springs, Shock Absorber Links, Water Pump, Fan, Bogie Wheel Suspension Linkage and Slides, Bumper Roller Bearings when so equipped.
17. DISASSEMBLED FOR LUBRICATION BY ORDNANCE PERSONNEL—(Gun) Torque Tube Gear Box, Motor Unit Cases, Azimuth and Elevation Gear Box Cases.

Copy of this Lubrication Order will remain with the equipment at all times; instructions contained herein are mandatory and supersede all conflicting lubrication instructions dated prior to the date of this Lubrication Order.

BY ORDER OF THE SECRETARY OF THE ARMY:

OMAR N. BRADLEY
Chief of Staff, United States Army

OFFICIAL:
EDWARD F. WITSELL,
Major General,
The Adjutant General.

LO 9-710-5

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RA PD 113853

Figure 32. Lubrication order—back (sample).

Section VII

AUTOMOTIVE MATÉRIEL—ENGINE LUBRICATING SYSTEMS AND GAGES

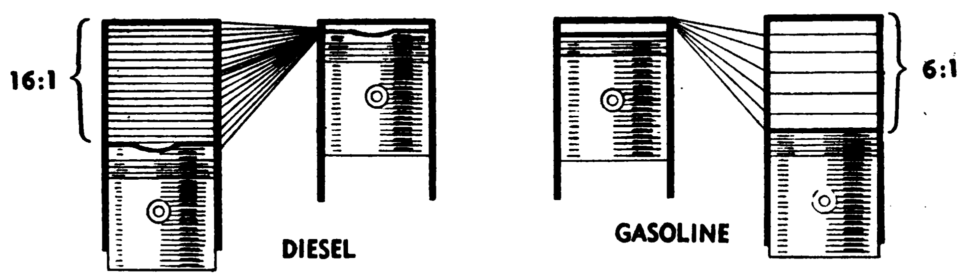
33. Principles of Internal Combustion Engine Lubrication

a. General. An internal combustion engine is one which obtains its power by the combustion of fuel in a confined space—its cylinders. The energy of the fuel is converted by combustion into heat, and the heat energy is in turn converted by the engine into mechanical energy. The useful energy obtained from most modern internal combustion engines is only about 25 to 35 percent of the energy of the fuel. This means that the other 65 to 75 percent, most of which is in the form of heat, has to be dissipated or removed from the engine to prevent excessive overheating. The problem of the dispersal of excess heat is of the utmost importance and probably has more effect on lubricants and lubrication than any other item involved. The lubrication of surfaces exposed to combustion is difficult and lubrication is one point that cannot be sacrificed to any extent if dependability is desired.

b. Heat Dispersion. Lubrication is directly tied in with the method used for cooling an engine or dissipating the waste heat. While most engines used in automotive matériel eventually waste unused heat into the air, they are commonly referred to as liquid- or air-cooled, depending upon the medium actually in contact with the outside of the cylinder walls. In liquid-cooling, the waste heat is absorbed by the liquid and then dissipated or wasted to the air by passing the heated liquid through a radiator. Air-cooled engines generally operate with higher cylinder temperatures than liquid-cooled, and this may necessitate differences in both lubricant and lubricating methods. At operating temperatures, there may be a greater variation in the temperatures of air used for cooling than there is in the temperature of liquid used for cooling, and this also may necessitate differences in both lubricant and lubricating methods.

c. Oxidization Problem. The lubricant must be of such quality as to resist undue oxidation or burning with the consequent loss of lubrication and seizure of piston rings, etc. It is obvious also that to confirm high compression and resulting high explosion pressure and to prevent the lubricant from being blown from the piston and cylinder walls requires closer fits, more or better fitted piston rings, etc., with a corresponding increase in the difficulties of maintaining sufficient lubrication. The lubricant must be able not only to lubricate the various bearing surfaces properly over a considerable range of temperature and pressure, but must resist oxidation or other deteriorating influences when subjected to the flame of combustion, and must serve also as an agent for transferring heat from one part to another.

d. Compression Ratios. One method of increasing the power delivered by a given size of cylinder is to increase the compression ratio, which is the ratio of the total volume of a cylinder with the piston at the bottom end of its stroke to the volume of the cylinder with the piston at the top end of its stroke (fig. 33). Increasing the compression ratio increases the compression pressure and temperature, which in turn increase the pressure and temperature resulting from combustion,



The compression ratio of Diesel engines may be as high as 22 to 1. The temperature of air so compressed is about 1000° F. Thus, when fuel is injected into such highly compressed air, combustion immediately occurs.

The compression ratio of gasoline engines may be as high as 8 to 1. The temperature of the air-fuel mixture so compressed is not high enough to cause ignition; thus, either a spark or some other method of introducing ignition is required.

RA PD 85960

Figure 33. Compression ratios in Diesel and gasoline engines.

and these factors have a decided effect upon lubrication. Depending on the type of engine and the fuel used, compression ratios may vary from about 4 to 1 to 22 to 1. Engines using spark ignition and gasoline use compression ratios from 4 or 8 to 1, semi-Diesel engines with auxiliary ignition use ratios up to about 12 or 14 to 1, and full-Diesel engines with ignition from the heat of compression use ratios up to about 22 to 1. When compression temperatures become sufficient to cause ignition (as in a Diesel), the resulting combustion temperatures are correspondingly high and the difficulty of keeping a film of lubricant on the cylinder wall is increased greatly.

34. Lubricating Systems

a. General. At the present time, most of the internal combustion engines used in automotive matériel 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*, *c*, *d*, and *e* below.

b. Splash Lubricating System. Splash lubrication is the simplest system commonly used for the distribution of lubricating oil to the various bearings (figs. 34 and 35). The moving parts of the mechanism (generally the connecting rods) dip into or strike the oil and

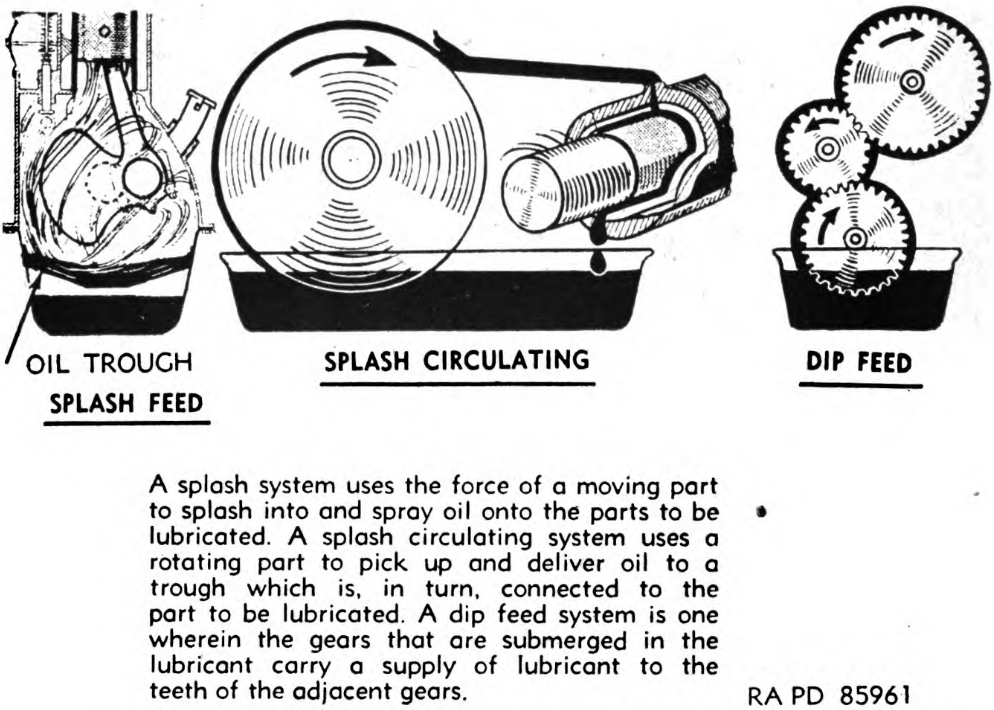


Figure 34. Splash and dip methods of oil distribution.

splash it onto 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 (fig. 35). 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.

c. Dip Lubricating System. In dip lubrication (fig. 34), some rotating part, such as a gear or wheel, is partially submerged in oil, and the oil adhering to it as it rotates 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, the other sys-

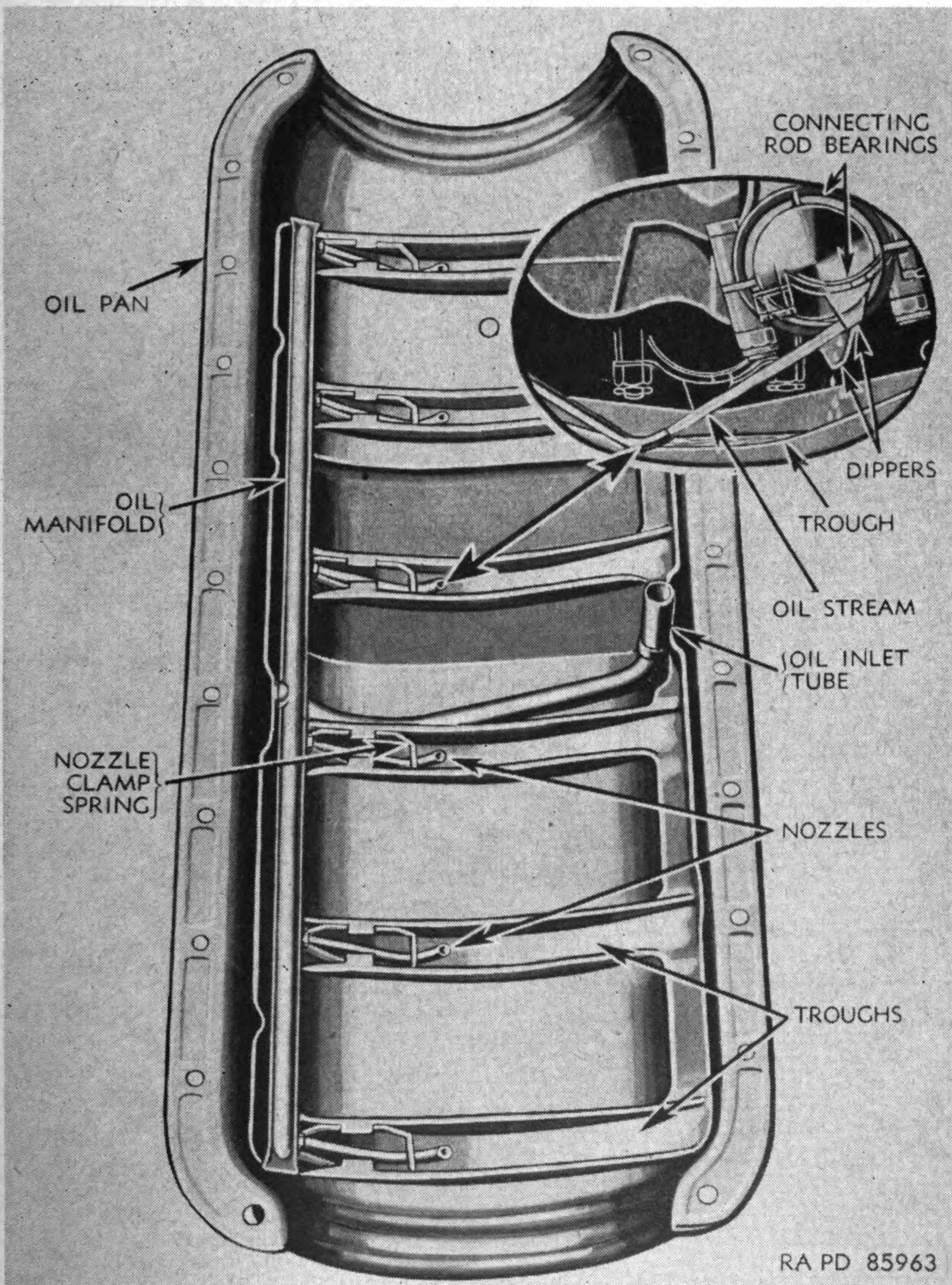


Figure 35. Combined splash and pressure lubrication of crankpin and connecting rod bearings.

tems being used to maintain the level of the oil into which the rotating part dips.

d. Gravity Circulation Lubrication. The gravity circulation system (fig. 36) 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

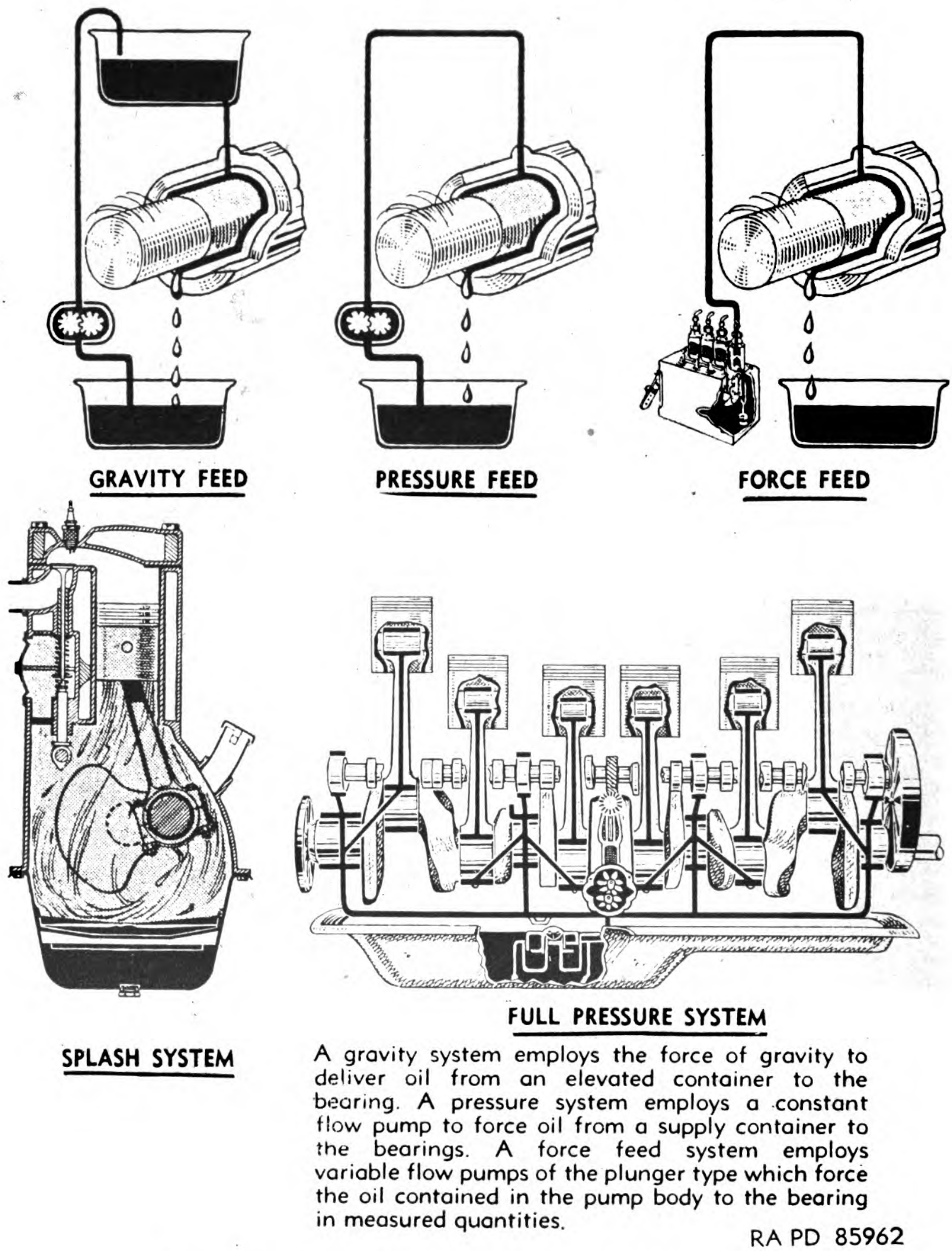


Figure 36. Various types of oil distribution systems.

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 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. A wet sump cannot be used in radial, X, or engines in which one or more cylinders are located below the centerline of the crankshaft, because the unused oil would drain into the lower cylinders and cause overlubrication, hydrostatic lock, or other troubles. Such engines use the dry sump system in which any unused oil collecting in the crankcase is returned to the oil reservoir by an auxiliary or sump pump. From the reservoir, the oil again is pumped to the lubrication points by the regular lubricating oil pump.

35. Oil Pumps

a. General. The gear pump, the vane pump, and the plunger pump are three general types of pumps in common use on automotive matériel (fig. 37). 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 either with a bypass or pressure relief valve as shown in the gear pump,

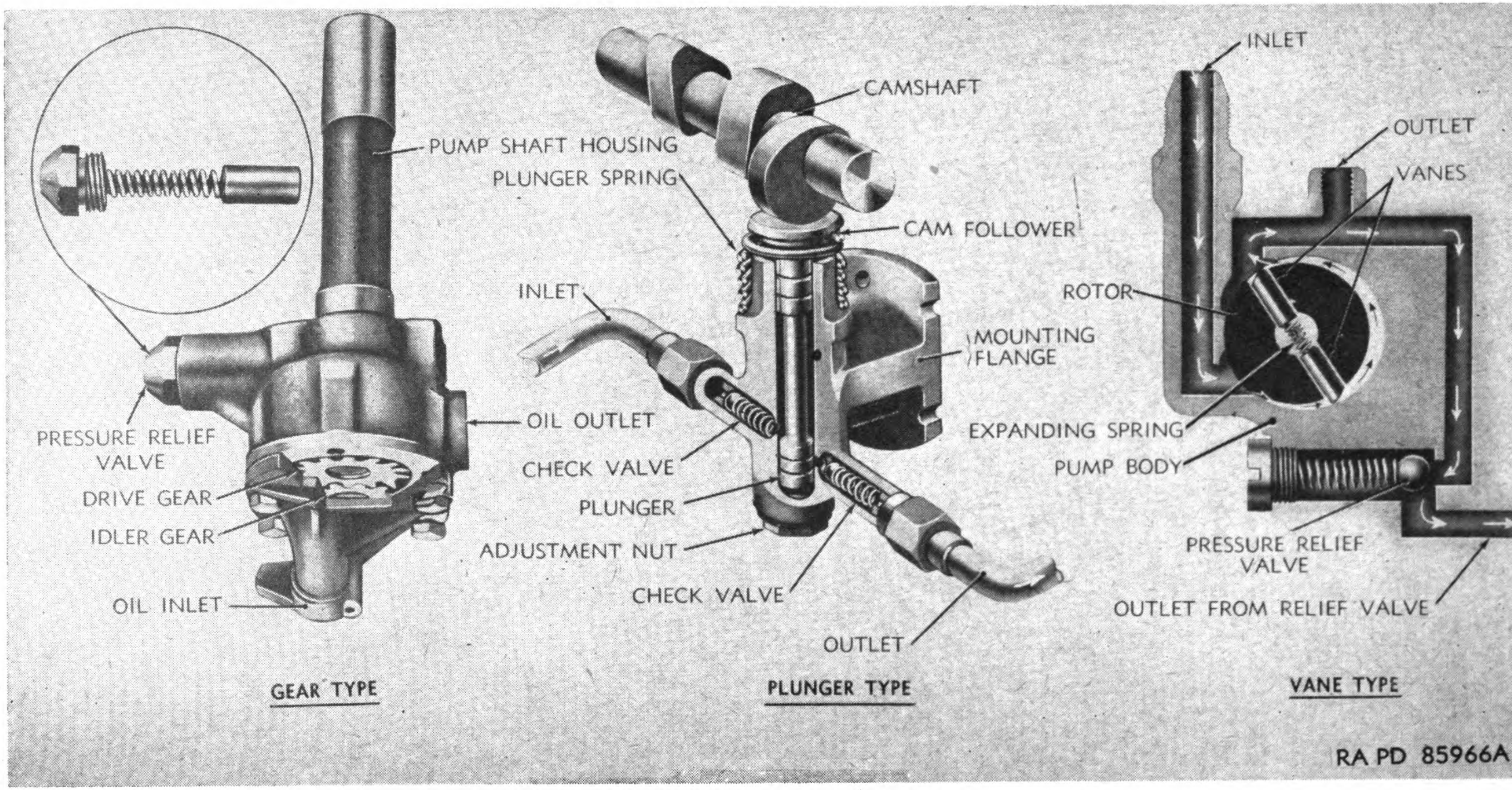


Figure 37. Various types of oil pumps.

or one is provided in the oil line (fig. 37). 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. 37) 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 wtih 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. 37) 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. 37) 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 by pumping oil from the oil pan to the oil troughs.

36. Oil Level Indicators

The dip stick is the simplest and most common method of determining the amount of oil in a crankcase or reservoir. The dip stick (fig. 38) consists of a graduated rod which is suspended into the oil pan or reservoir. In order to obtain a clear reading, the dip stick should be withdrawn, wiped off, reinserted carefully, and again withdrawn. A correct reading cannot be obtained if a dip stick 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.

37. Pressure Gages

A pressure gage (fig. 39) 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 ac-

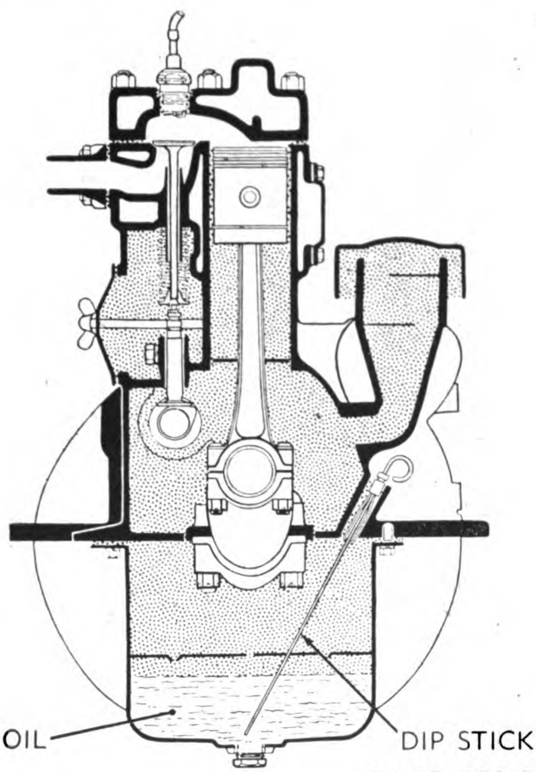


Figure 38. Dip stick.

tuated by the pressure of the air trapped above the oil in a very small tube connecting the gage to the lubricating system. 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.

38. 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 crackcase oil. As the temperature of the oil increases, the fluid vaporizes and the pressure operates a gage calibrated for temperature on the instrument panel.

39. Oil Filtering Devices

a. Screens and Strainers. In most engines a fine mesh bronze screen is located in the lubrication system so that all oil must pass

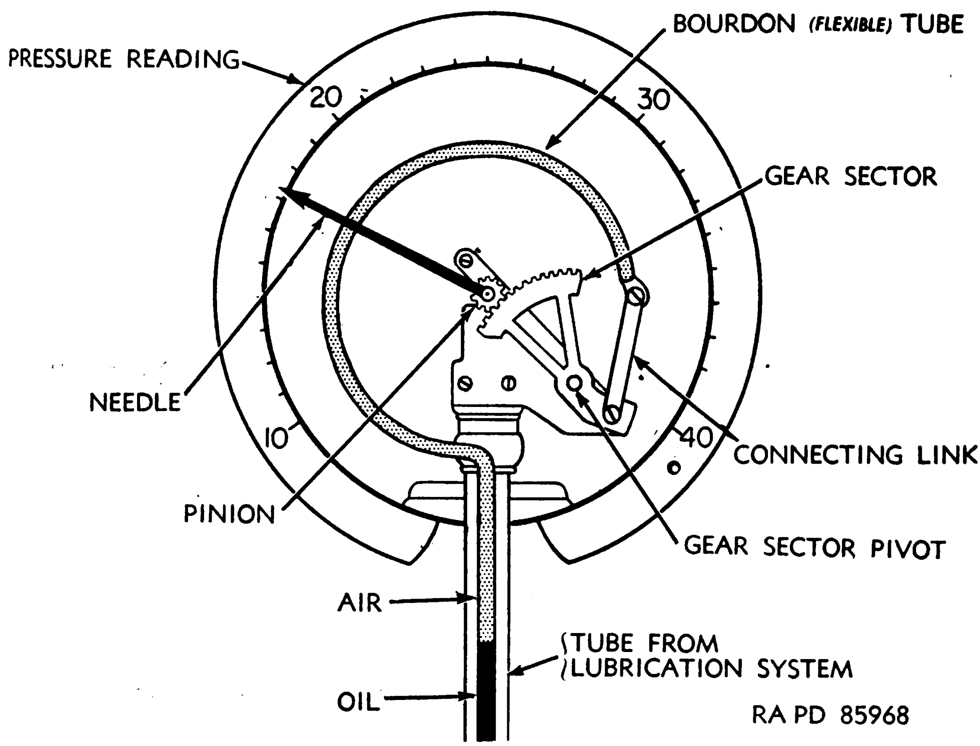


Figure 39. Construction of a pressure gage.

through it before it enters the oil pump. In some cases the strainer is attached to the bottom of an air tight bulb or float that rides on top of the oil so that all oil taken into the pump comes from the surface of the oil in the oil pan. Ordinarily it is not necessary to clean screens or strainers except when the engine oil pan is removed.

b. Filters. Practically all automotive engines are equipped with some form of oil cleaning device or oil filter. Oil filters may be divided into three general types—first, those which must be completely replaced when dirty; second, those which have removable elements (fig. 40) that can be replaced as required; and third, those made from metal disks (fig. 41) and provided with either hand-operated or automatic cleaning devices. Filters which must be replaced completely are of similar construction except that the filtering element is sealed in a light metal case and complete unit must be changed. Most of the oil filters today are known as the bypass type and filter only a portion of the total volume of oil passing through the lubricating system at any given time. The so-called full-flow type are not as widely used, because the entire oil supply must pass through them and they must be

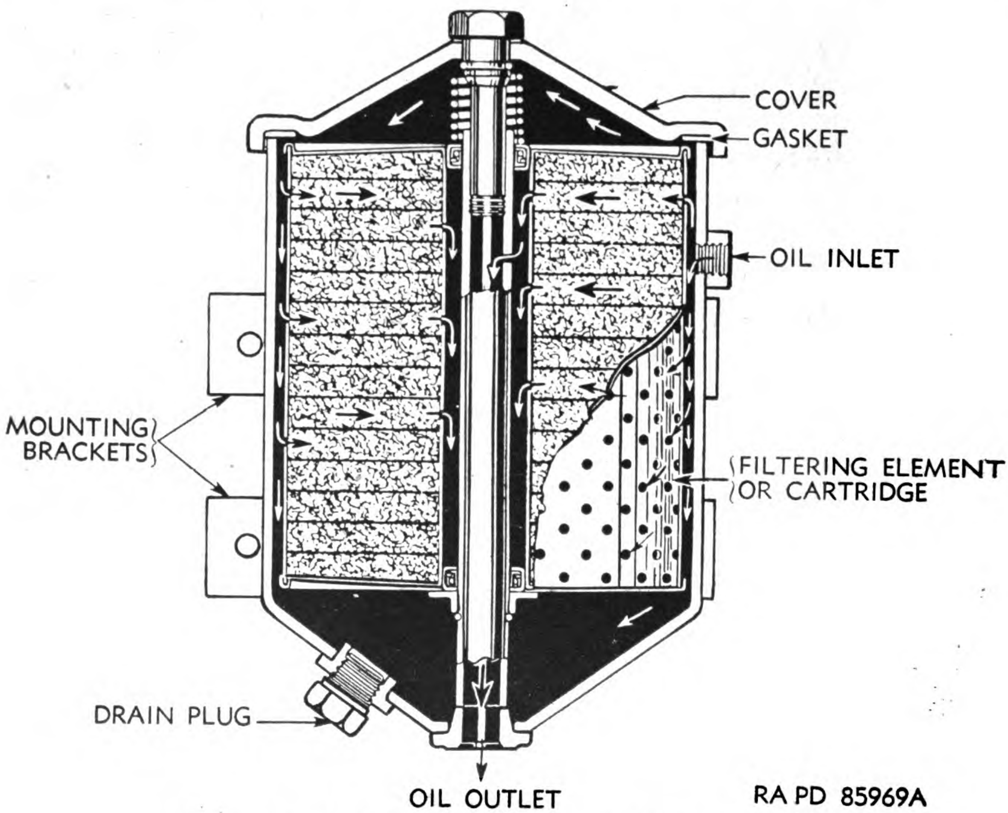


Figure 40. Oil filter with removable filtering element.

large and bulky to handle the volume of oil circulated through an engine. Further, if a full-flow filter becomes clogged, the entire oil flow to the engine is interrupted.

c. Filtering Elements. Filtering elements of the first two types of filters generally consist of an assembly of metallic wire screen, cotton waste or fiber, felt, rock wool, clay, or other filtering material. As the oil passes through the filtering material, the dirt and sludge is removed. The filtering elements gradually accumulate dirt and become less and less efficient and should be replaced at intervals as specified in pertinent lubrication orders. The filtering element of a disk-type filter

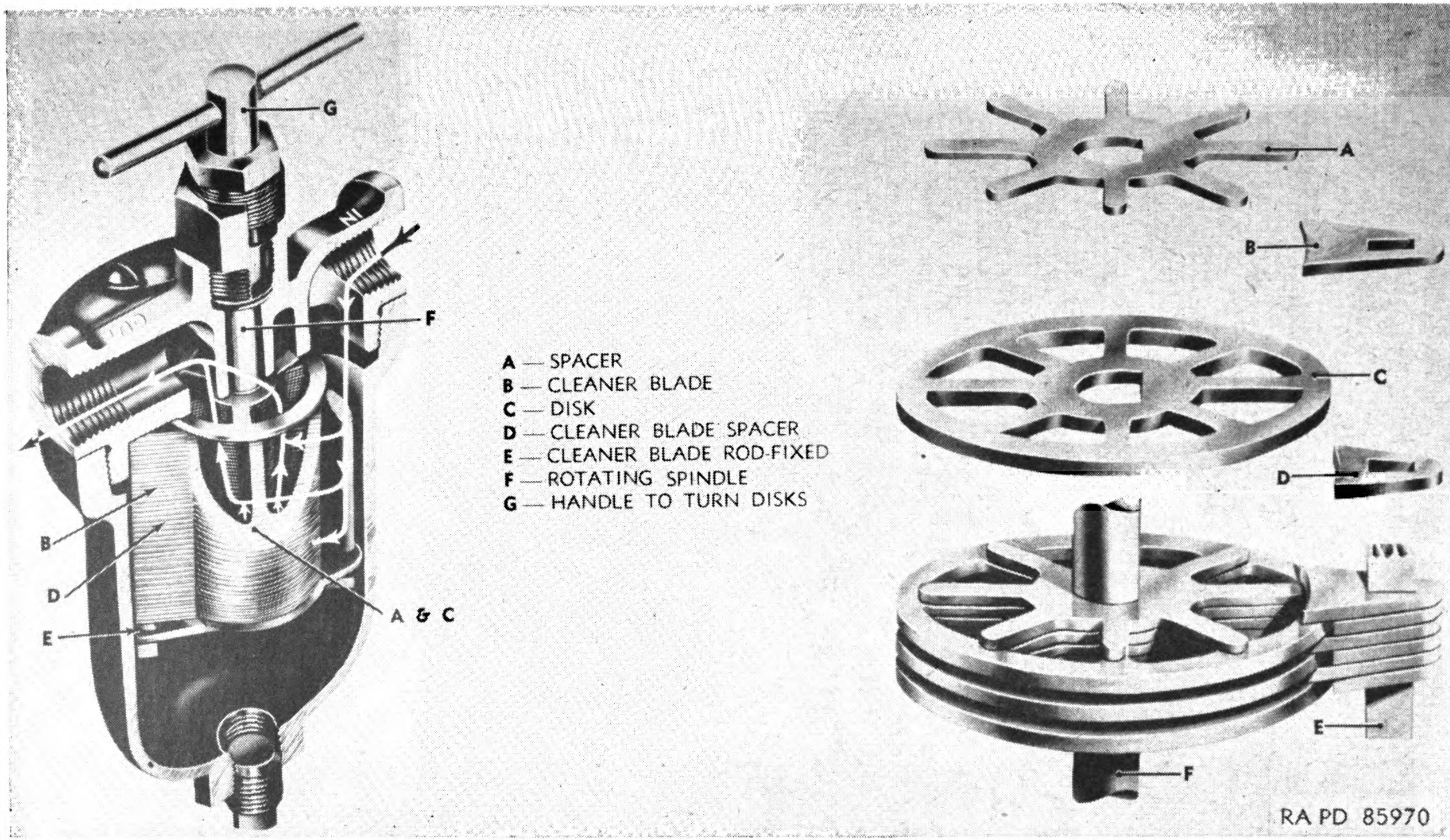


Figure 41. Disk-type oil filter.

consists of a series or pile of thin steel filtering disks and spacers alternately assembled upon a spindle. The oil enters the outside casing, passes through the minute spaces between the filtering disks into the inside perforations, and passes out of the filter through the outlet connection. Any sizeable pieces of dirt drop to the bottom of the outside casing, while smaller solids stick on the outside edges or between the filter disks. The spindle (fig. 41) may be turned by rotating the handle or automatically by a small oil motor incorporated in the head of the filter. Cleaner blades, which fit between the cleaner disks, are mounted on stationary cleaner blade rods. When the filter disk assembly is turned, the disks pass between the cleaner blades, and the spaces between the disks as well as the edges of the disks are cleaned of dirt which falls to the bottom of the casing. At intervals, as directed in pertinent lubrication orders, the drain plug should be removed and the sediment drained.

d. Replacement of Filter Elements. 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 matériel should be followed. Prescribed periodic filter service includes checking the oil filter connecting lines for clogging, draining accumulated sediment, 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 the 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 dirty fluid in the same length of time than will a coarse strainer.

e. Oil Coolers. Due to engine location in some vehicles the normal cooling air flow is restricted, resulting in excessive oil temperatures. To correct this condition oil coolers, resembling a radiator, consisting of multiple tube passages through which hot engine oil is pumped and

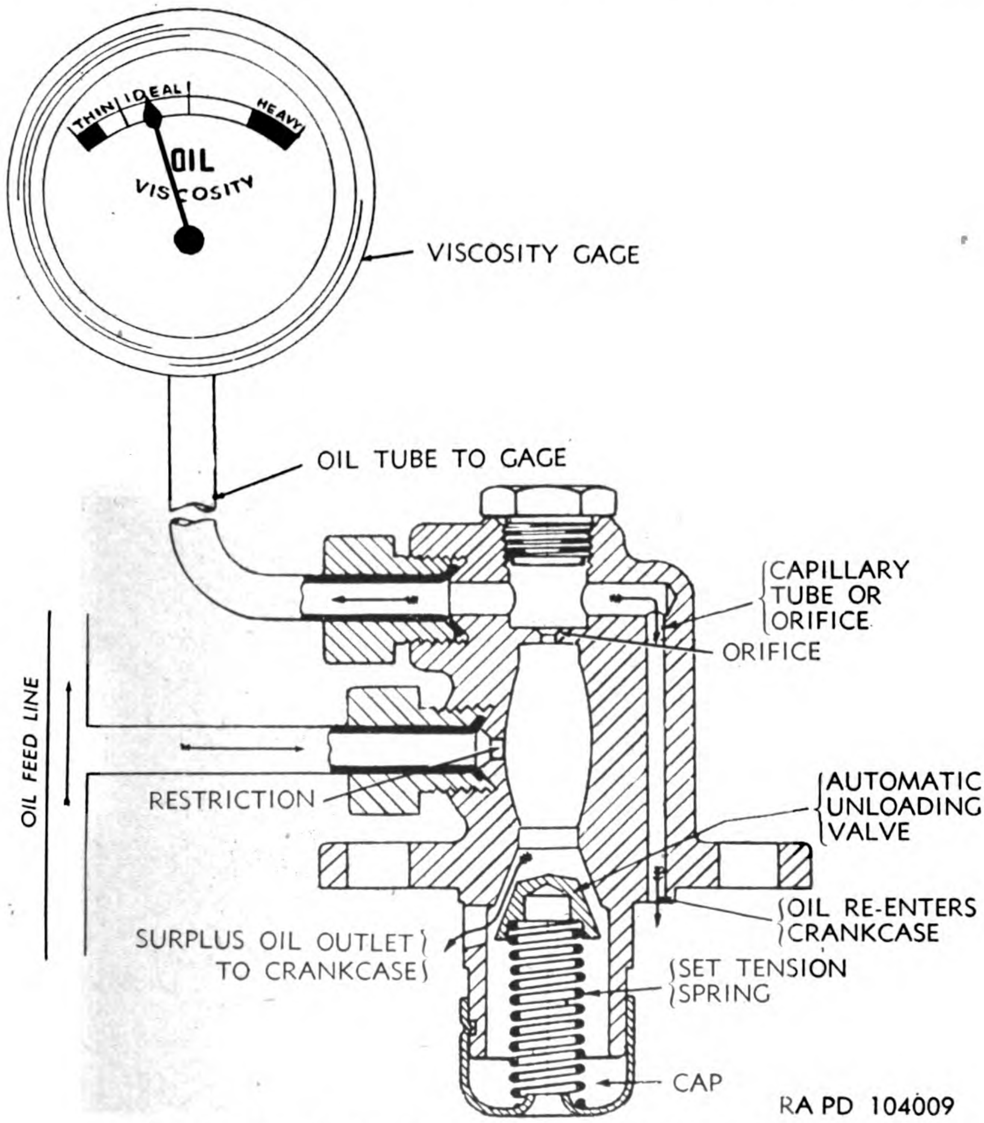


Figure 42. Schematic section of an oil viscosity gage.

cooled are supplied. This cooling action is necessary since engine oil acts as a coolant for bearings, crankpins, etc., as well as a lubricant.

f. Oil Viscosity Gages. Heavy-duty vehicles may be equipped with an oil viscosity gage graduated to read thin, ideal, or heavy rather than the actual viscosity of the oil in seconds. Such an instrument (Fig. 42) is attached to the main oil feed line, a restriction limiting the amount of oil withdrawn. Oil passing the restriction enters a chamber held at a constant pressure by an automatic unloading valve. Under the pressure, oil passes through an orifice into a second chamber and then to the crankcase through a second and smaller orifice or capillary tube. As viscosity of the oil changes, the pressure in the second chamber is changed. This pressure is shown on a pressure gage calibrated to indicate thin, ideal, and heavy oil.

g. CRANKCASE VENTILATORS. Because of the wide range of conditions under which an automotive engine must operate, the vapors in the crankcase often accumulate harmful contaminating materials such

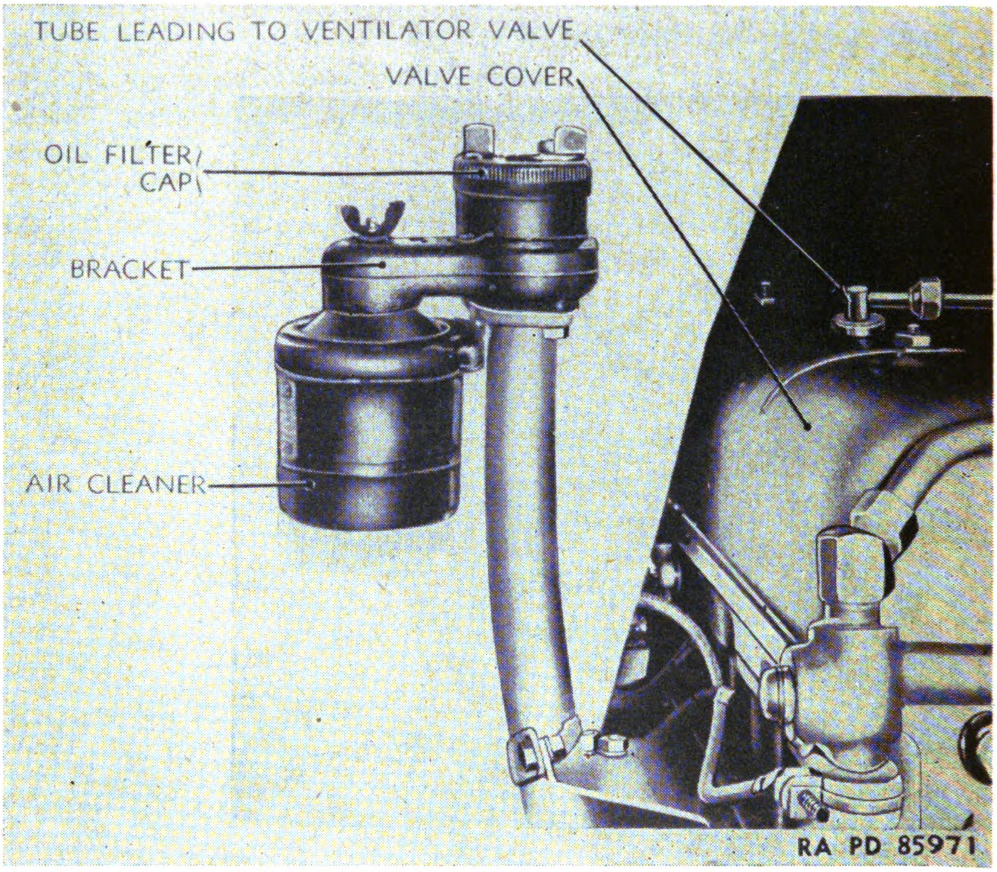


Figure 43. Air cleaner on crankcase ventilator and oil filling tube.

as dust, dirt, water vapor, fuel vapor, etc. Water from the blow-by gases of combustion or from condensation will mix with the oil and accelerate low temperature sludge formation. Unburned fuel will condense and dilute the oil. To get rid of these contaminants, most engine crankcases are provided with air inlet and outlet ports, the latter generally being so made that air blowing by creates a suction which causes a flow of air through the crankcase. Some engines use the oil filler pipe as the air inlet, and the outlet is often a tube connected to the rear valve cover plate. The purpose and function of these ventilating systems are essentially the same, but the mechanical devices and principles employed may vary somewhat in detail. Due to the dusty conditions under which most Army vehicles operate, the crankcase inlets customarily are equipped with air cleaners (fig. 43). These cleaners are similar in construction to those used for cleaning the air for combustion and are described in paragraph 41. Vehicles used on short runs, particularly in cold weather, seldom are warmed up to the proper operating temperature, with the result that vapors of combustion blown by the piston strike the cool parts in the crankcase and condense before being drawn from the crankcase. This water (for every pound of gasoline burned a little over a pound of water is formed in the cylinders) starts corrosion and rust and eventually leads to the formation of sludge. To remove this vapor before it condenses, the crankcase or the top of the valve cover sometimes is connected to the intake manifold by a ventilator valve and necessary tubing. This ventilator valve controls the volume sucked out of the crankcase into the manifold according to the speed of the engine and consequently the amount of blow-by. When the engine is idling and the vacuum in the manifold is strongest, the valve stays nearly closed and only a small volume is pulled by the valve into the manifold. As the throttle is opened, and the blow-by increases, the vacuum in the manifold decreases, opening the valve and drawing a large volume by the valve into the manifold. The installation (fig. 43) shows the connection leading to the ventilator valve from the top of the valve cover.

40. Crankcase Lubrication

a. Drain Intervals. Crankcase drain intervals for engines are prescribed by current 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 reinstall 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, speed engine to a fast idle and hold for 1 minute. 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 condition.

(6) Fill crankcase with the prescribed oil. Refer to applicable technical manual or lubrication order for crankcase capacity.

41. Lubrication of Other Engine Units and Accessories

a. 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 on the cylinders with resulting abrasive action on cylinder walls, pistons, and other parts. Air cleaners are of two basic types; namely,

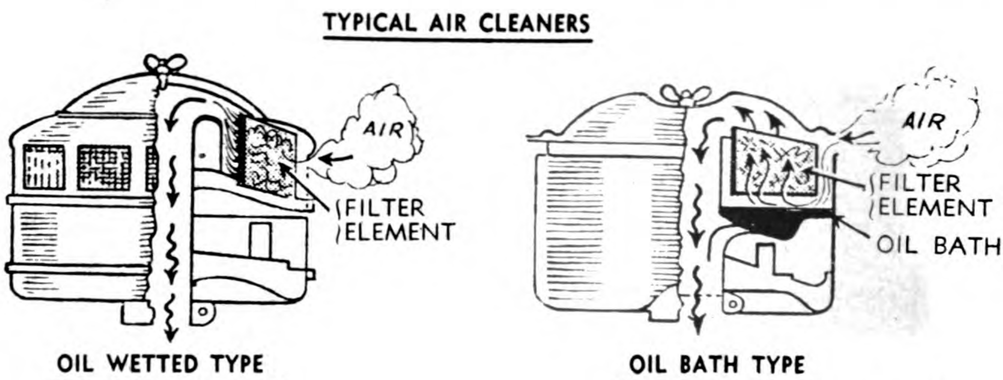


Figure 44. Air cleaners showing the two methods of operation.

the oil-bath and the oil-wetted types (fig. 44). In the former, 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 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. In the oil-wetted types, the filter is dipped in oil and the dust in the air is picked up by it. Oil-wetted filters must be cleaned and freshly oiled more frequently than the oil-bath type. If the unit is of the oil-wetted type, it is disassembled and both the container and the filter washed in dry-cleaning solvent. Then, the filter is dipped in oil and drained, replaced, and the unit assembled. In the oil bath type, the dirty oil is discarded and, after the container or the filter is carefully washed, the proper quantity of new or used crankcase oil is put in and the unit reassembled.

b. COOLANT PUMPS AND FANS. Various methods of construction and lubrication for water pumps (fig. 45) have been used. The most common type incorporates a shaft running on ball bearings which are sealed in grease and require no lubrication during their life. Water pumps are sealed against liquid leakage by spring-loaded seals having longitudinal contact between metal and some such material as synthetic rubber, fiber, carbon, etc. The spring-loading keeps a contant pressure on the surfaces of the seal and prevents fluid leakage. Lubrication orders or technical manuals must be consulted for specific lubrication instructions for pumps. Generally where the lubricant comes in contact with the liquid, a water-pump grease should be used. For spring-loaded seals, the lubricant must not have too heavy a body or the sealing elements may be held apart with resulting leakages. Fans which are not mounted on water-pump shafts are oil lubricated.

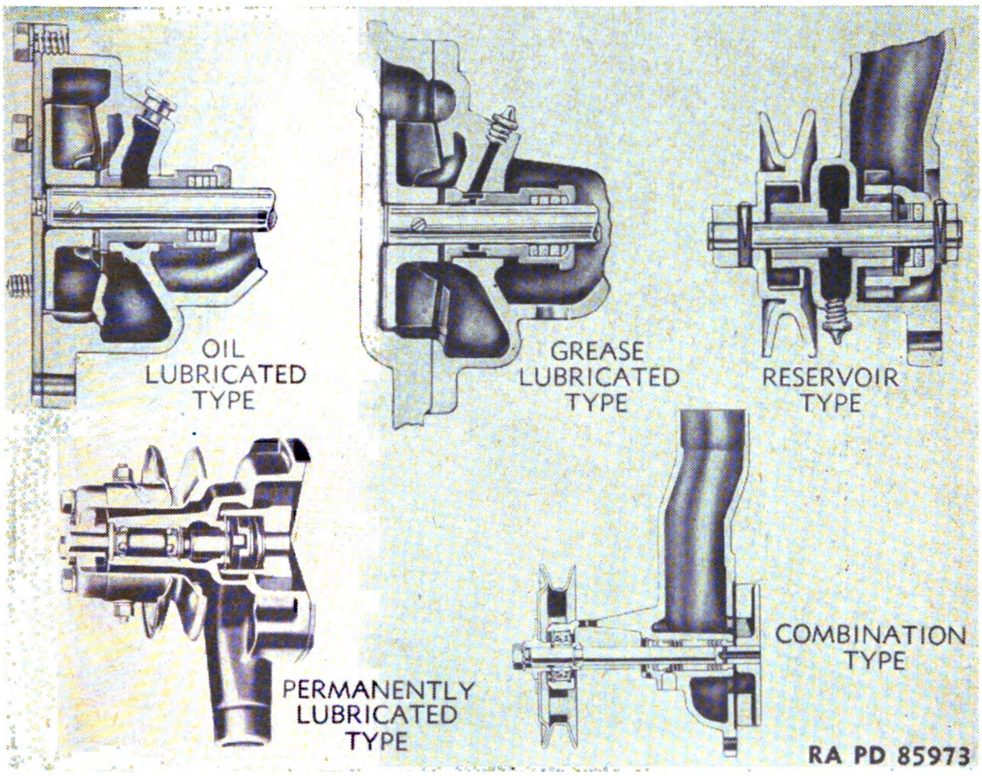


Figure 45. Various types of water pumps.

c. STARTERS, GENERATORS, DISTRIBUTORS, AND MAGNETOS. Starters, generators, distributors, and magnetos must be lubricated according to current 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,

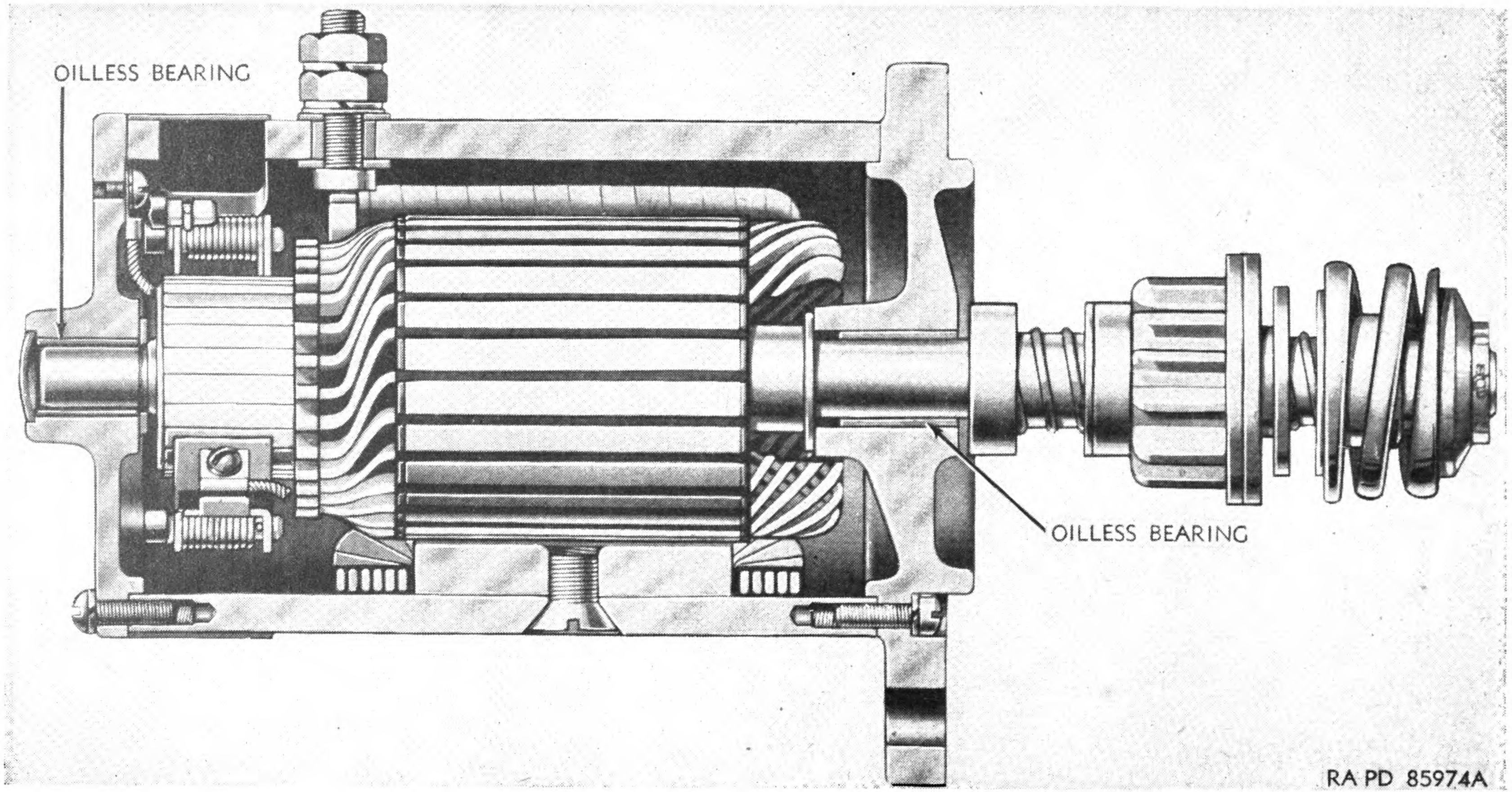


Figure 46. Cross section of typical starter.

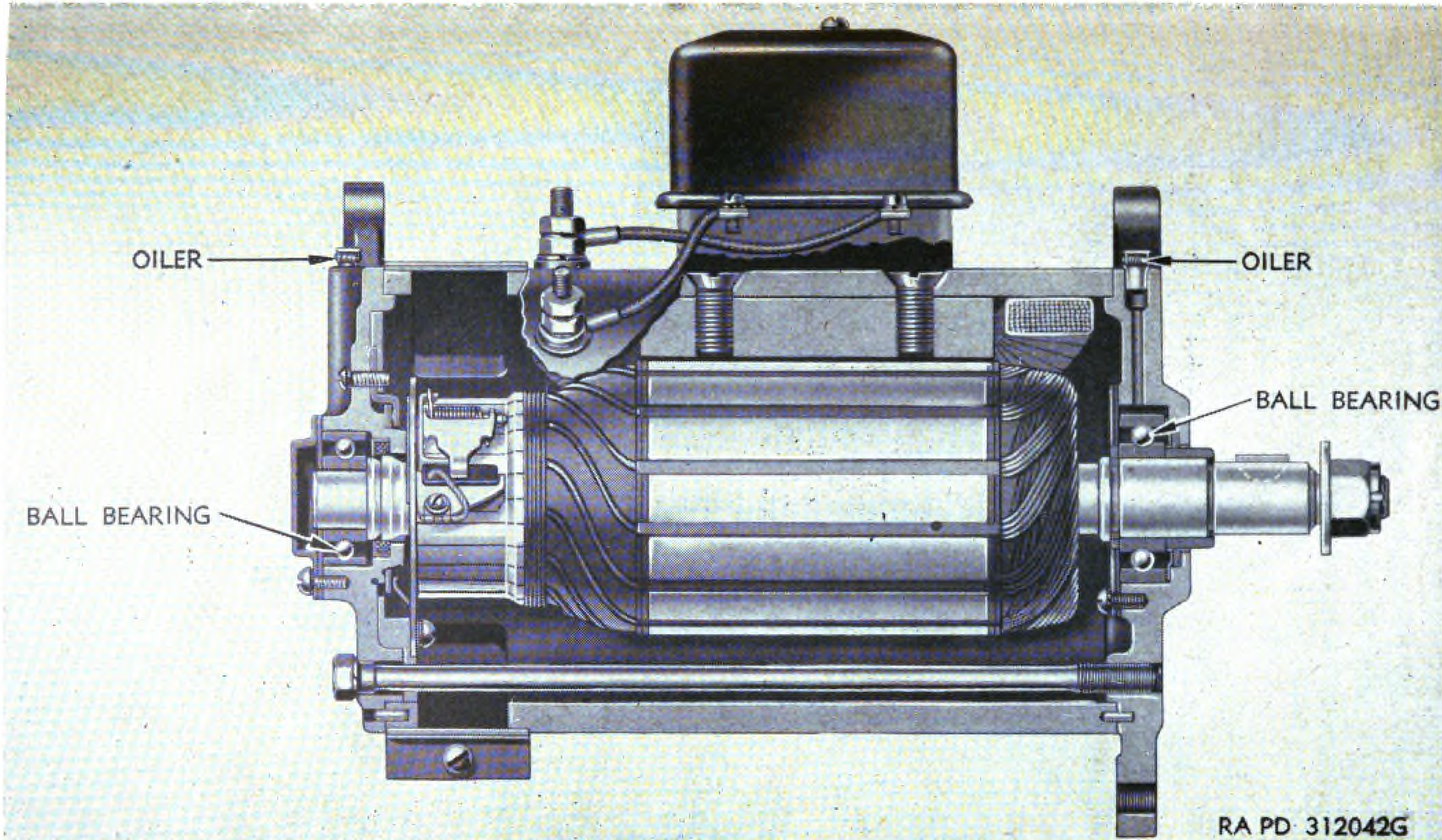


Figure 47. Cross section of typical generator.

etc., which would cause insulation deterioration, short circuits, excessive arcing or sparking at brushes, etc.

(1) *Starters.* Starters (fig. 46) operate only intermittently and then only for short periods. They generally are 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

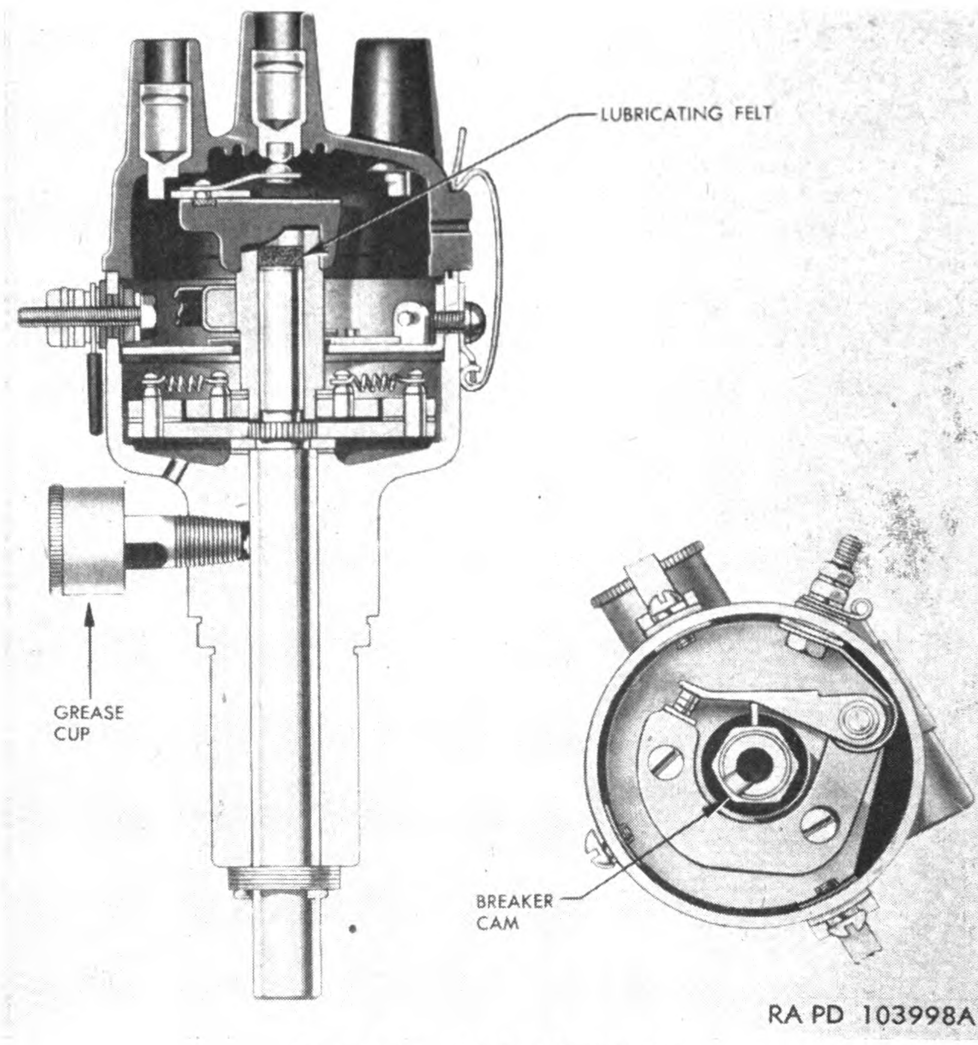


Figure 48. Typical distributor.

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.

(2) *Generators.* There are two common types of bearing arrangements in generators (fig. 47)—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 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. Overlubrication must be guarded against.

(3) *Distributors.* Distributors (fig. 48) commonly use plain bronze bearings lubricated by a single grease cup. 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 current pertinent lubrication orders or technical manuals.

(4) *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.

d. 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.

e. AIR COMPRESSORS. Since air compressors (fig. 49) tend to collect oil contaminants from the engine lubrication system, the effects of insufficient maintenance of engine oil first become evident in the compressor. Lubrication of a compressor is generally by the pressure circulation system, and the lubrication of the various parts closely parallels the lubrication of similar engine parts. The lubrication system may be complete in itself for the compressor or may be a part of the engine lubrication system. Ball bearings generally are used on the crankshaft, while the rest of the bearings are friction type. Lubrication of pistons, cylinders, and valves in an internal combustion engine differs from the lubricator of those in an air compressor in that oil on the surfaces requiring lubrication is not subjected to the flames of combustion, and oil consumption may be appreciably less.

While a compressor must receive sufficient lubrication, overlubrication is not desirable because lubricating oil will be carried over into the reservoir and, unless removed before being carried over into the brake operating mechanisms, may cause trouble.

f. Vacuum Pumps. Vacuum pumps (fig. 50) for brake operation are hardly engine accessories but, like air compressors, often are lubricated by the engine lubricating system and so are included in this

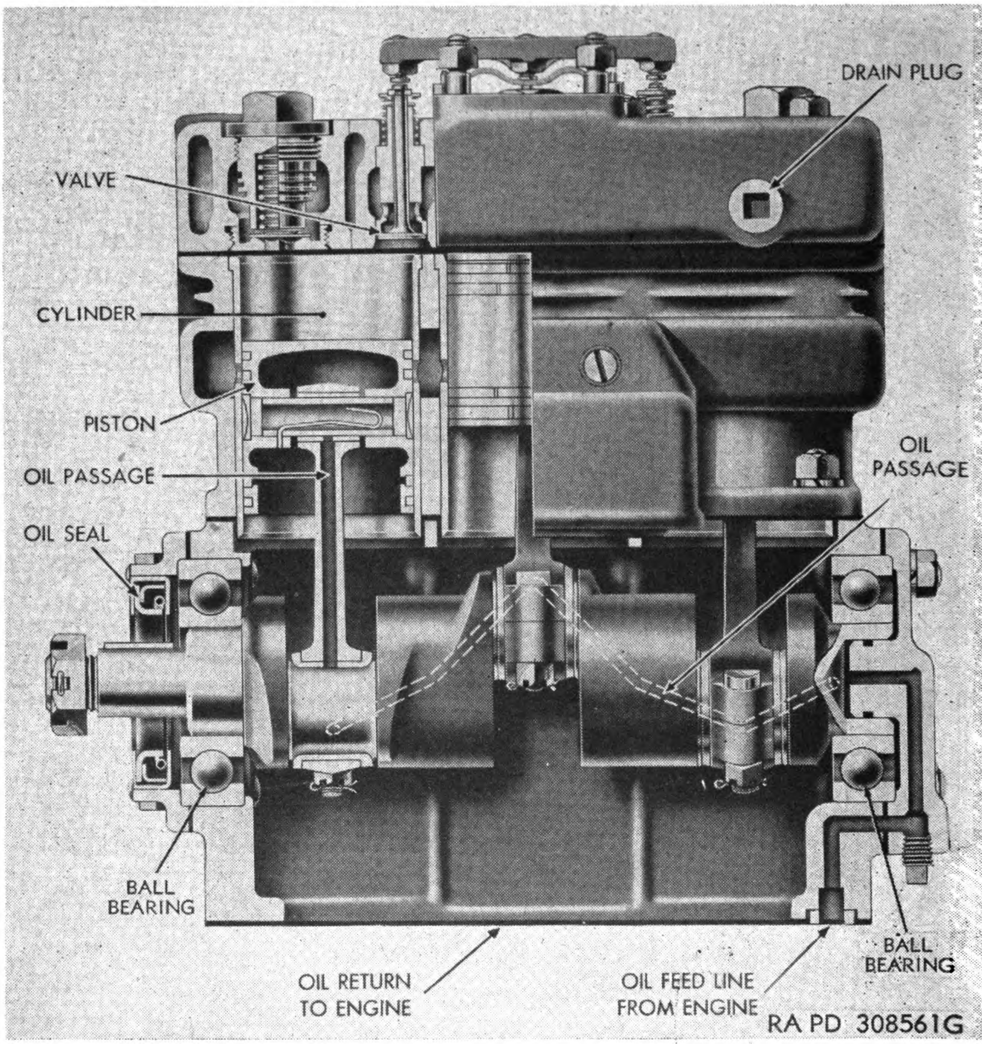


Figure 49. Three-cylinder, engine-lubricated air compressor.

section. The pumps are generally of the vane type, with three vanes, and are equipped with a ball bearing on the drive end and a plain friction-type bearing on the other end. Lubrication to both the bearings and the vanes is supplied by connections to the pressure circulation system of the engine.

g. Engine Controls, Linkages, etc. A number of controls, linkages, levers, rods, flexible wires, etc., always are found on any engine,

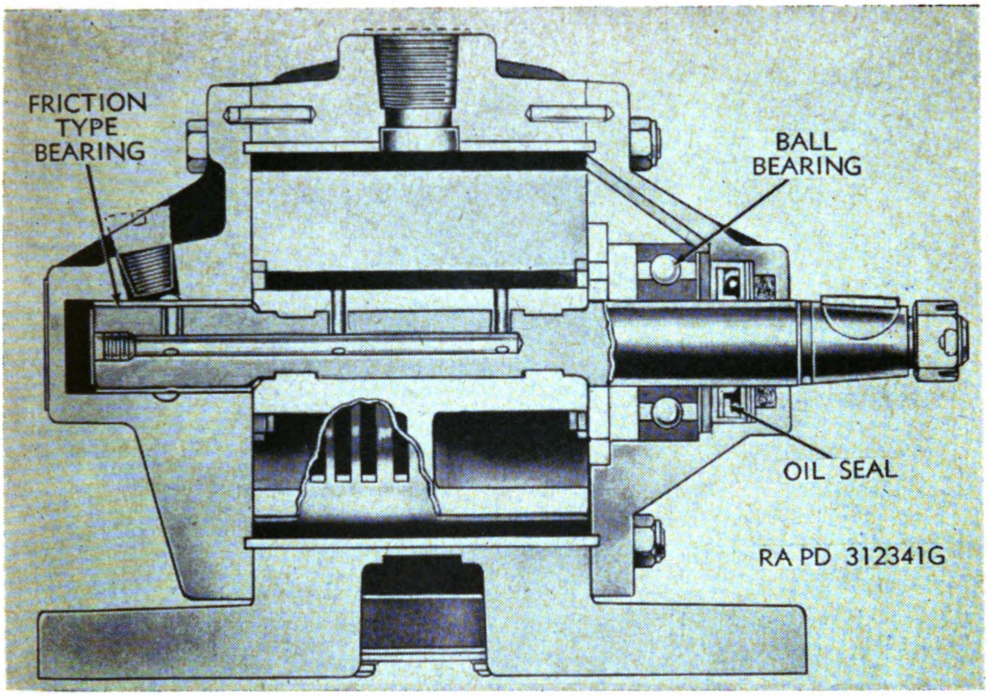


Figure 50. Section of vacuum pump.

and these have various connections where friction and consequent sticking can occur if the parts are not lubricated. Such parts must be lubricated with oil following instructions given in the current pertinent lubrication orders or technical manuals.

Section VIII

AUTOMOTIVE MATÉRIEL—DRIVING MECHANISMS

42. General

A driving mechanism is a mechanism through or by which power is transmitted in traveling from the engine to the vehicle wheels or tracks or to some driven accessory such as a winch, crane, or pump. These mechanisms fall according to function into the following classes: Clutches, transmissions, transfer cases, universal joints, driving gears, and differentials. The general arrangement of these driving mechanisms differ in various vehicles (figs. 51 and 52).

43. Clutches

A clutch is a mechanism the operation of which allows the driver of the vehicle to connect or disconnect the engine from the other units of the driving mechanism. A clutch, generally, is built onto one end of an engine and connects directly to one end of the crankshaft. There are two types of clutches that have had general use on automotive matériel—dry and fluid.

a. Dry Clutches. The dry clutch (fig. 53) is strictly a friction mechanism and requires no lubrication on its working surfaces. Lubrication is required, however, on the pilot bearing between the driving and driven shafts on the clutch-release bearing and on the yoke. The pilot bearing is only in operation at such times as the clutch is released and the disk is rotating at a different speed than the engine flywheel, and in consequence an oilless bushing generally is pressed into the flywheel or end of the crankshaft. When the clutch pedal is pushed and the clutch is out (disengaged), the force required to compress the clutch springs is transmitted through the clutch collar and the release bearing (generally of the ball type) which is designed to carry the thrust and the rotating load. A clutch release bearing of the ball type may require occasional lubrication but generally is packed with grease at disassembly of the clutch. Some clutch-release bearings are made of compositions of graphite, bronze, car-

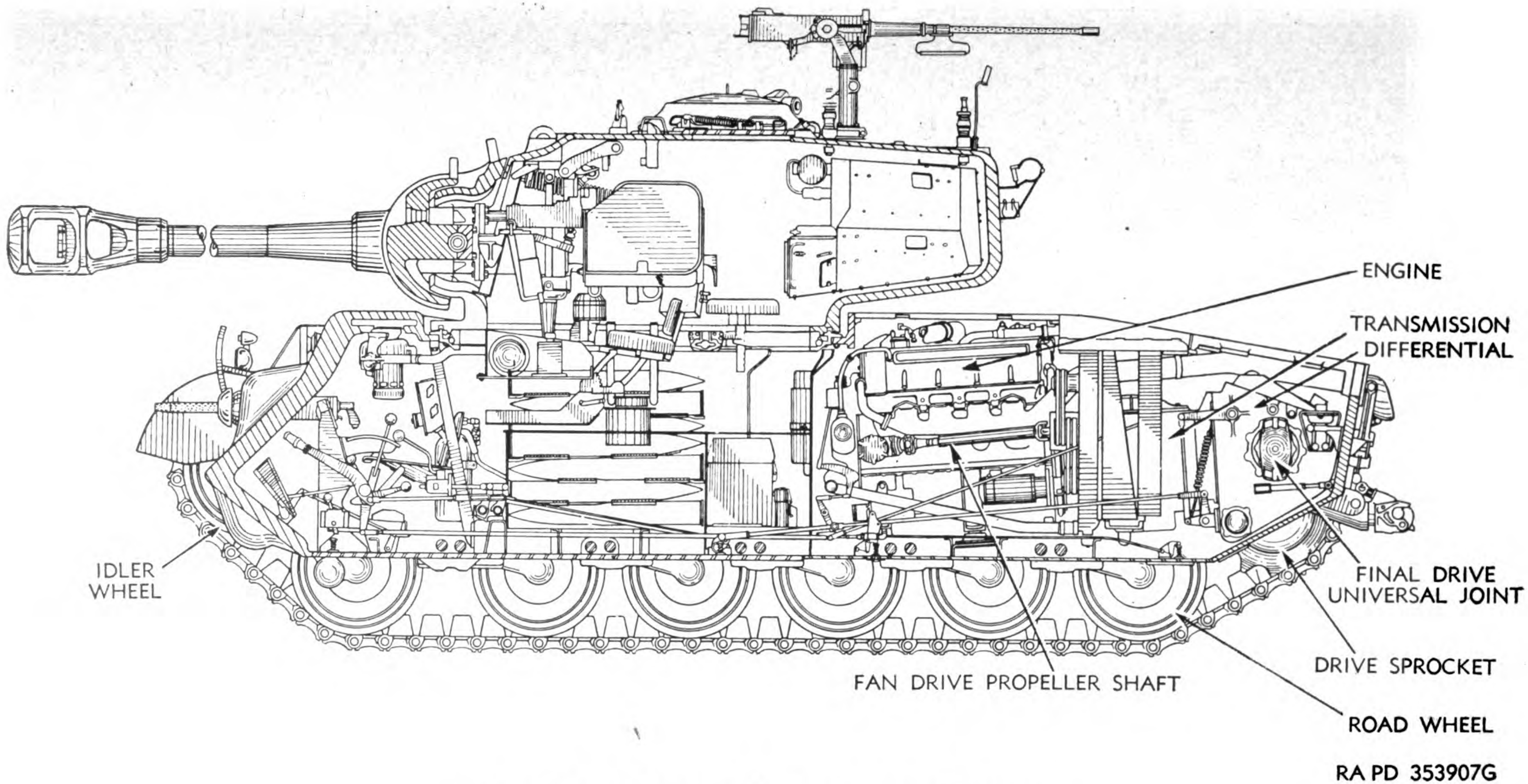


Figure 51. Driving mechanisms of a medium tank.

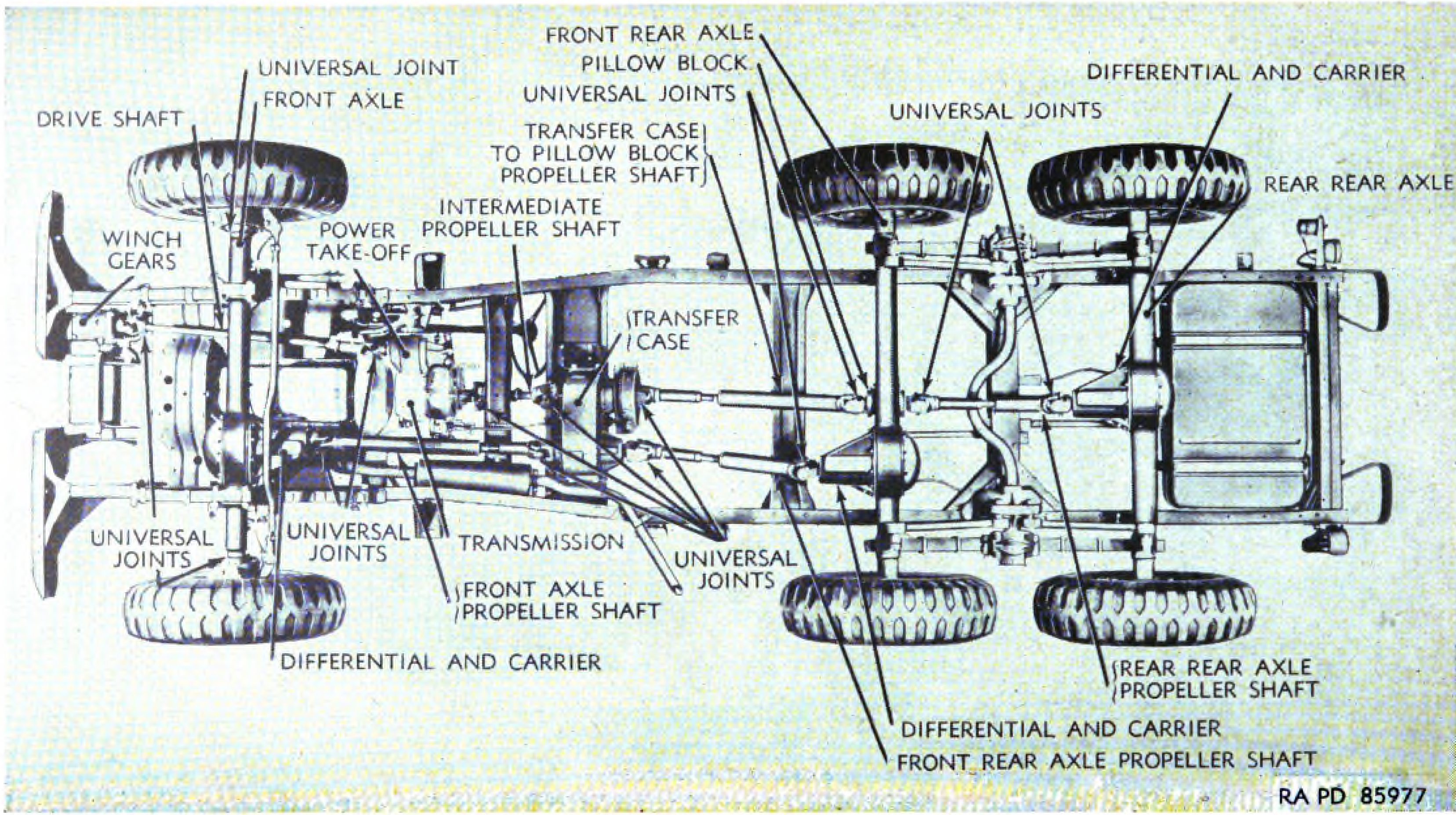


Figure 52. **Bottom view showing the driving mechanisms of a 6 x 6 truck with winch.**

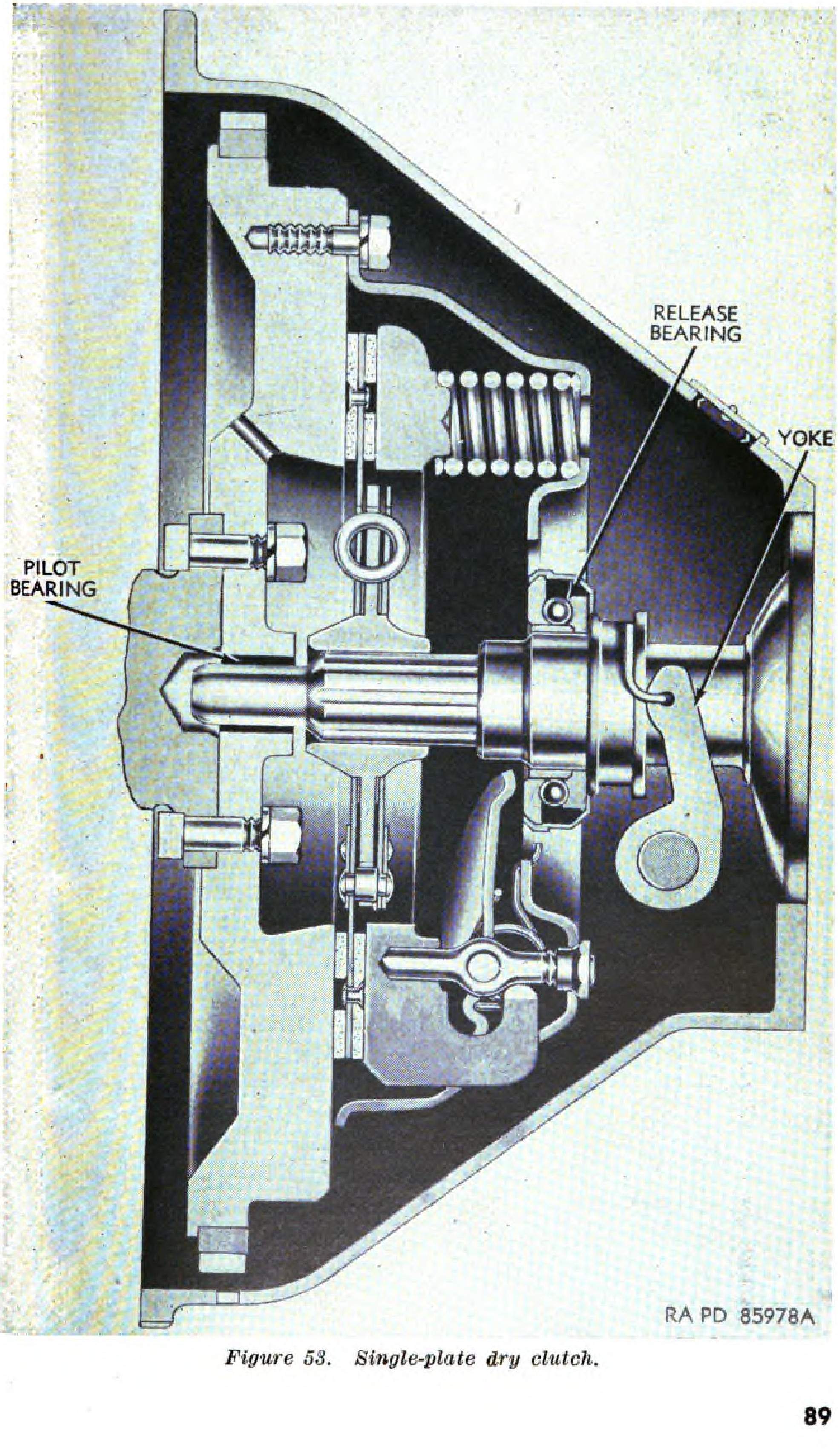


Figure 53. Single-plate dry clutch.

bon, etc. Such materials normally require no lubrication, but may be lubricated slightly if squeaks occur. Instructions in pertinent lubrication orders and technical manuals must be followed. It also is important not to overlubricate release bearings because excess lubricant may get on clutch facings or linings and cause slipping, chatter, or burned-out facings. The driven shaft on a multiple disk clutch has two or more driven disks sliding on splines and separated by driving plates splined to the flywheel. As with the single-disk clutch, the disks and plates are held in contact by the pressure plate and springs except when released by the pedal. The lubrication problems on multiple-disk clutches are the same as on single-disk clutches.

b. Fluid Clutches. A fluid clutch uses the fluid as a medium for transmitting motion and power from the driving to the driven parts of the mechanism. Figures 54, 55, and 56 show a typical mechanism of this type. The clutch consists of two torus members fastened respectively to the driving and driven shafts of the clutch. These torus members incorporate radial vanes and face each other inside of an oiltight case or housing. The case is filled with oil and rotation of the driving member sets up centrifugal force which tends to make the oil flow radially outward, this tendency increasing very rapidly as the rotating speed increases. As the oil is forced to the outer part of the driving torus, it crosses over and sets up a driving force in the driven torus which causes the driven torus to rotate at nearly the same speed as the driving member. At idling speed of the engine, the driving torus does not set up sufficient force to cause rotation of the driven torus. The only parts of a fluid clutch requiring lubrication are the bearings between the clutch housing and driving and driven shafts. These bearings obviously are oiled by the clutch oil and on this account, it is necessary that the same precautions be taken in handling this oil as would be taken in handling engine lubricating oil. The oils used must be able to withstand the high temperatures caused by the fluid friction and must have favorable viscosity index characteristics.

c. Torque Converters. The torque converter (fig. 57) acts as both a clutch and transmission and uses fluid as a medium for transmitting motion and power. The converter consists of four major parts—a centrifugal pump that is driven by the engine; a coaxial three-stage turbine (or rotor) attached to the output shaft of the engine; a hydraulic chamber or housing; and reactor blades attached to the inside of the chamber. As various load conditions are encountered the fluid temperature rises to the point where it becomes necessary for it to be cooled. This cooling is accomplished by utilizing the pressure differential across the converter pump thereby circulating the fluid through a cooling radiator (fig. 58). Pertinent lubrication orders and technical manuals should be followed regarding the changing of

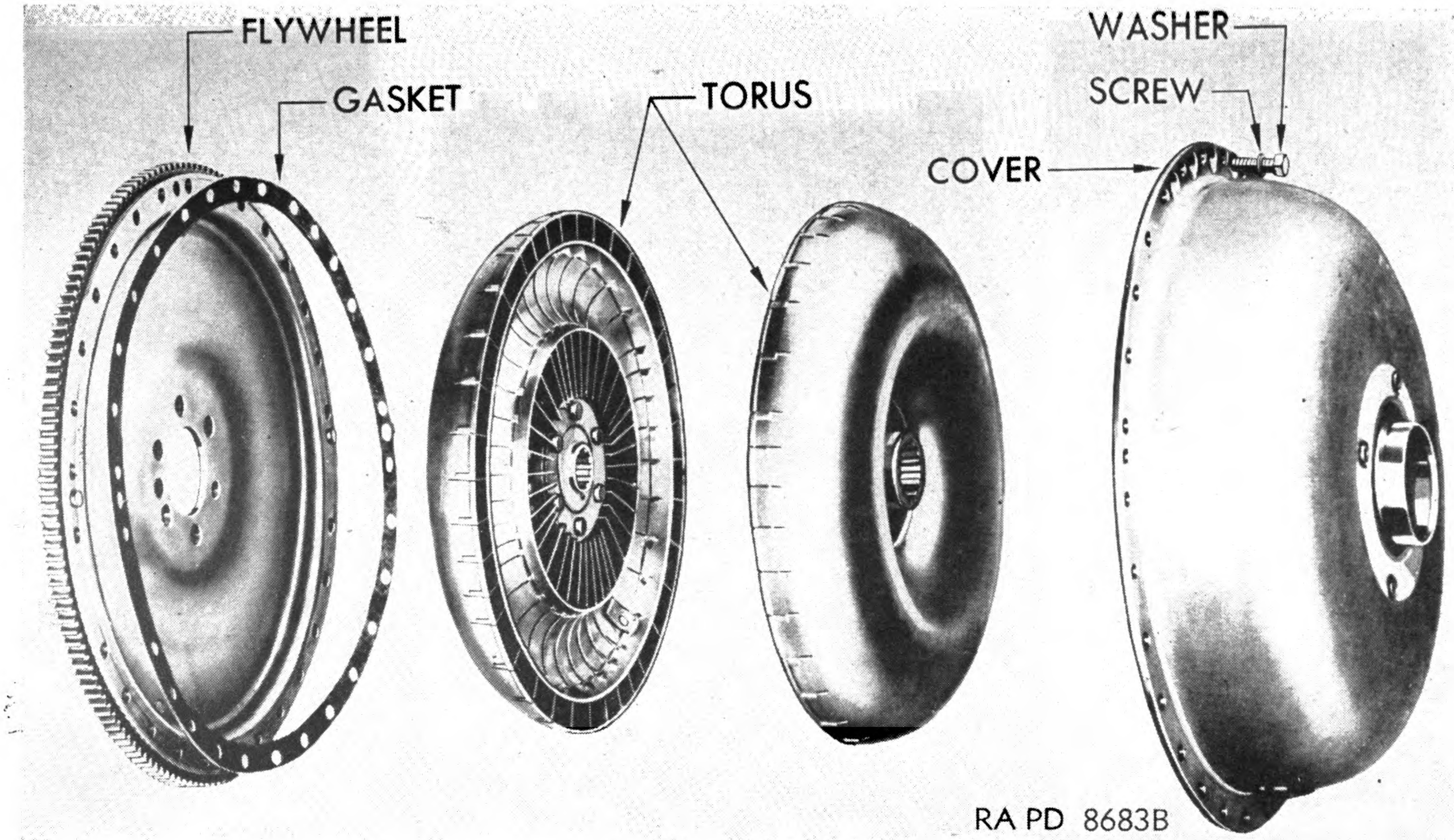


Figure 54. Fluid clutch disassembled.

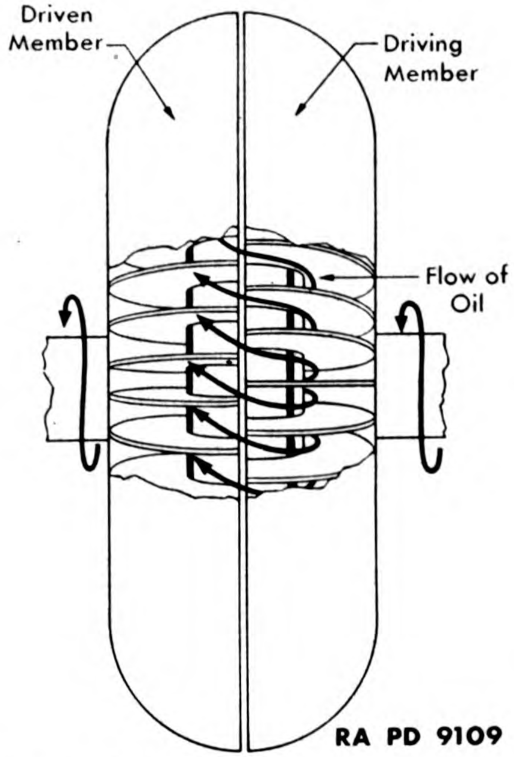


Figure 55. Schematic view of fluid clutch.

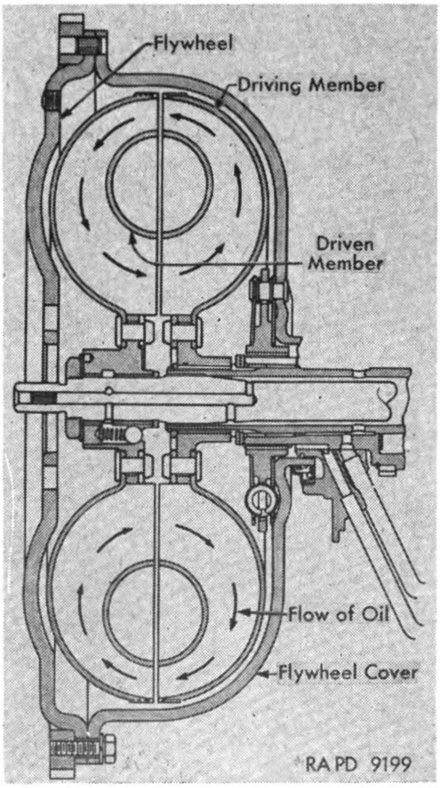


Figure 56. Schematic cross section of fluid clutch.

fluid filters, radiator vent line filters, and the draining and refilling of the converters. The internal converter mechanism is lubricated automatically by its self-contained fluid.

44. 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 units, combine the dip and pressure circulation

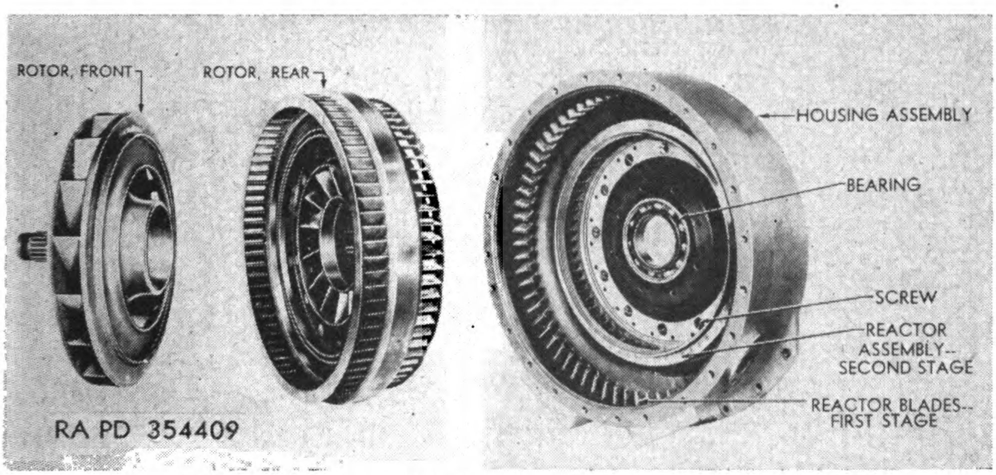


Figure 57. Torque converter showing rotors, housing, and reactors.

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 transmission. Figures 59 and 60 show various transmissions. Figure 59 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 60 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 roller 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. On later production of this same transmission, oil from the pump passes through an oil cooler before going 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 winch, crane, etc., requiring

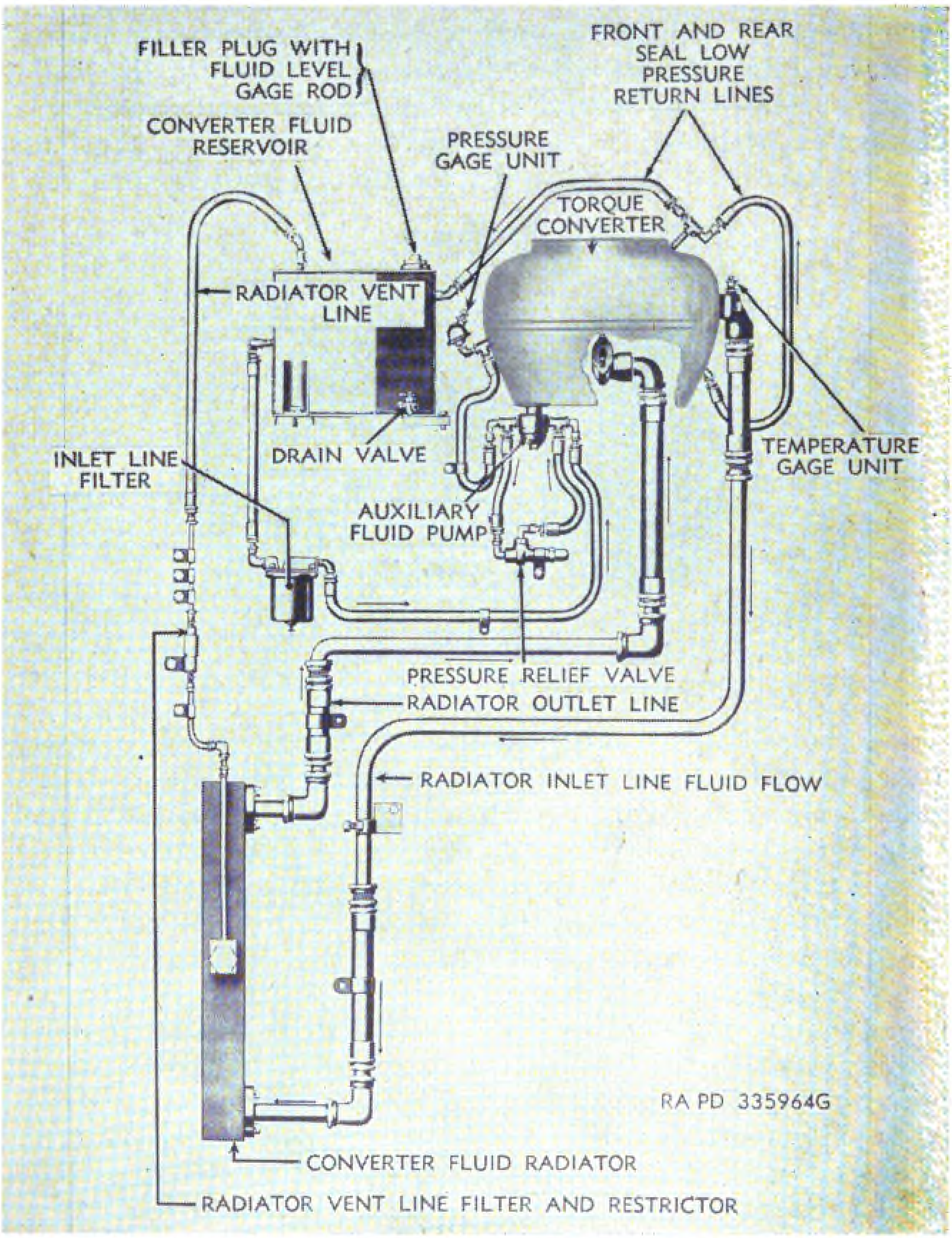


Figure 58. Torque converter fluid circulatory system.

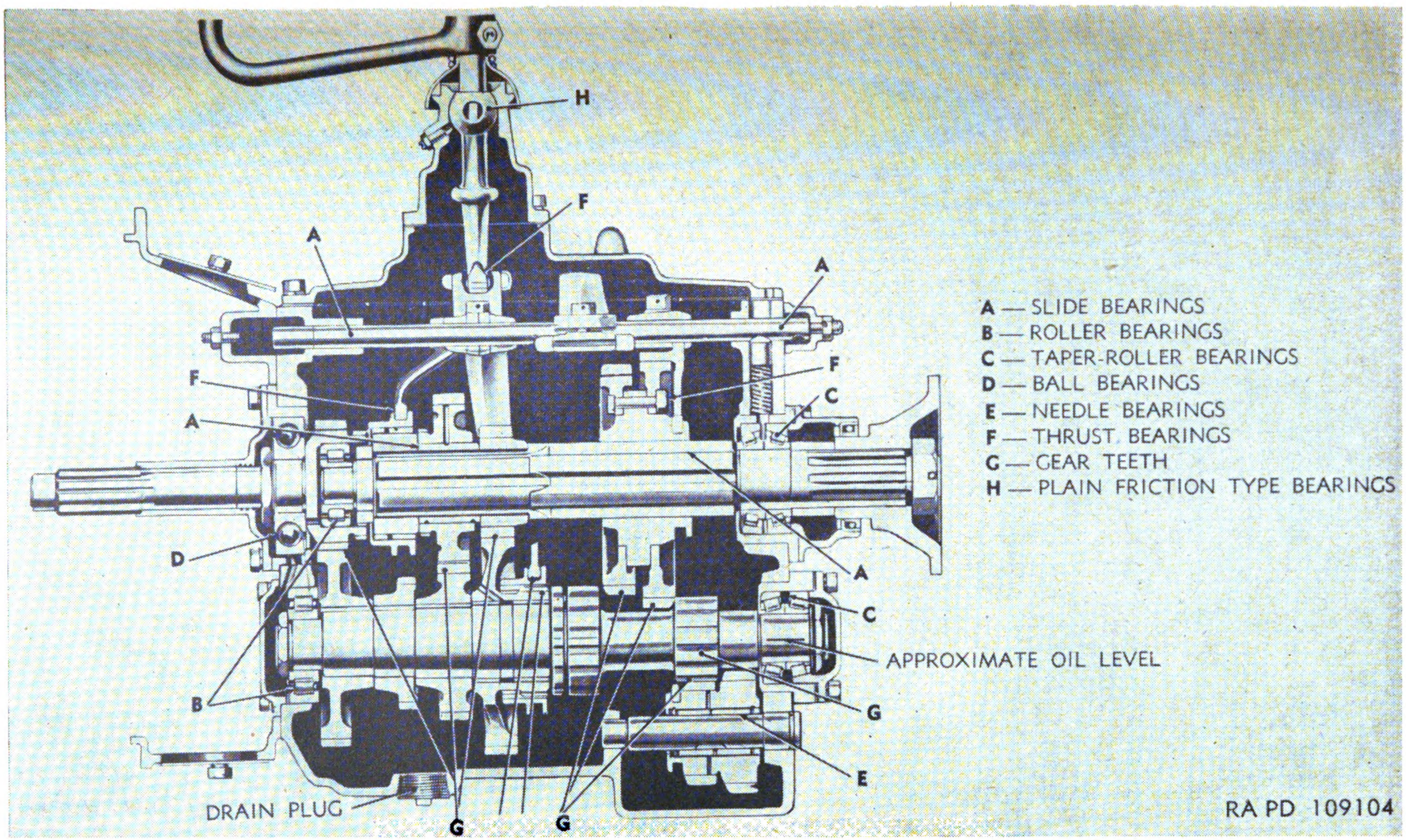


Figure 59. Cross section of typical five-speed transmission.

power drive generally are so constructed as to allow power take-off. Surfaces to be lubricated in the power take-off 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 transmissions is so varied, the lubrication instructions in current pertinent lubrication orders and technical manuals should be followed carefully. Special attention should be given to checking the oil levels (they sometimes vary for summer and winter as shown in figure 61), proper draining and flushing, and cleaning of magnetic drain plugs.

45. Transfer Cases

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 62 shows a typical transfer case incorporating high- and low-speed driving ranges, drive to front axle, and drive to the real 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 63 shows a transfer case using a silent chain, the dip system being used for lubrication.

46. Universal Joints

a. Universal Joints for Drive Shafts. Basically the universal joint in most common use (fig. 64) 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 is necessary to remove a plug and install a lubricating fitting to lubricate the joint. The lubricating fitting must be removed and the original plug reinstalled 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 carry manufacturer's instruction plates which specify the lubricant to be used for the lubrication of universal joints. This instruction is probably in contradiction to the lubricant prescribed by the current applicable lubrication order

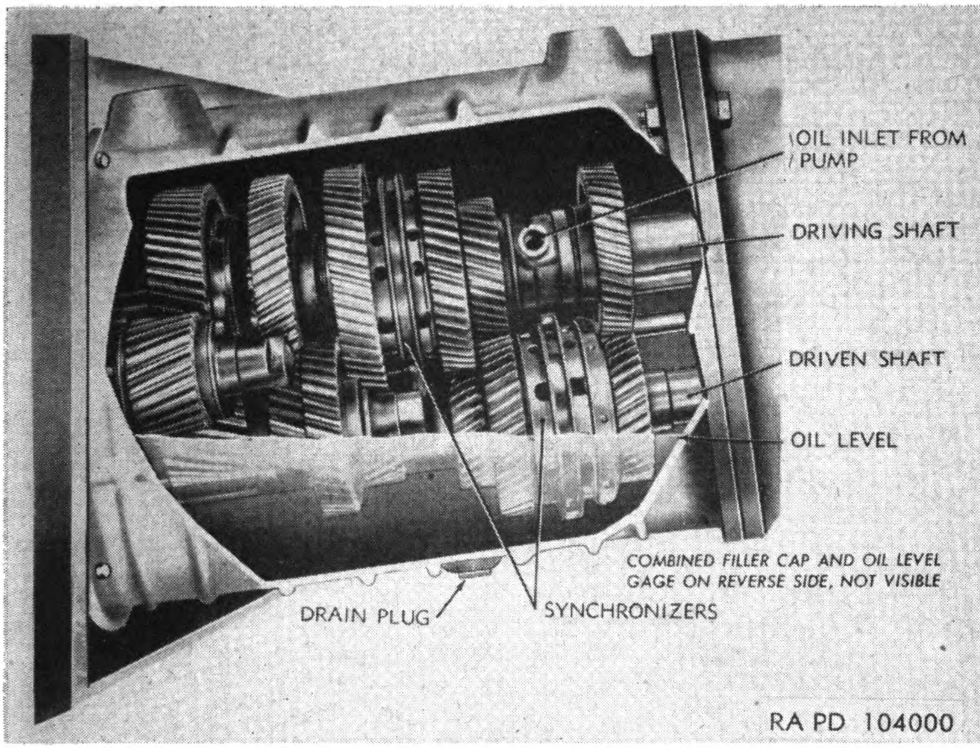


Figure 60. Synchromesh tank transmission incorporating pressure circulation system.

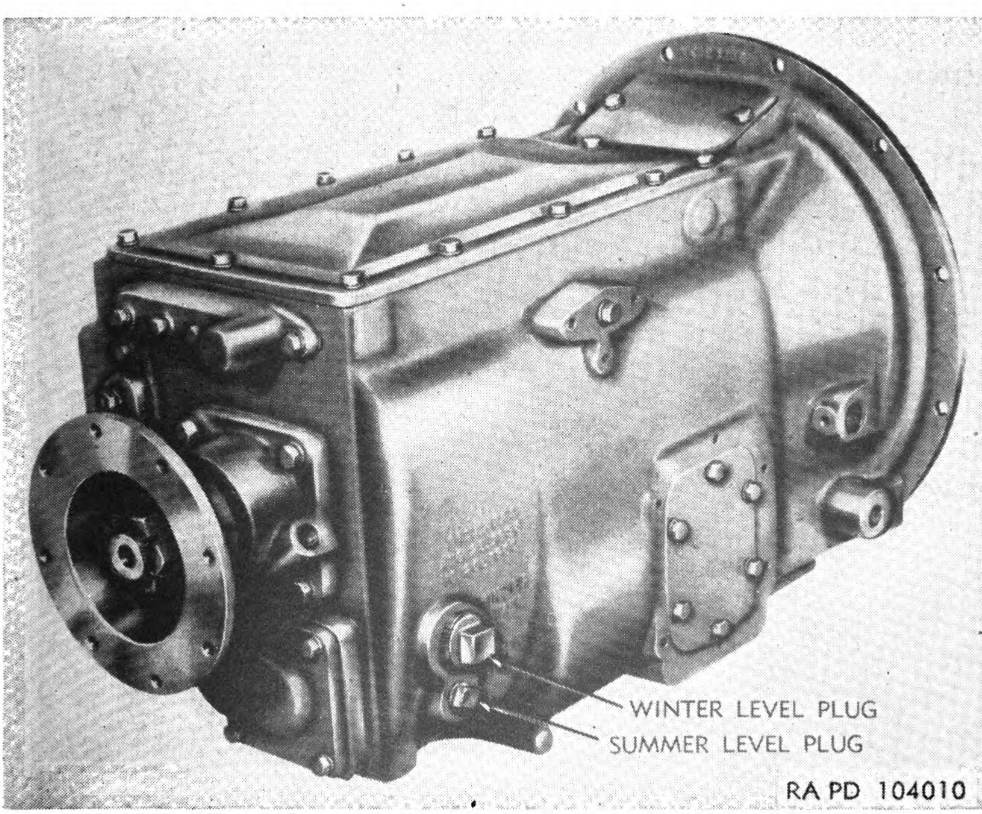


Figure 61. Transmission with two oil level plugs—one for winter, one for summer.

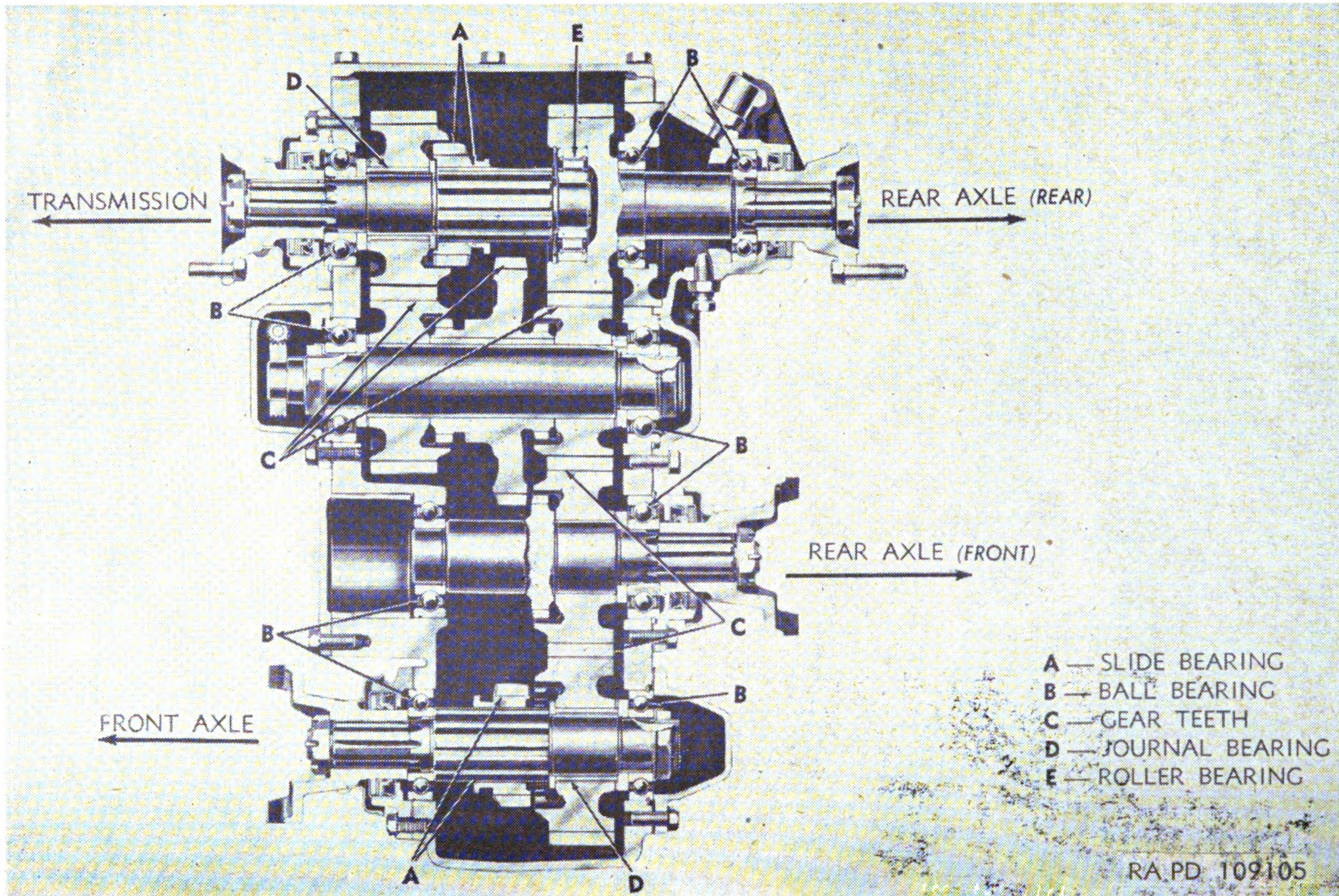


Figure 62. Cross Section of a typical transfer case.

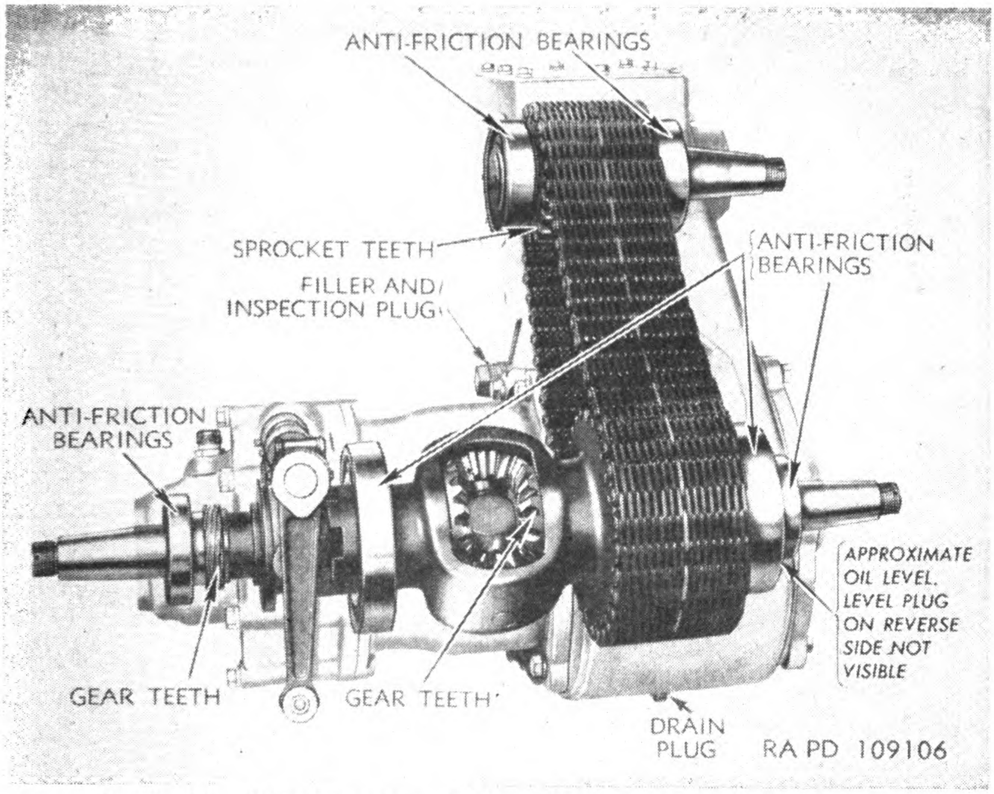


Figure 63. Phantom view of a transfer case using a silent chain.

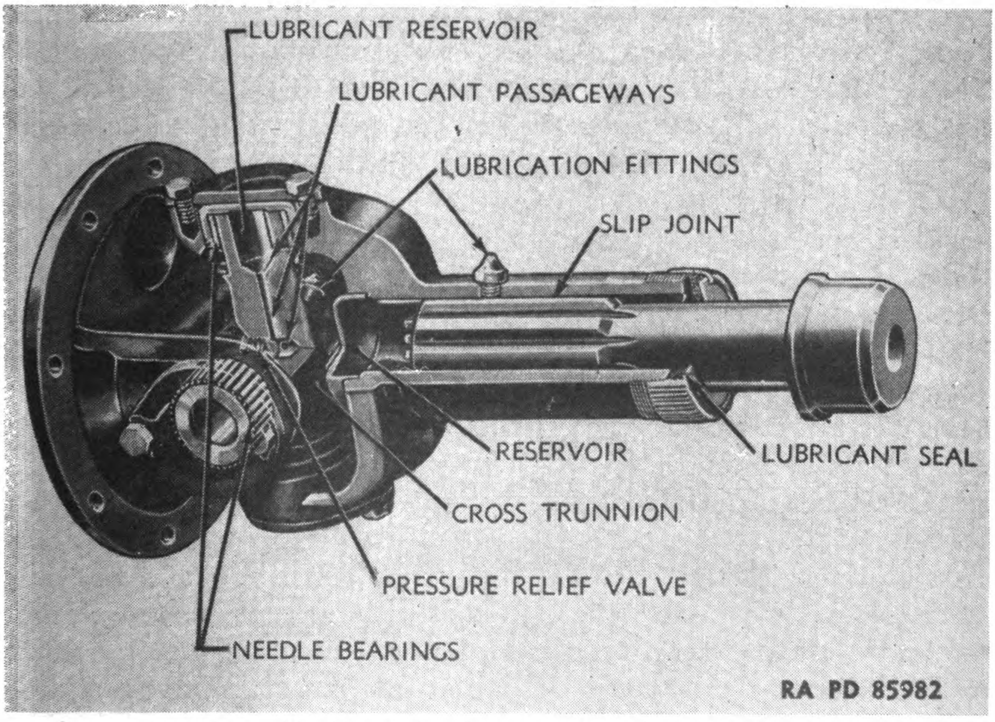


Figure 64. Typical universal joint with slip joint.

and therefore must be ignored. Instructions on current applicable lubrication orders will be followed regardless of contrary instructions on manufacturer's plates. At time of rebuild or removal from vehicle, the manufacturer's instruction plate will 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 (figs. 65 and 66). Front wheel universals always are inclosed by parts of the axle and although the surfaces to be lubricated vary, they are usually lubricated with general purpose 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 and 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 current pertinent lubrication order and technical manual.

47. 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 being necessary in cold weather when the thick lubricant may pile at the end of the filling nozzle and give an incorrect indication of the amount of lubricant introduced.

b. DRIVING GEARS. Driving gears may be divided into the following classifications: 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

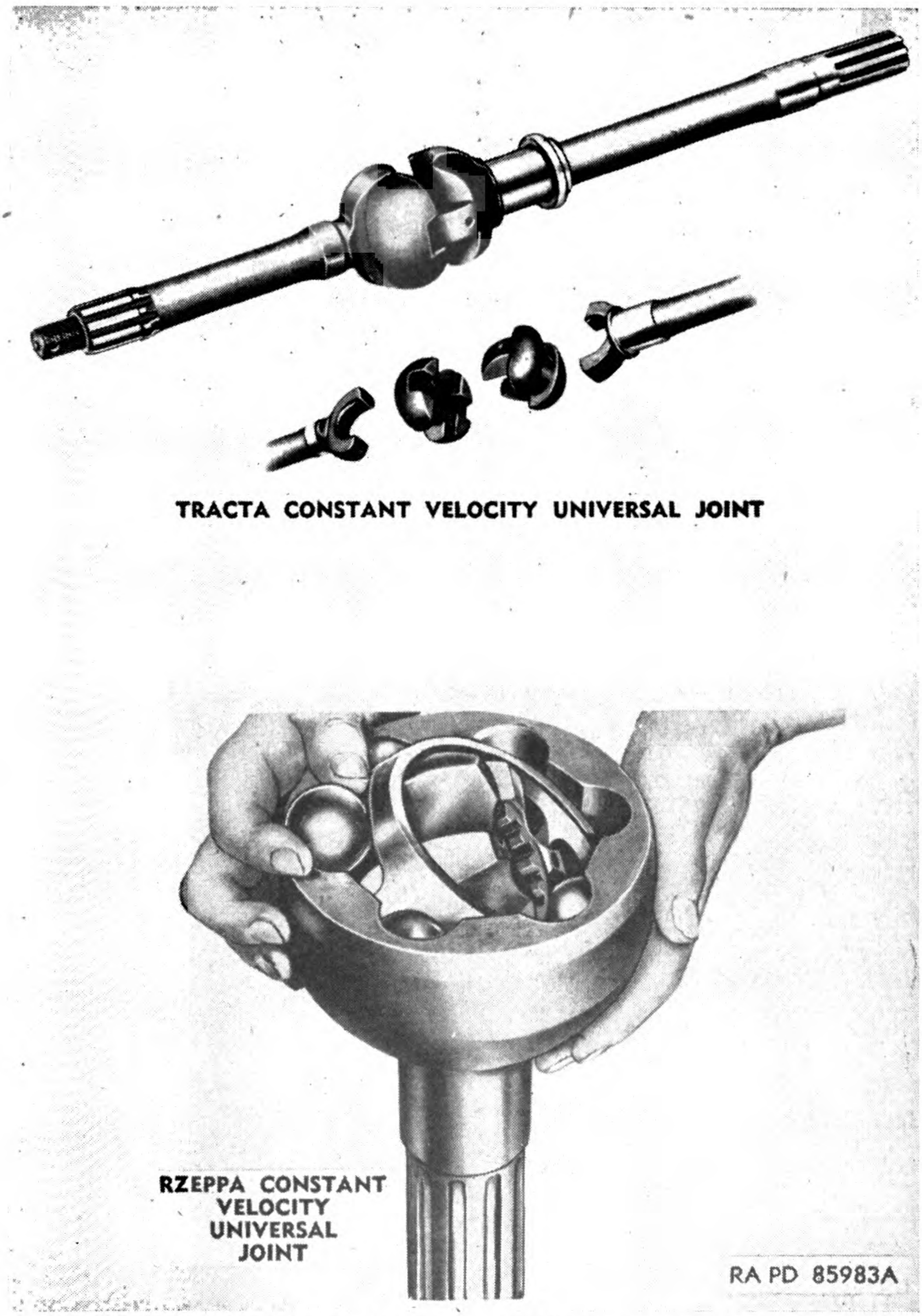


Figure 65. Two types of universal joints for front wheel drives.

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. 67) 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 pin-

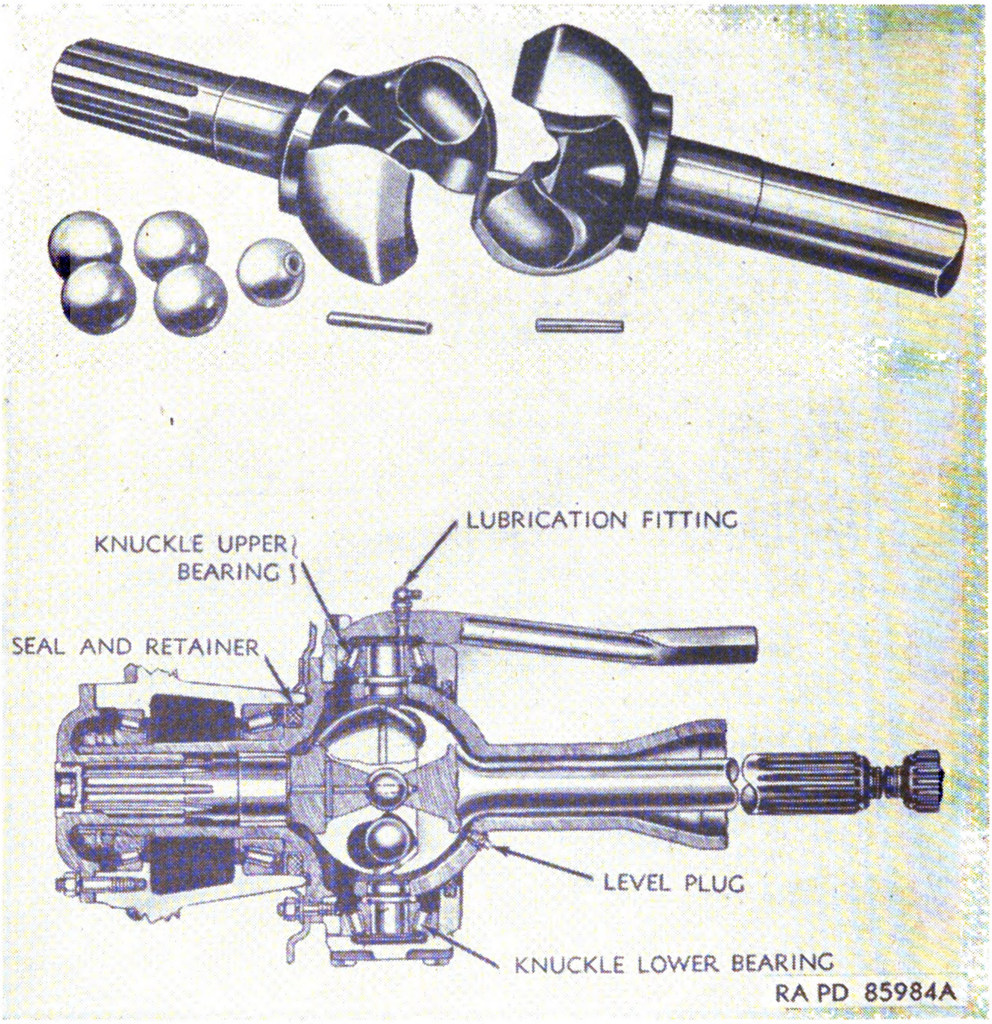


Figure 66. Universal joint for a front wheel drive (Bendix-Weiss).

ions in the cage. All of these 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. 68). 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 matériel 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 anti-

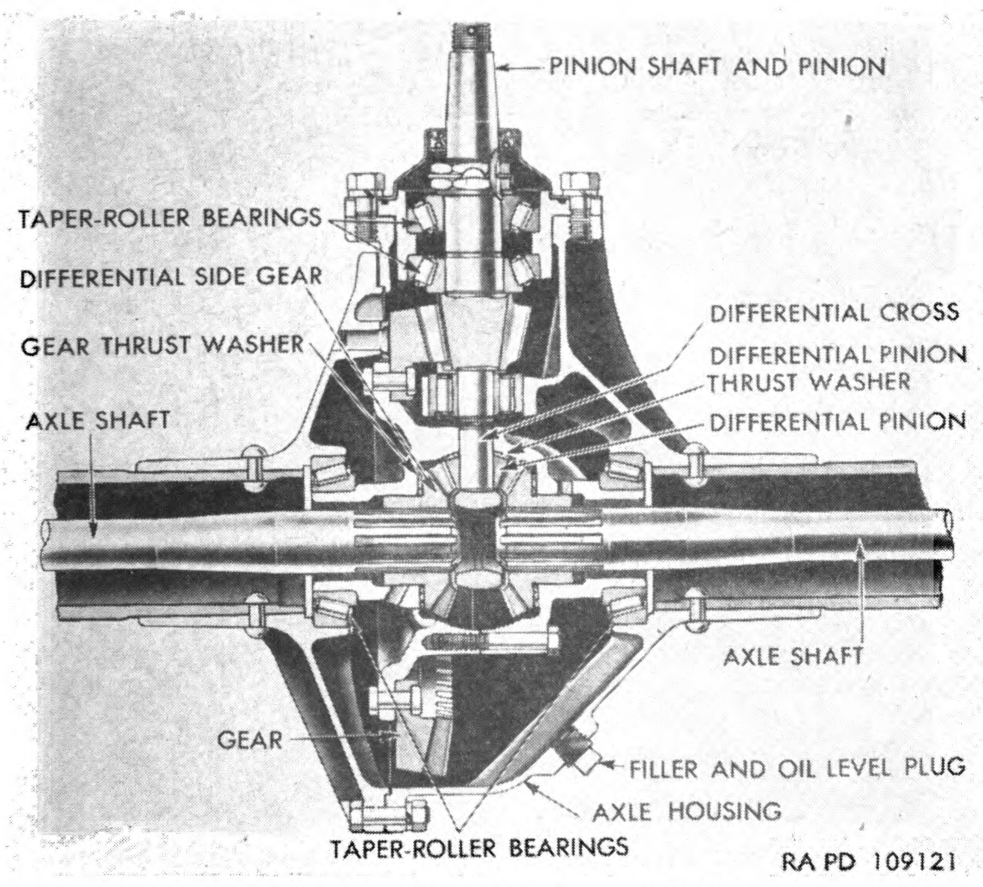


Figure 67. Drive gears and differential.

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

e. Controlled Differentials. Controlled differentials (fig. 69) 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 brake drums and brakes by means of which resistance may be applied at will to either side, resulting in the slowing of the track on that side and consequent turning of the entire vehicle. 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 not only must be lubricated but cooled as well,

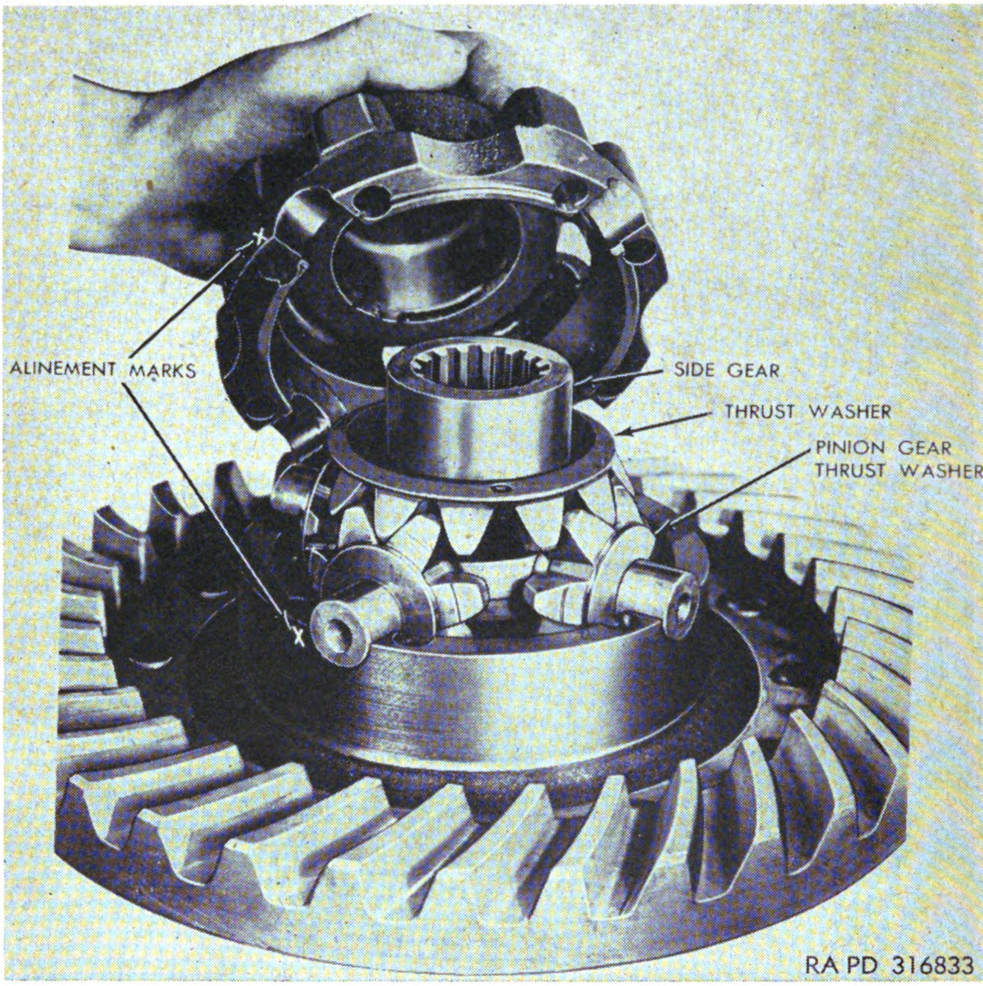


Figure 68. Differential with half of cage removed to show construction.

because the friction resulting from the braking action in steering introduces very considerable amounts of heat. This is accomplished 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 incorporate an oil pump which circulates the oil from the bottom of the housing through a

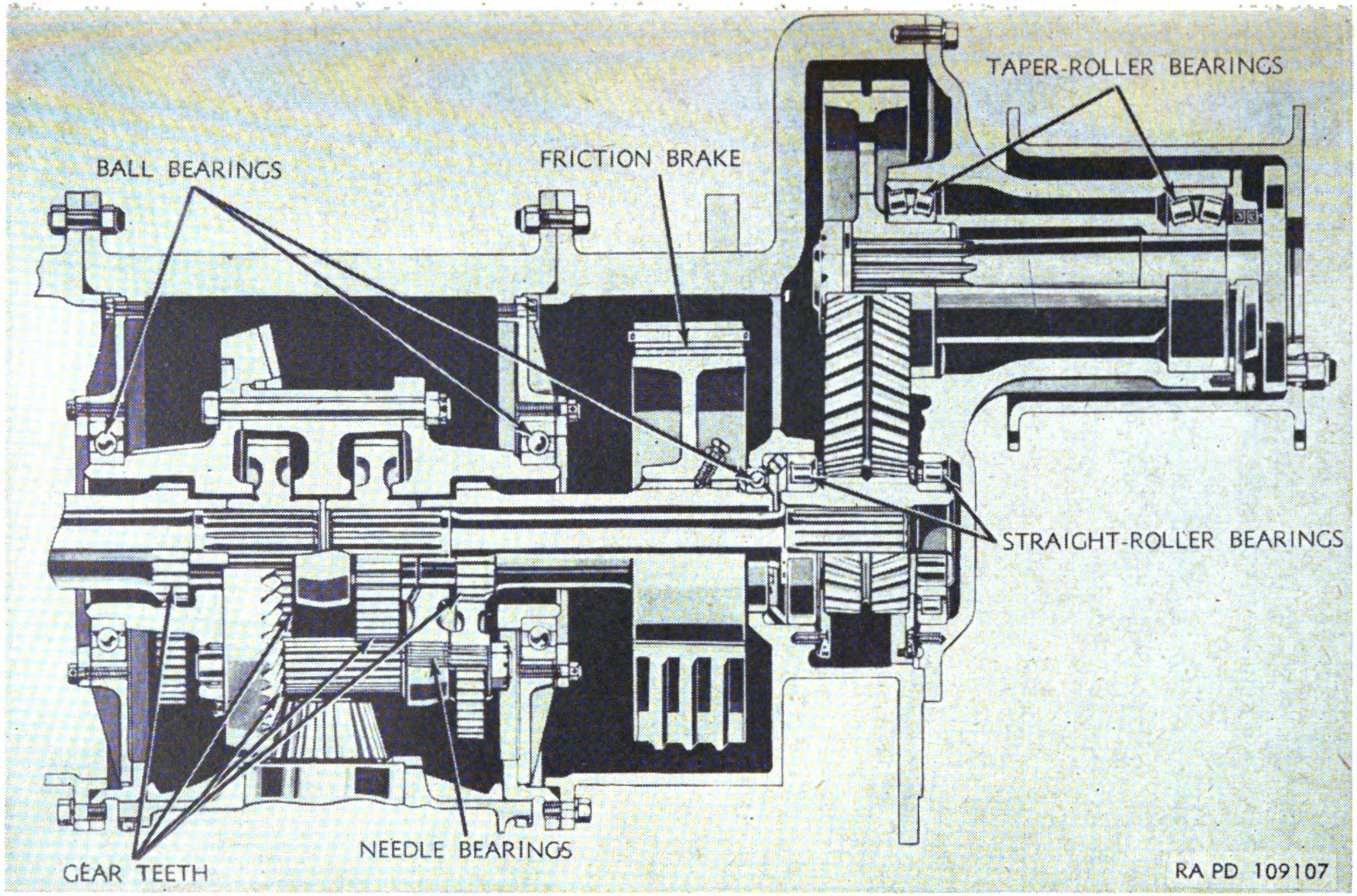


Figure 69. Partial section of a controlled differential and final drive with steering brake.

radiator or cooler to dissipate the excess heat. The transmission often is 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. 69) generally consist of antifriction bearings carrying both thrust and radial load and a set of herringbone gears. Lubrication is by the dip or splash systems from oil held in the bottom of the housing.

Section IX

AUTOMOTIVE MATÉRIEL—STEERING BRAKING, AND SUSPENSION

48. Braking Mechanisms

a. HYDRAULIC BRAKES. Lubrication problems on hydraulic brakes are comparatively simple as only the operating levers and links, the master cylinder, and the wheel cylinders (figs. 70 and 71) require lubrication. The cylinders have metal pistons and rubber packing cups, and all parts are lubricated by the hydraulic brake fluid used for operating purposes. Internal parts of hydraulic brakes are lubricated by hydraulic brake fluid. The maintenance of proper level of the fluid in the reservoir is mainly one of preventive maintenance rather than lubrication. Lubrication of the friction-type bearings in pedals, levels, and links, etc., will be in accordance with current pertinent lubrication orders.

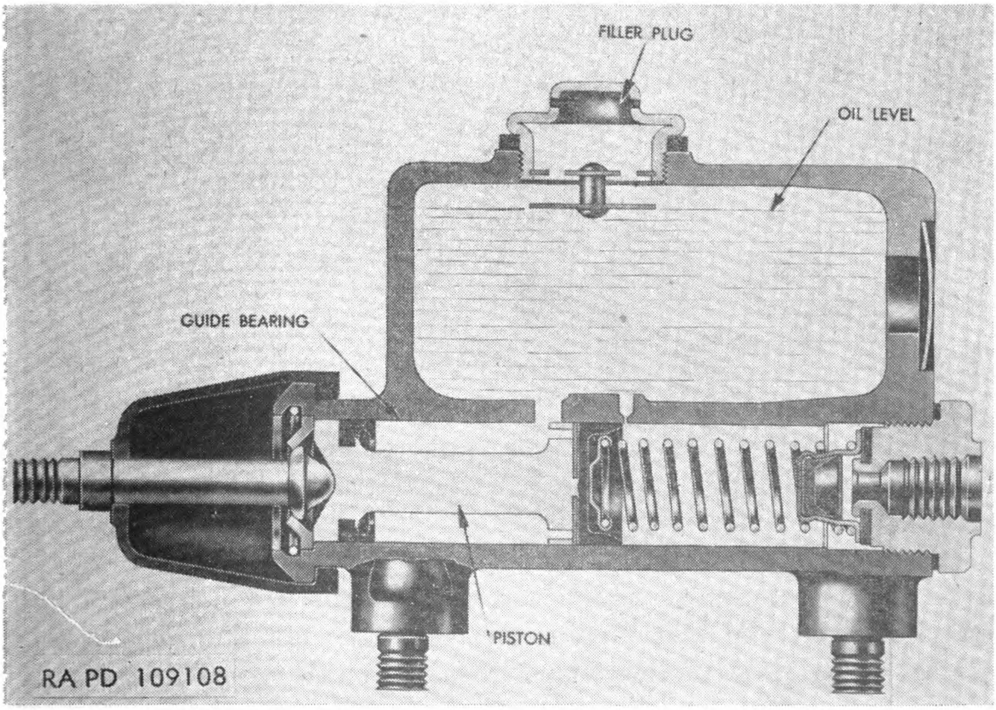


Figure 70. Cross section of typical master cylinder.

b. VACUUM BRAKES. The vacuum brake system known as "Hydrovac" is in reality a complete hydraulic brake system plus a vacuum cylinder and a hydraulic slave cylinder interposed between the master cylinder and the wheel cylinders. Figure 72 shows a typical installation with the brakes in released position. When the brake pedal is depressed, the pistons 1 and 3 move to the right in the cylinder, the bearings between the cup packings on the pistons and the cylinder walls generally being the only additional lubrication points aside from those in a regular hydraulic system. Lubricate in accordance with pertinent lubrication order. On some installations, a pump is used to supply the vacuum (par. 41 *f*).

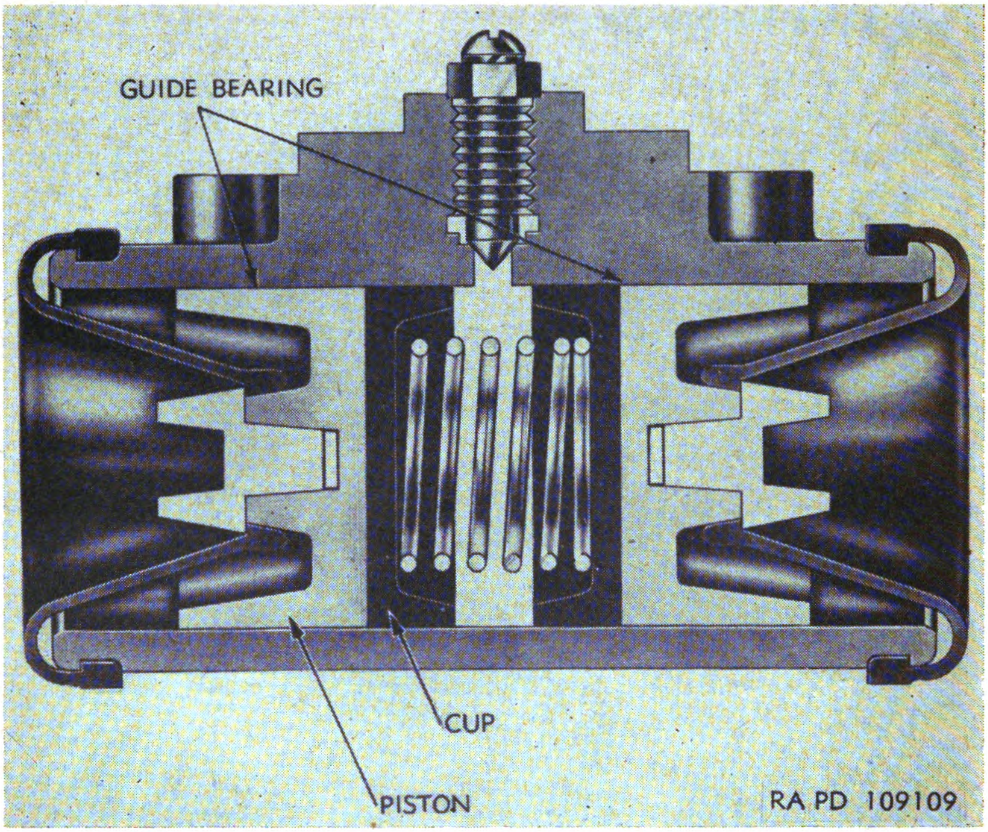


Figure 71. Cross section of typical wheel cylinder.

c. AIR BRAKES. Air brakes generally are used on heavy vehicles where the power required for manually operated brakes is greater than reasonably can be required of the operator. Bearing surfaces as incorporated in the control units are quite varied but are generally of the friction type. They ordinarily have only a very limited and intermittent movement. Lubrication problems are not severe, but care has to be used that surplus lubricant does not find its way into the air lines. Instructions in pertinent lubrication orders and technical manuals must be followed carefully.

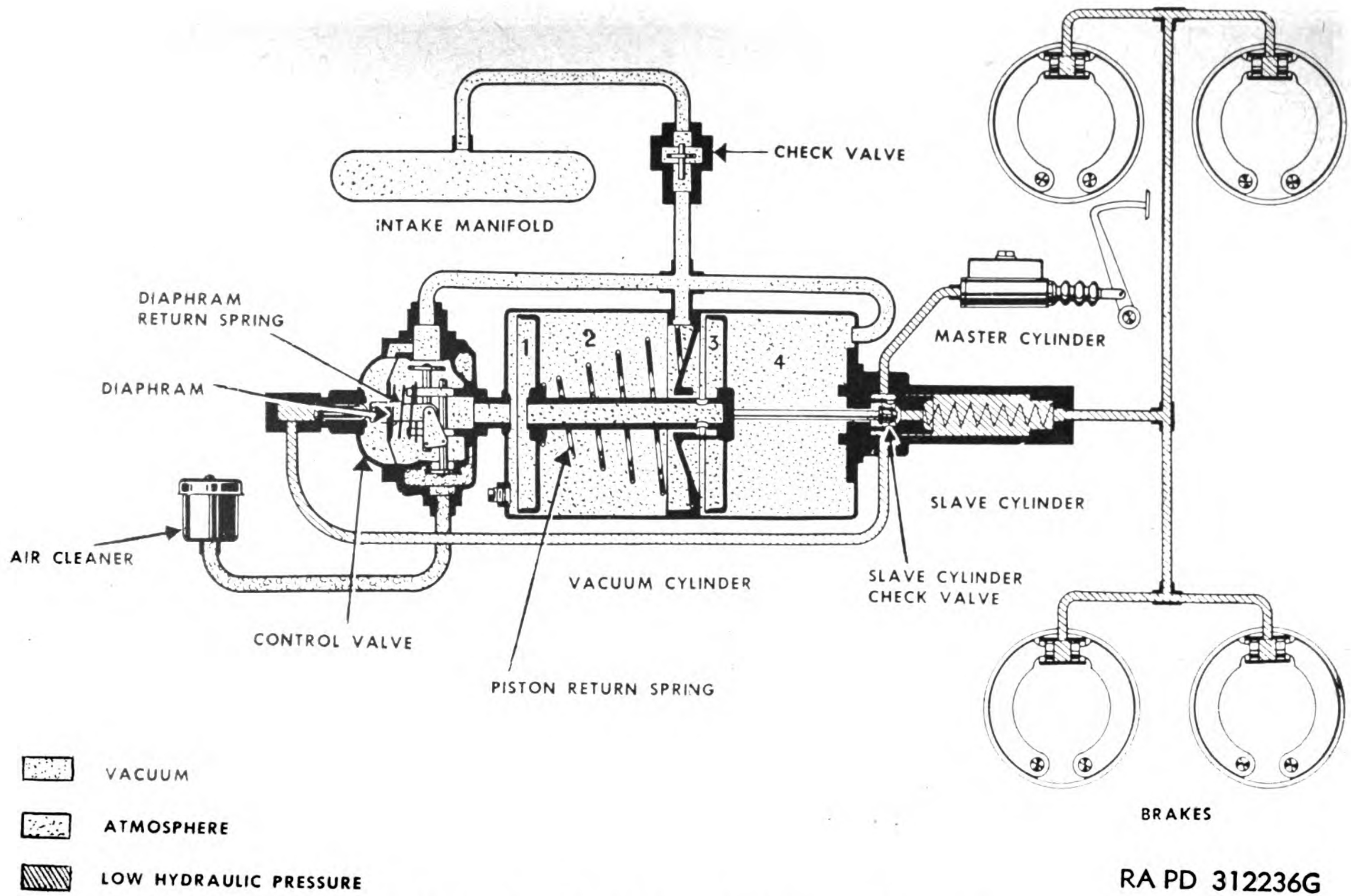


Figure 72. Schematic lay-out of vacuum brake system.

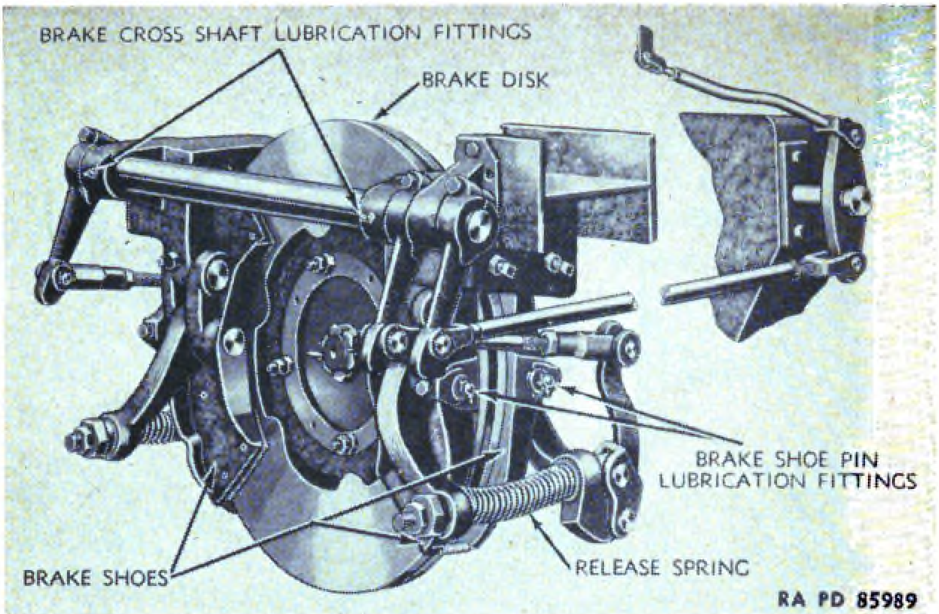


Figure 73. Typical transmission brake.

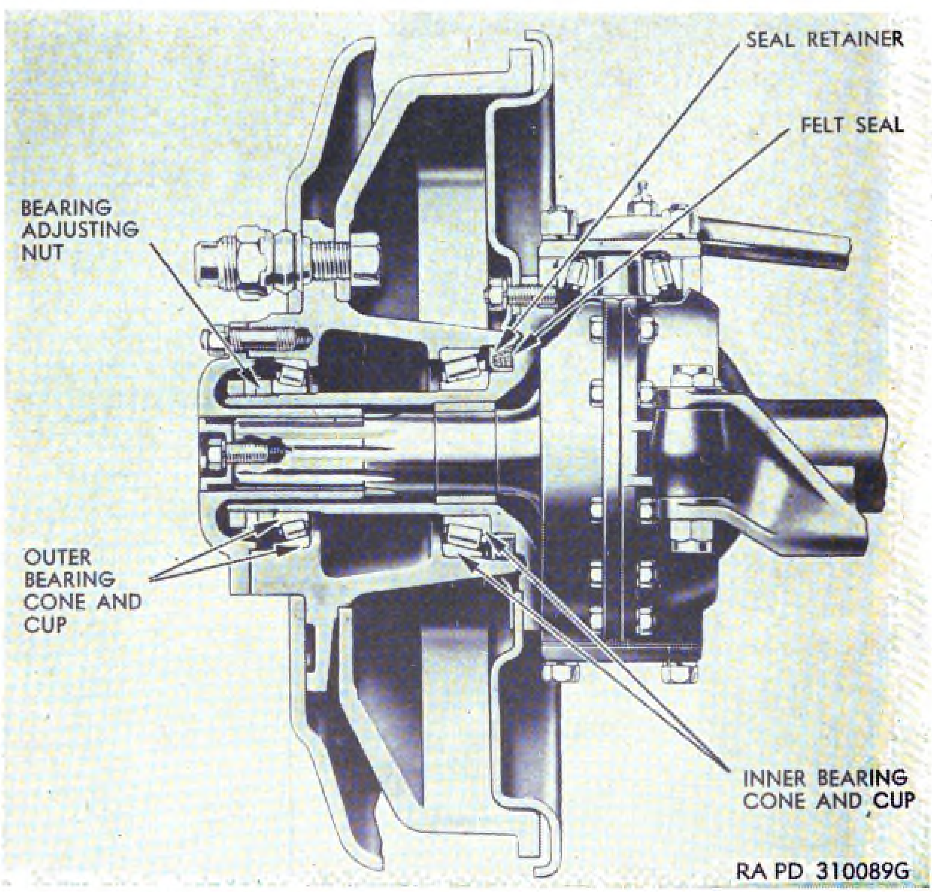


Figure 74. Section of typical front wheel bearings.

d. Transmission Brakes. Transmission brakes are operated mechanically by a hand brake lever and serve to prevent movement of the vehicle when parked or for emergency use in case of failure of the service brakes. They generally are mounted at the rear of the transmission or transfer case, the only parts needing lubrication being the cross shaft, pins, yokes, levers, etc., making up the operating linkages (fig. 73). These parts have only slight motion at intervals, and this lubrication is by grease or oil through lubrication fittings or oilcan points.

49. Suspension, Steering, Shock Absorber, 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 of the automotive vehicles of today (fig. 74) 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, do not use compressed air, as it is likely to damage the bearing and also cause rusting if the air contains moisture. 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 $\frac{1}{16}$ in.) 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 must be taken not to tighten it sufficiently to injure the balls or rollers.

c. Rear Wheel Bearings. Rear wheel bearings of automotive matériel are also of the antifriction type (fig. 75) and generally are grease lubricated. The method of introducing the lubricant varies

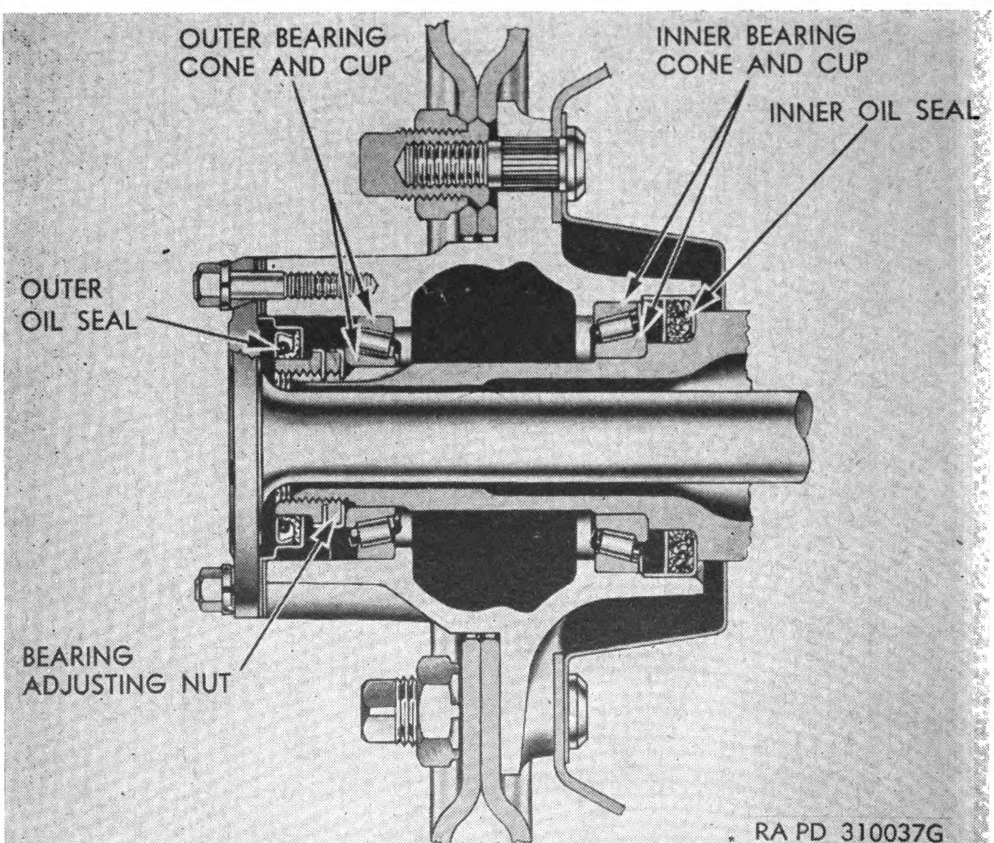


Figure 75. Section of typical rear wheel bearings.

according to the type of axle construction, the most common methods being grease cups or lubrication fittings, or by removing the wheels and packing the bearings manually. When grease cups or 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*(1) and (2) above apply.

d. STEERING SYSTEMS. A steering system (fig. 76) 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

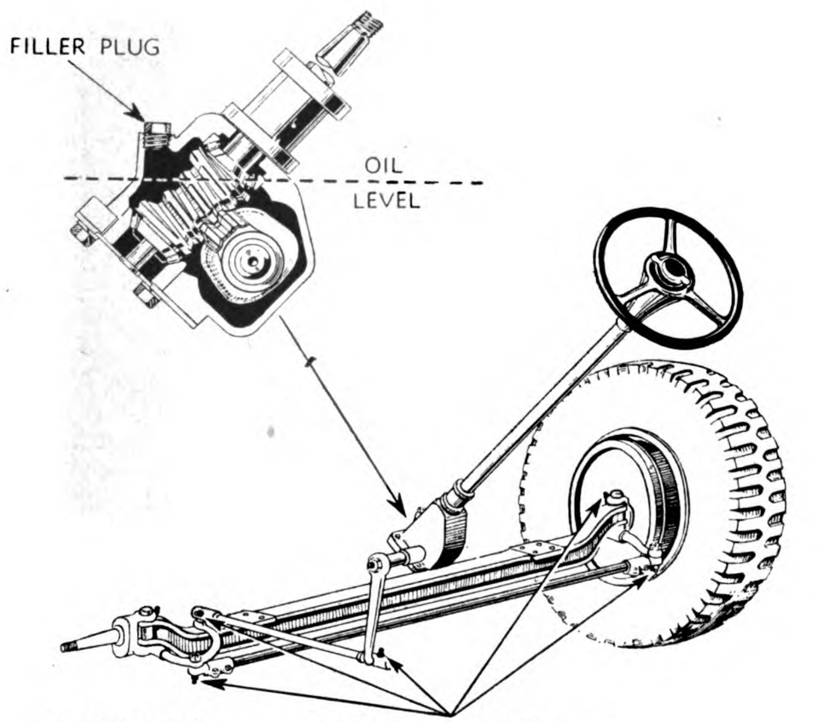


Figure 76. Schematic lay-out of a steering system.

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. 77), 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

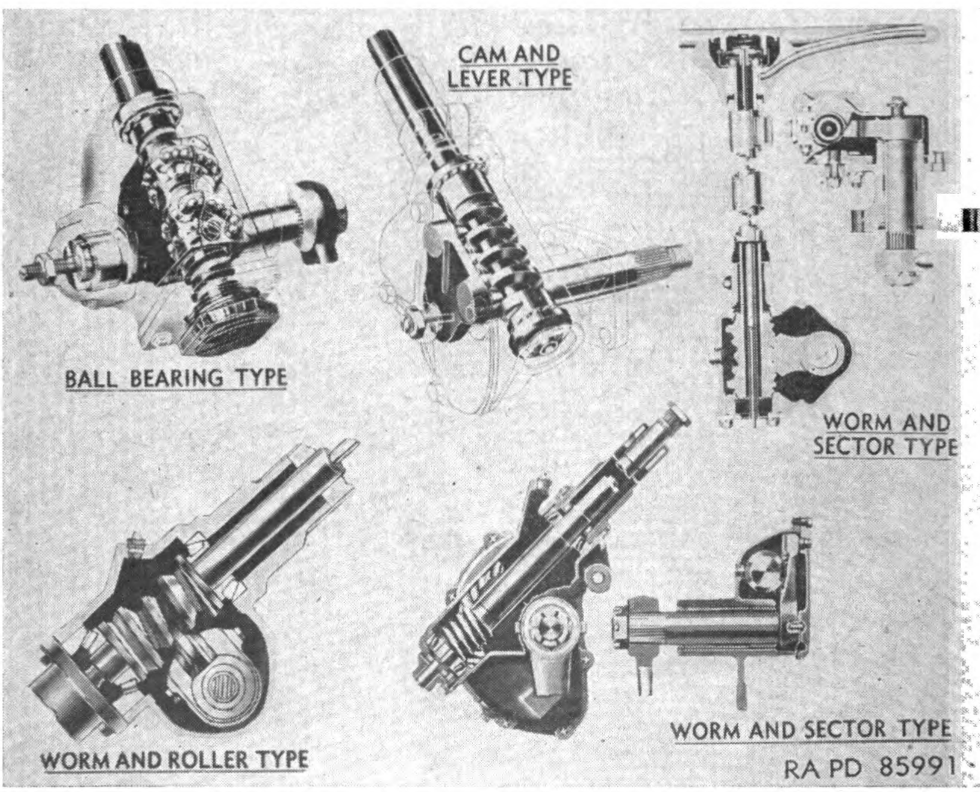


Figure 77. Steering gears of various types.

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. 77) 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) *Worm and roller type.* A steering gear of the worm and roller type (fig. 77) 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.* Figue 77 shows two types of steering gears using a worm and sector. In one type the sector is in the same plane as the worm shaft 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 all 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 current pertinent lubrication orders or technical manuals.

e. Tracks, Track Rollers, Driving Sprockets, Idlers, and Bogie Wheels. Tracks are used on vehicles that are expected to negotiate

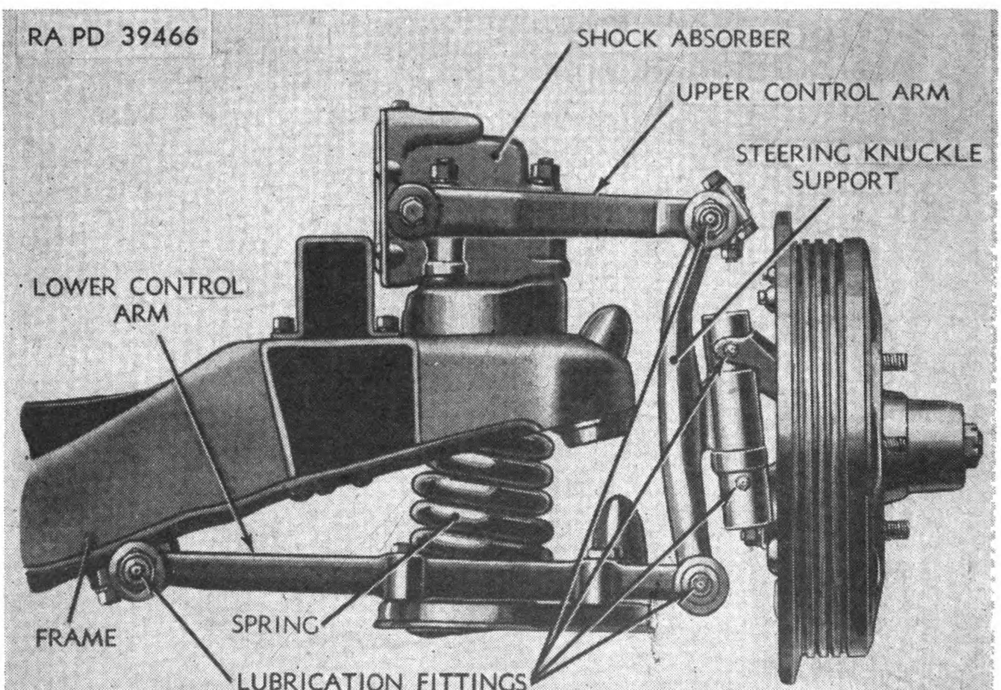


Figure 78. Front wheel suspension using a helical spring.

rough, sandy, wet, or muddy terrain. Many of the bearing surfaces, such as those between the tracks and the sprockets, idlers, bogie 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, bogie levers, bogie arms, rubbing plates, and bogie arm gudgeons receive no lubrication for the same reason. Bogie 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 weekly with general purpose grease but pertinent lubrication orders and technical manuals should be consulted for specific cases.

f. Springs. A majority of the springs used for supporting automotive 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 or bending of the spring steel itself. If a spring depends entirely upon the bending of the steel, the friction between the spring leaves may be held at a relatively constant minimum by a lubricant, and a spring cover generally is provided to keep the lubricant in place at all times. 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. 78). 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.

g. 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 matériel. 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.

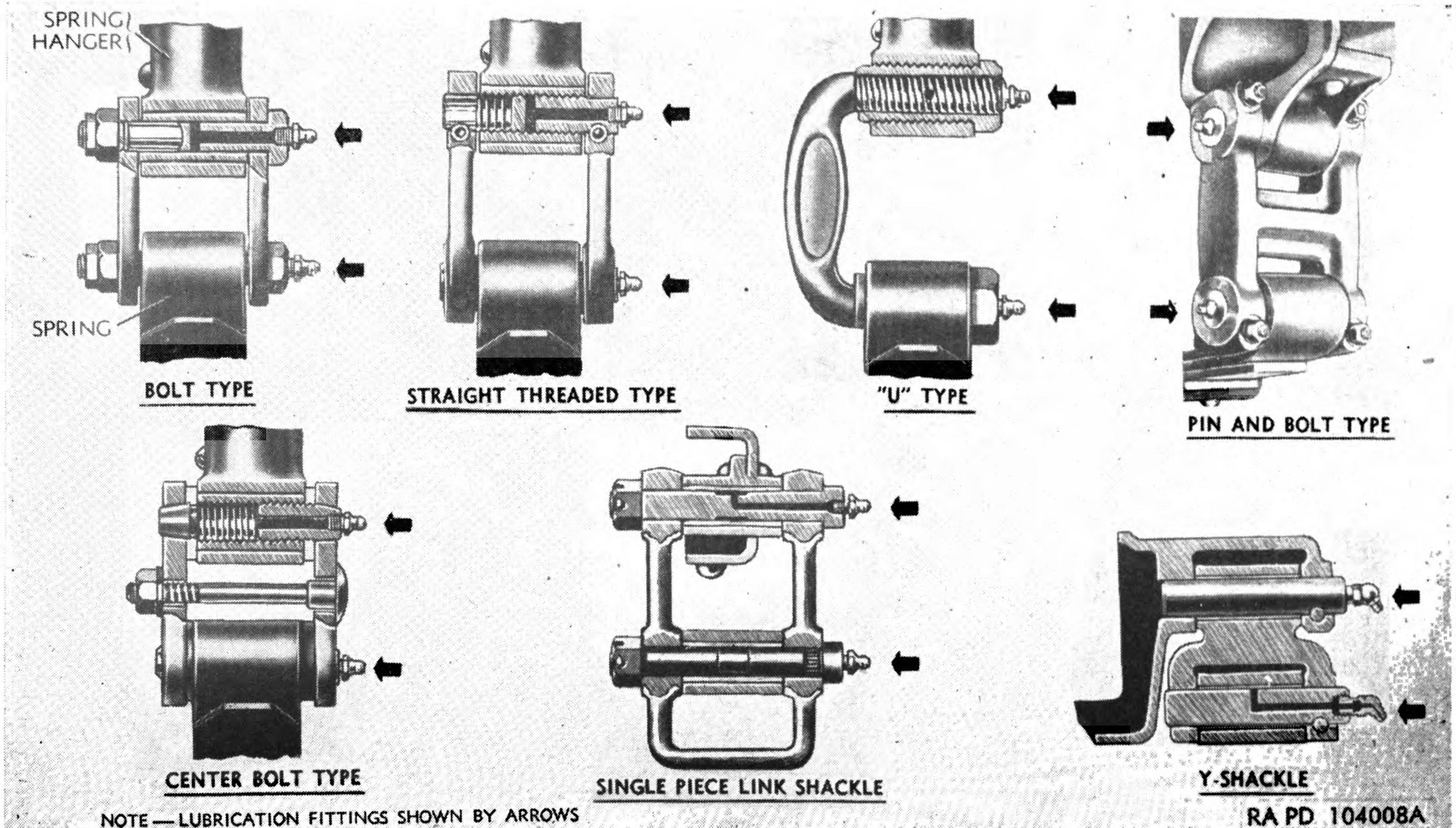


Figure 79. Spring shackles of various types.

(1) *Bolt or pin-type shackles.* A shackle of the bolt or pin type (fig. 79) 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) *Treaded- and* U*-type shackles.* In shackles of the threaded type, either straight or U-shaped (fig. 79), 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.

h. Shock Absorbers. Four types of hydraulic shock absorbers are in general use—the double-acting piston type, the single-acting piston type, the direct-acting or telescopic type, and the vane 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, to construction. Servicing of shock absorbers gradually will disappear from lubrication orders, as it is considered a problem of maintenance rather than lubrication.

(1) *Piston-type shock absorbers.* Figure 80 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.* 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. It is necessary to remove some shock absorbers of this type when filling becomes necessary, while others are the sealed type and cannot be refilled.

(3) *Vane-type shock absorbers* (fig. 81). The lubrication points on vane-type shock absorbers include the bearing between the wing or vane and the side and ends of the cylindrical operating chamber, the bearing between the wing or vane shaft and other parts of the housing, and the check valves. All lubrication is by the fluid used for operating purposes, which

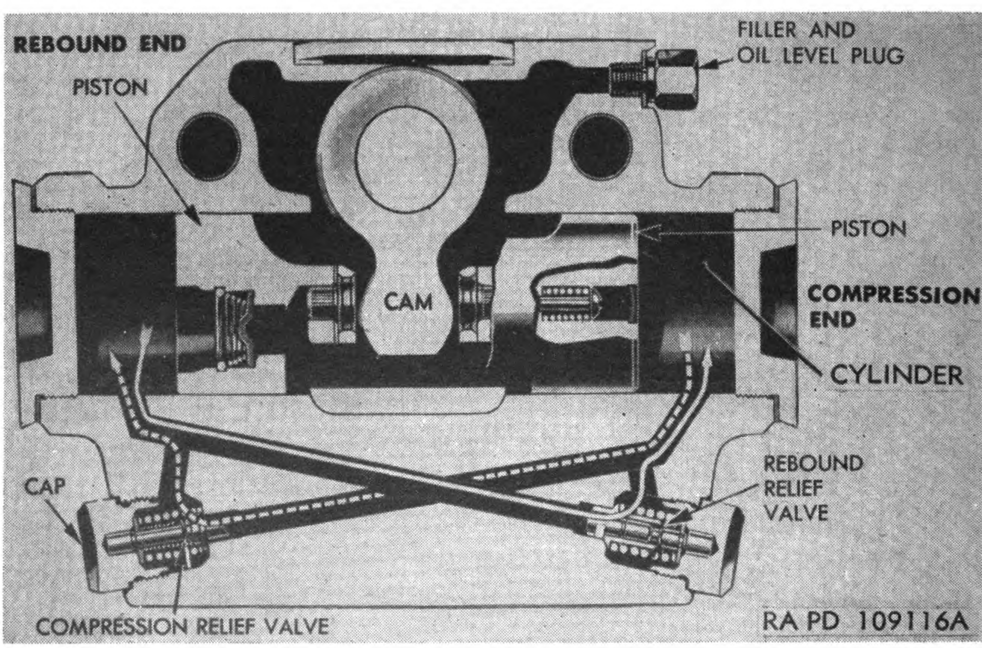


Figure 80. Double-acting piston-type shock absorber.

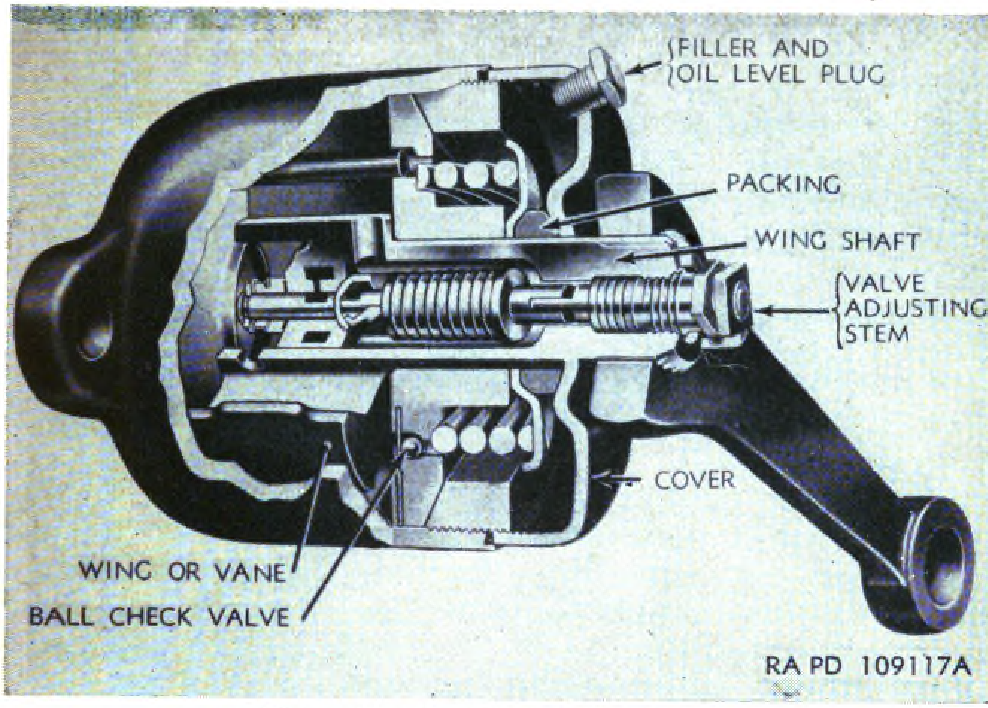


Figure 81. Vane-type shock absorber.

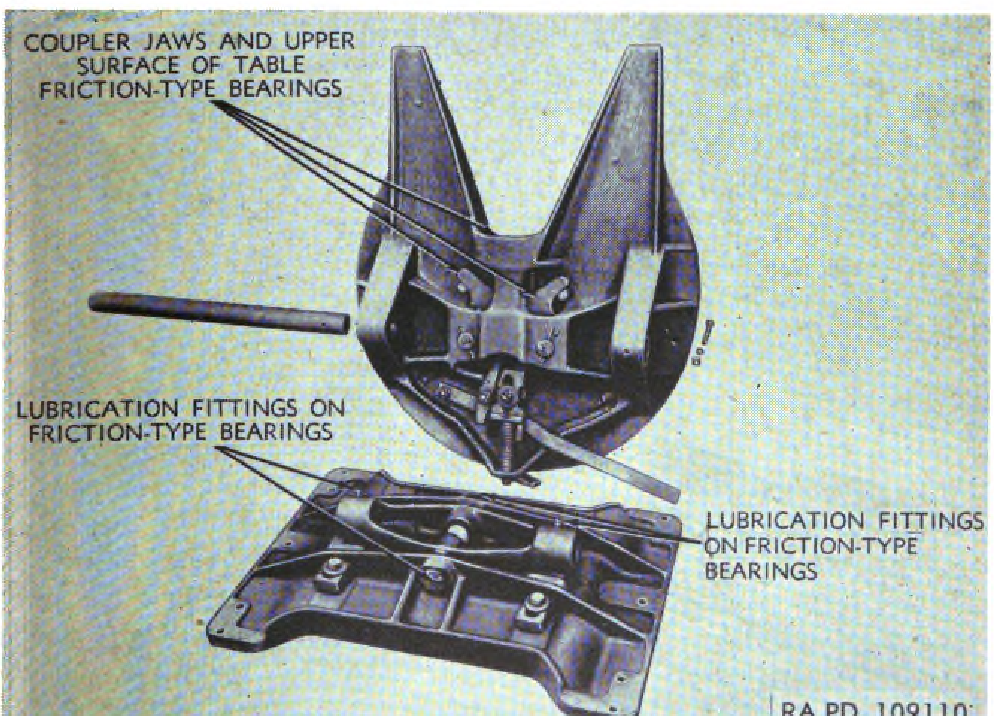


Figure 82. Fifth wheel partially disassembled.

must be replenished as directed in pertinent lubrication orders.

i. Individually Sprung Front Wheels. Individually sprung or suspended front wheels (fig. 78) are used on some 4 x 2 vehicles. 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 absorber and to the steering knuckle support, and these plain friction-type bearings are lubricated with grease through lubrication fittings as directed in current 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.

j. Turntable (Fifth Wheel). A turntable or fifth wheel (fig. 82) 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 include the top of the turntable, coupler pin locking jaw and guides, parts of the king pin locking device, the supporting shafts, pick-up 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 king pin 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 relubricated thoroughly.

Section X

AUTOMOTIVE MATÉRIEL—EFFECT OF WEATHER ON INTERNAL COMBUSTION ENGINES

50. 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° F. to +135° F. are on record. There is also a 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° F. and +32° F.* Winterization kits not prescribed; however, certain precautionary and engine warming steps essential.

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

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

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

51. 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 function 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 stems, piston scuffing, burned valves, break-down 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 meeting Specification USA 2–104 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.

52. 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 crackcase 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 abrasion, metal particles, and pulverized dirt will be washed down into the crackcase 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 receptables are responsible for a high percentage of engine damage in dusty or sandy areas. Sand or dirt entering the crackcase 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.

53. 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 +50° 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 black sludge. Crankcase oil pans may become loaded and oil screens plugged (fig. 83). Valves (fig. 84), 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 (see par. 39). Oil 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 blow-by of soot

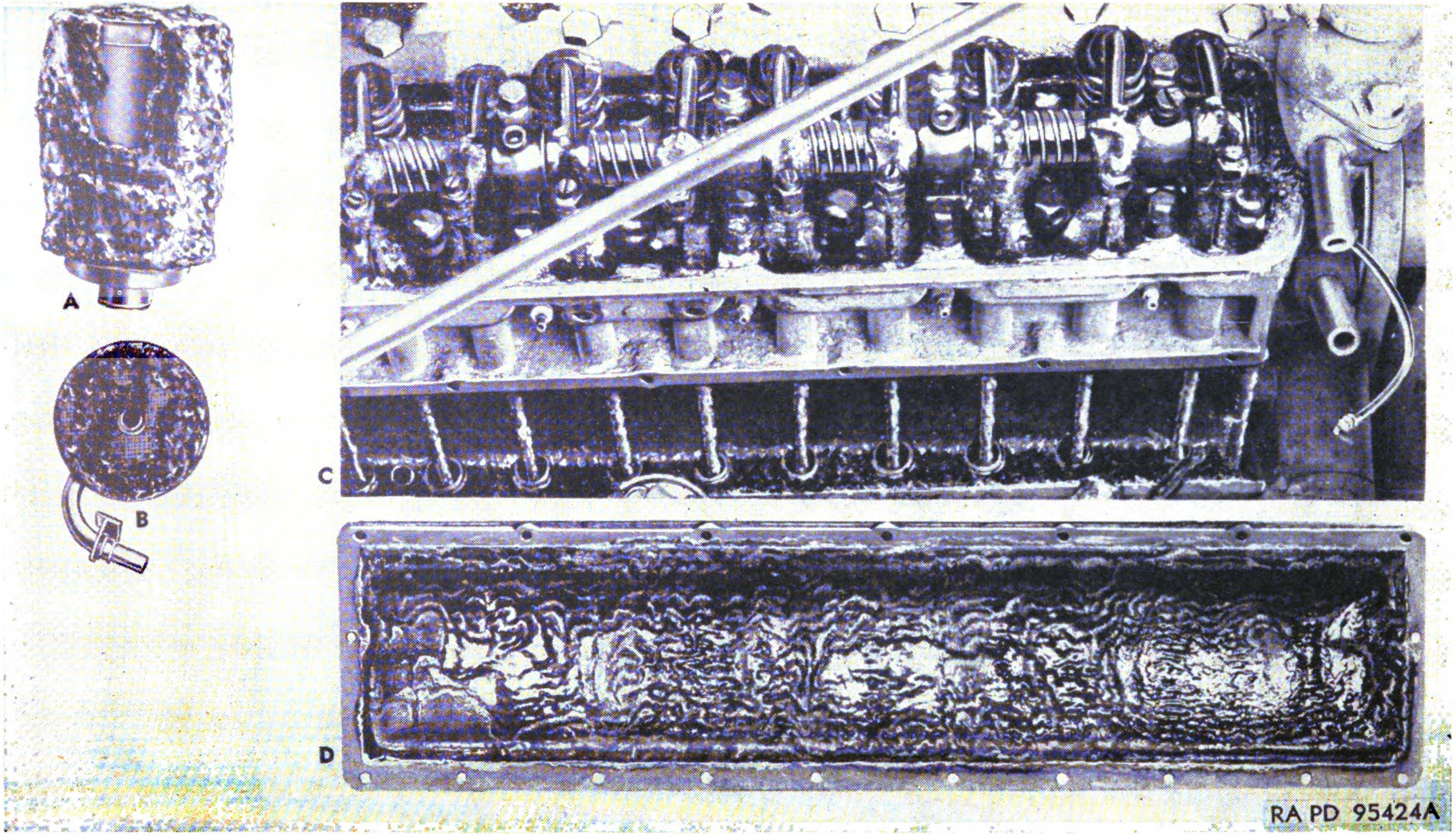


Figure 83.—Sludge accumulation on (A) oil filter, (B) oil pump strainer, (C) valve mechanism, and (D) valve cover plate.

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° F. 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.

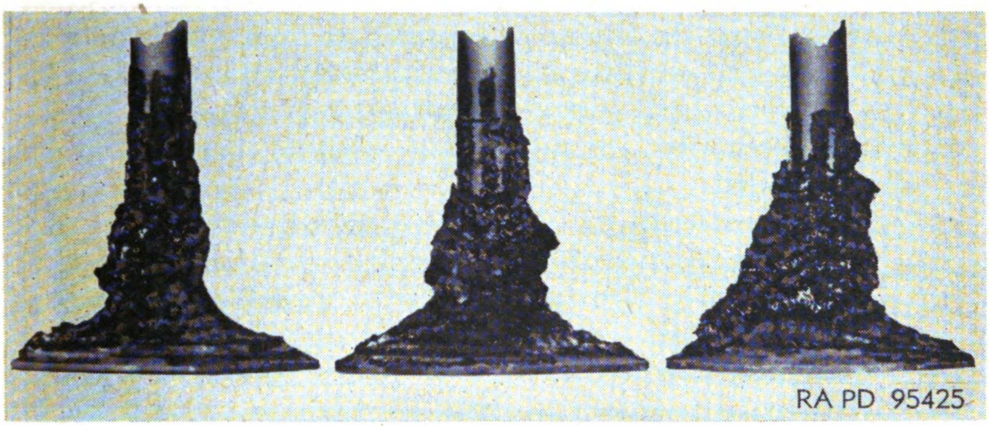


Figure 84. Gum deposits on valve stems.

(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° F. 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° F. 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 practice of running engines for prolonged periods at idling speeds to warm them will be discontinued. 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 solely to charge batteries is prohibited.

(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 following procedures will be used in flushing:

(*a*) Fill the crankcase with an engine conditioning oil to half capacity for engines with pressure circulation systems or to the full mark for engines with splash systems.

(*b*) Run the engine at fast idle for one-half hour with the radiator blanketed in order to assist in warming the oil.

(*c*) Maintain the cooling system between +180° and +200° F., watching the water temperatures and oil pressure gage continuously.

(d) Drain crankcase, replace filter elements, and refill with proper oil.

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 85 shows graphically how engine depreciation develops progressively when preventive maintenance operations are not performed or are ineffective for any reason.

54. 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 86 to 90 inclusive show average results of operation under varying climatic 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. 86). 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 86 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° decrease in temperature.

c. Engine Sludge. From figure 87 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

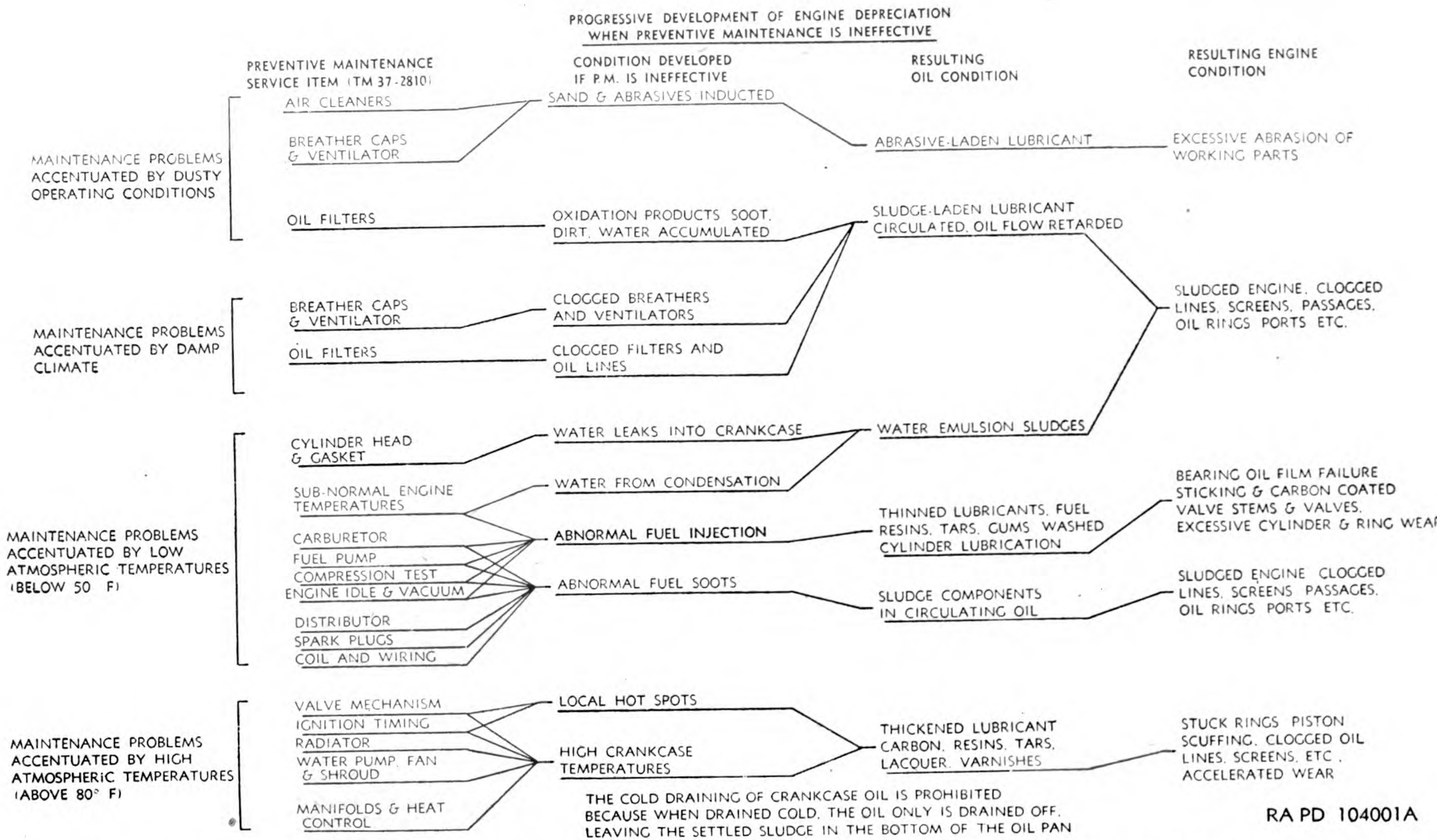


Figure 85. Progressive development of engine depreciation when preventive maintenance is ineffective.

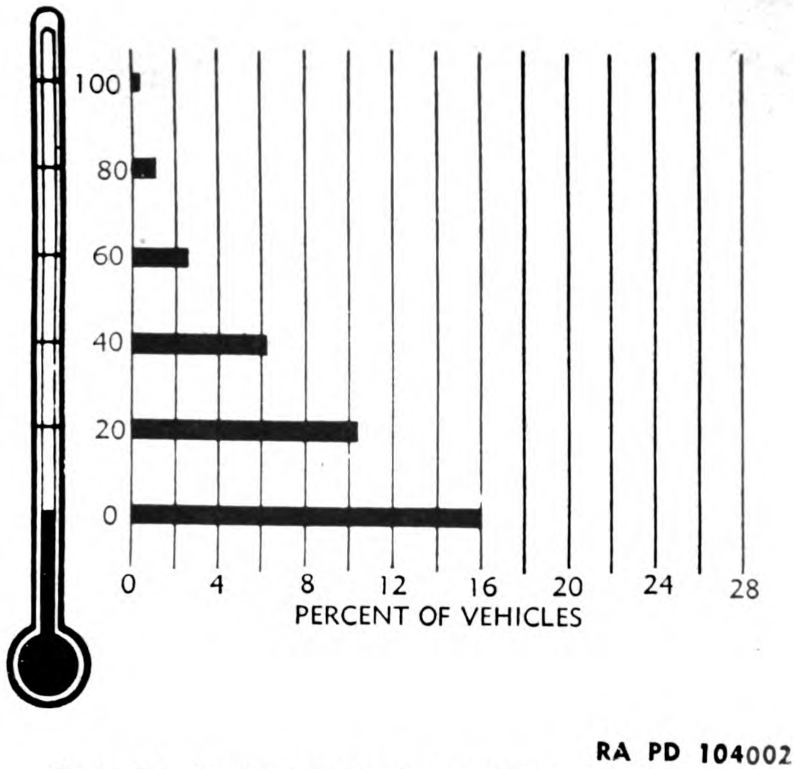


Figure 86. Prevalence of water emulsion in crankcase oil.

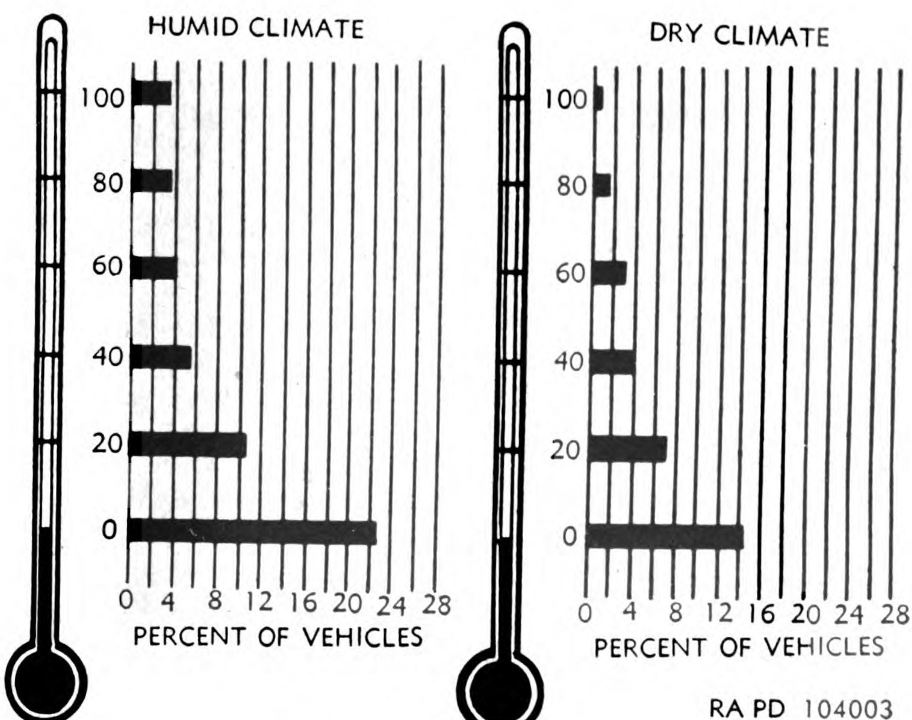


Figure 87. Prevalence of sludge in crankcase oil.

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.

d. INEFFECTIVE FILTRATION. It will be noted from figure 88 that the increase in rate of filter loading or the decrease in filtering effectiveness closely parallels the formation of sludge (fig. 87). 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 temperature, is an important element in the rate of filter loading.

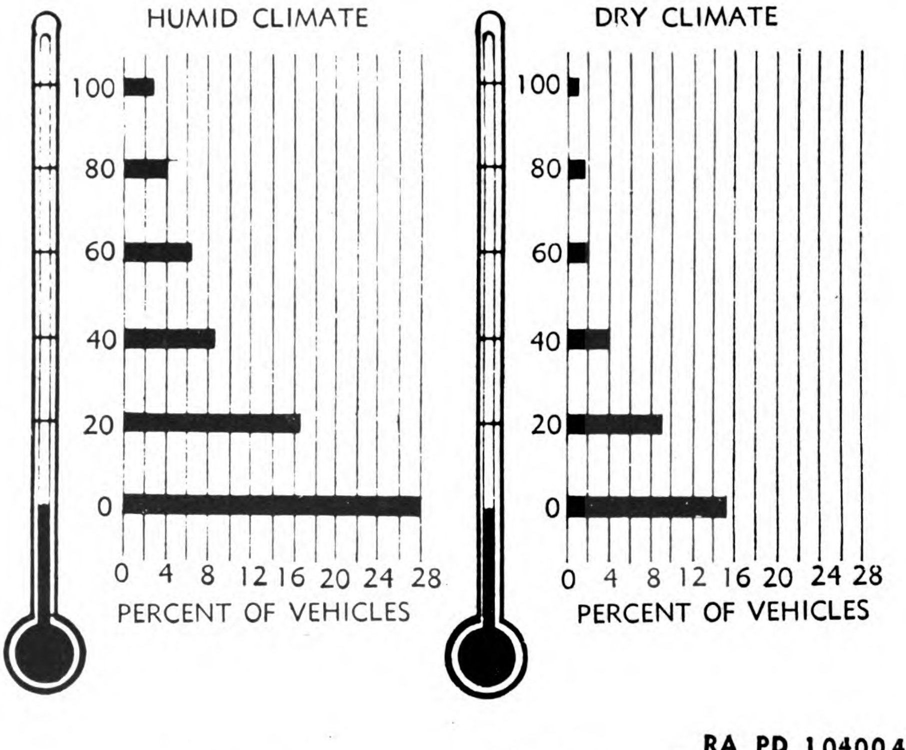


Figure 88. Prevalence of ineffective filtration.

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 soot and unburned fuel (fuel dilution) increases at corresponding rates (fig. 89.)

f. ACCELERATED WEAR. Two prime causes for abnormal wear of military vehicle engines are cold engine starting and dusty operating conditions. Figure 90 shows the relative rate of increase in abnormal wear chiefly due to cold starting of engines in relation to the prevailing

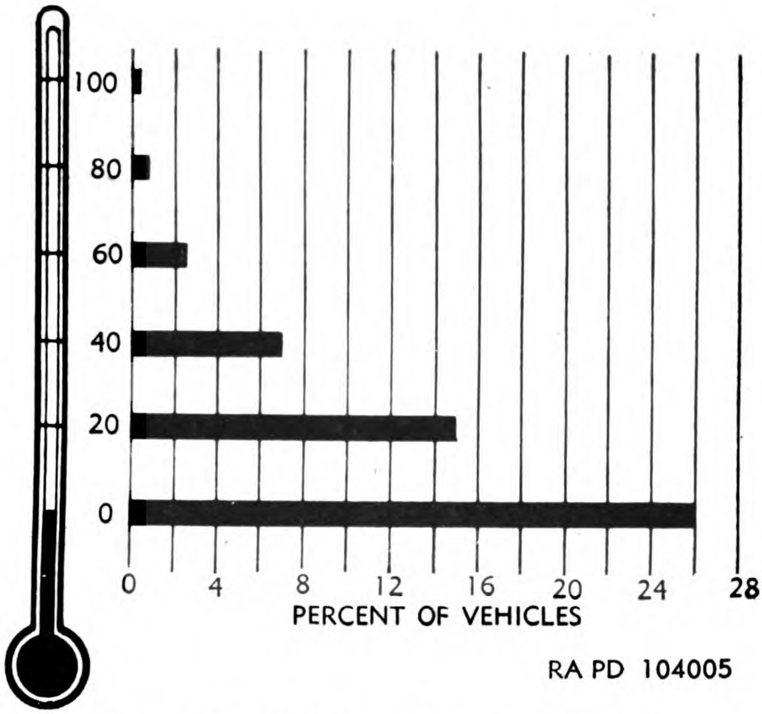


Figure 89. Prevalence of poor combustion.

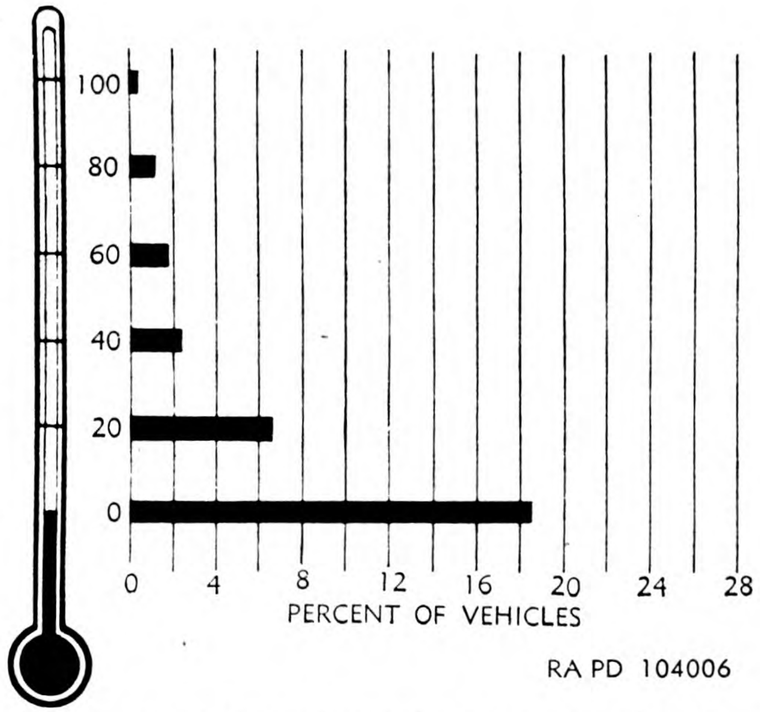


Figure 90. Prevalence of abnormal wear due to low atmospheric temperatures.

air temperature. In this connection it must 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 warm-up procedures be followed for operation at temperatures below this point.

g. **Results of Tests.** Charts showing average results of tests from vehicles of training organizations within continental United States

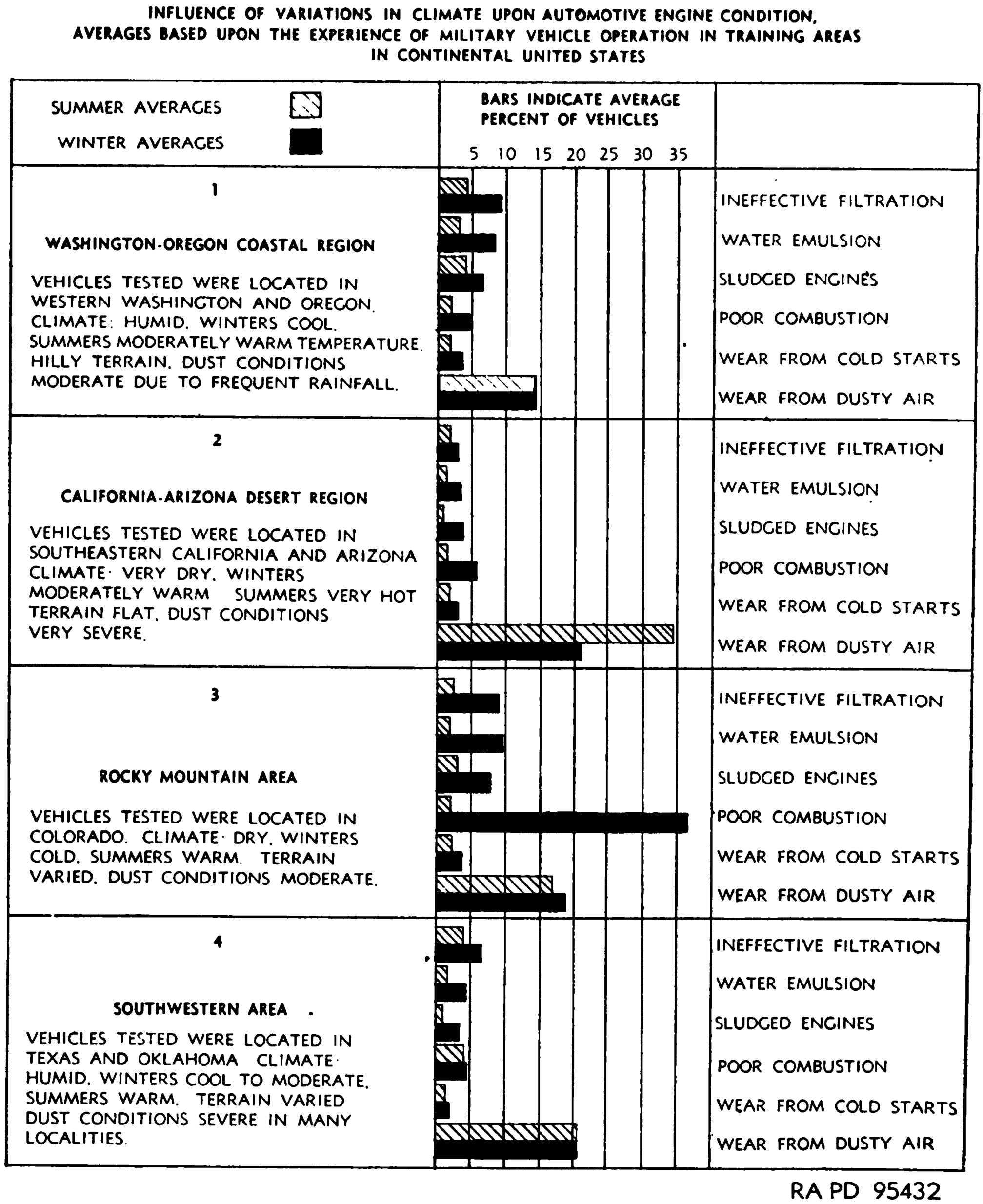


Figure 91. Influence of variation in climate upon automotive engine condition.

are shown in figures 91 and 92. The locations of installations from which tests were taken are indicated on the outline map (fig. 93) on which zones of average temperatures are shown. A world outline map (fig. 94) 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 I gives climatic data for representative points throughout the world.

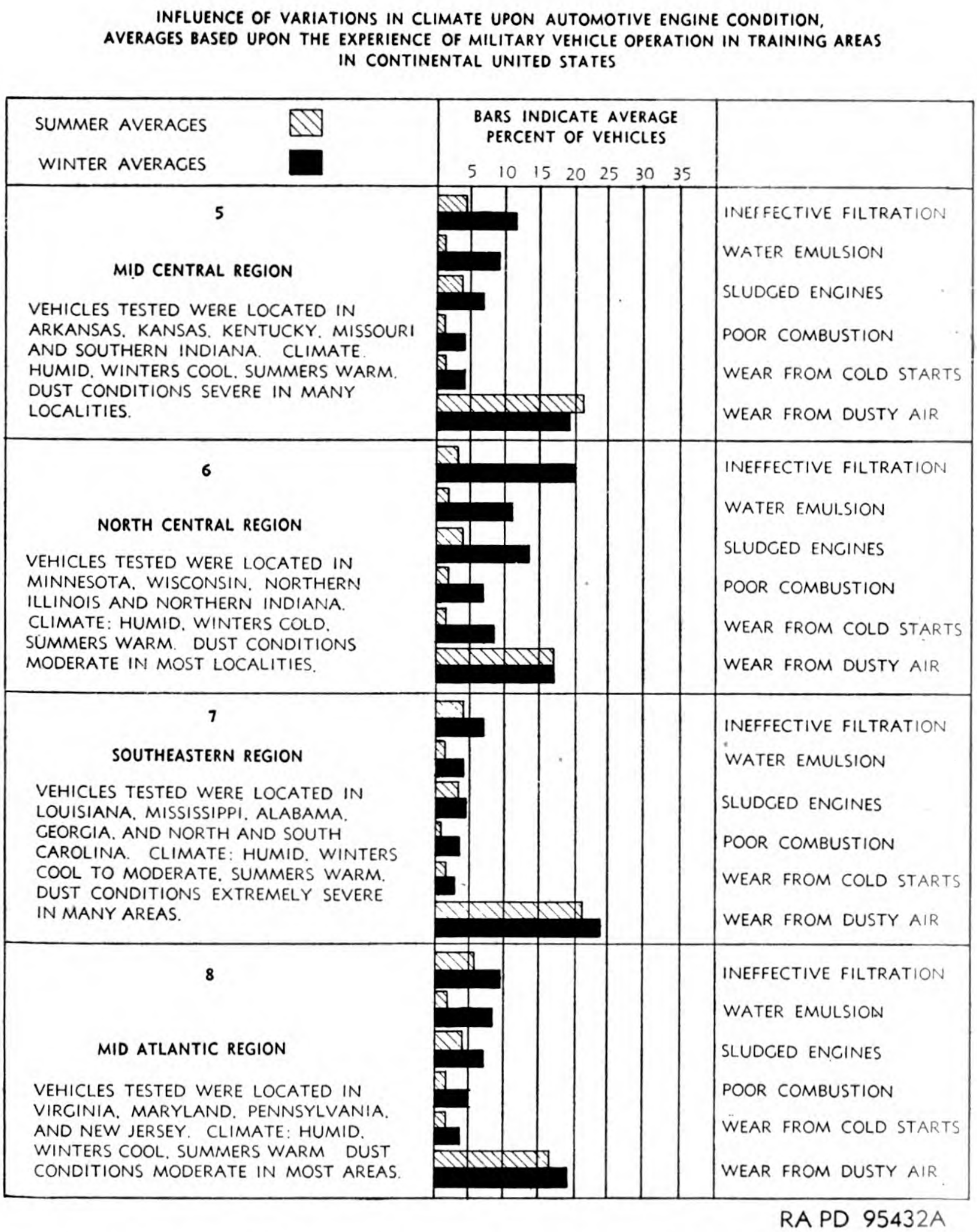


Figure 92. Influence of variations in climate upon automotive engine condition.

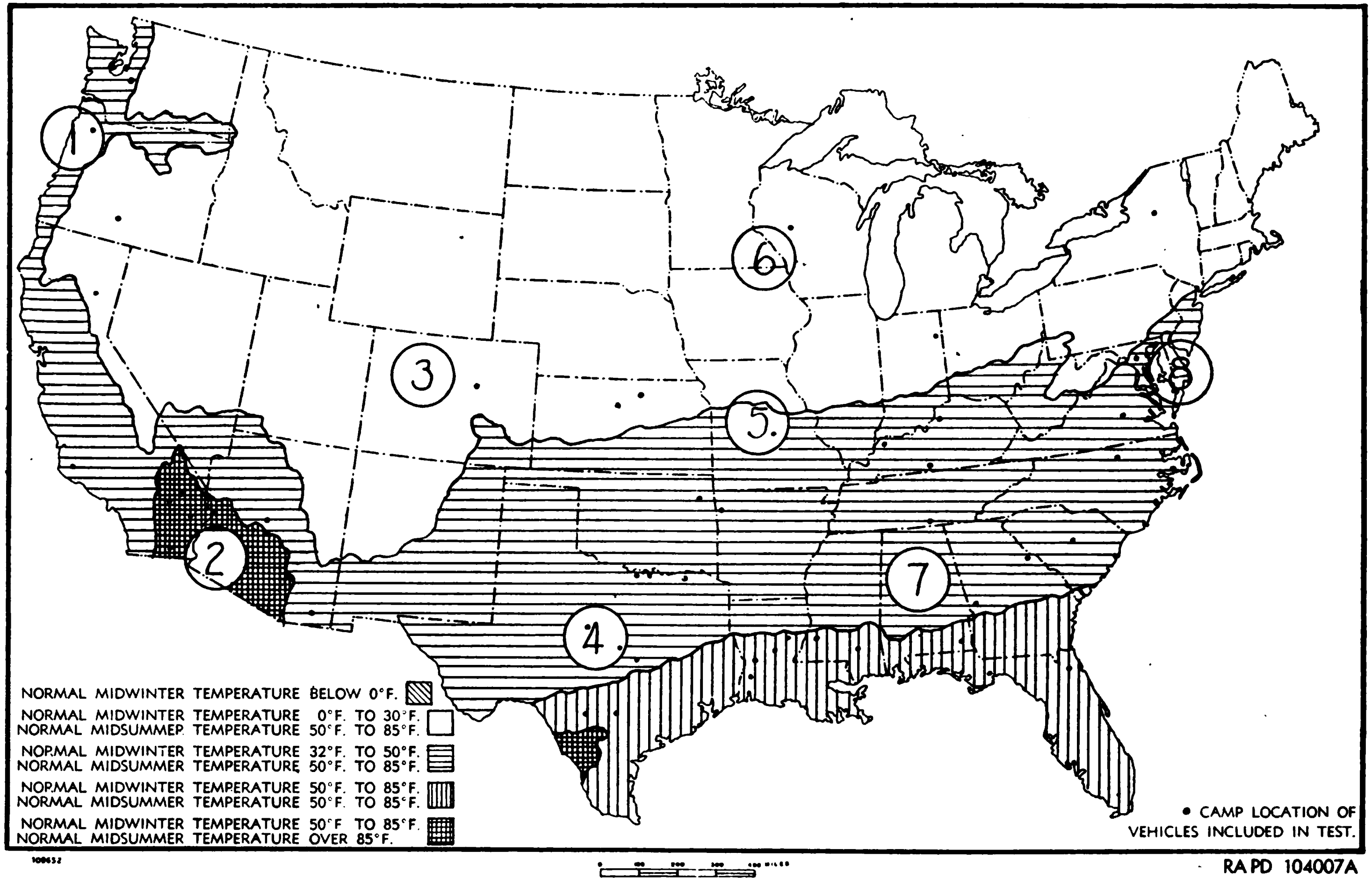


Figure 93. Map of the United States showing test points and temperature zones. Figures in circles indicate areas discussed in figures 91 and 92.

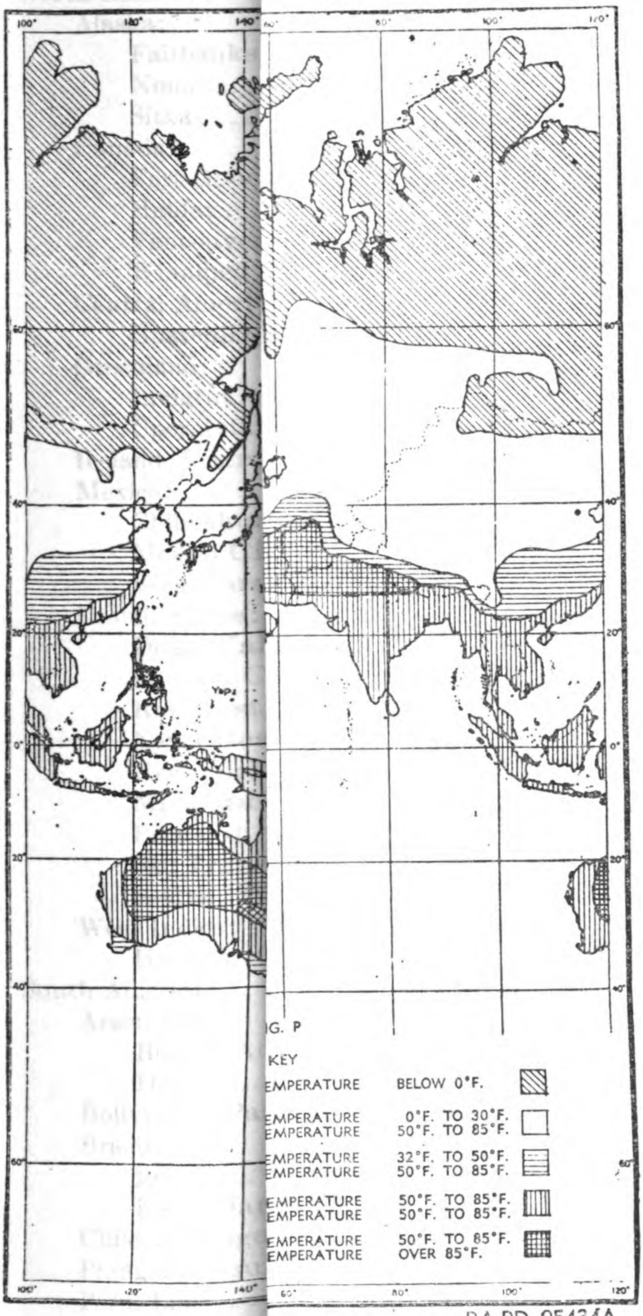


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Table 1. Climatic Data for Representative Points Throughout the World

	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	−20	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

Table 1. Climatic Data for Representative Points Throughout the World—Con.

	Normal temperatures (Degrees F.)		Extremes (Degrees F.)		Annual rainfall (Inches)
	January	July	Max.	Min.	
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
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
Portugual, 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

	Normal temperatures (Degrees F.)		Extremes (Degrees F.)		Annual rainfall (Inches)
	January	July	Max.	Min.	
Asia—Continued					
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
Iraq, 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
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:					
Bulun	−40. 0	52. 7	85	−75	8. 75
Guriev	12. 2	78. 4	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. 5	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

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Section XI

AUTOMOTIVE MATÉRIEL—COLD WEATHER LUBRICATION

55. 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 current applicable lubrication orders and technical manuals for prescribed lubricants and pertinent instructions for extreme cold weather operation.

b. ENGINE LUBRICATION OILS.

(1) *General.* Refer to paragraph 53 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 stand-by 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*) Engine oil may be diluted with gasoline prior to shut-down (see (4) below).

(*d*) 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 the oil too hot. Heat to not more than 180° F. (Heat only to a point where the bare hand can be inserted without burning.)

(*e*) 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° F. 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 (refer to par. 53). Consult the applicable operator's (100-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.

(4) *After operation.* After each operating period, the engine lubrication system must be inspected and serviced to insure necessary conditions for the next starting attempt. Inspect oil pan, valve covers, gaskets, and any external units of the en-

gine lubrication system for leaks, and correct as necessary. Check quantity of engine oil and fill to prescribed level. Unless it is known that engine oil will remain sufficiently fluid under existing temperatures during the shut-down period, all vehicles which have no equipment available to warm the engine oil will dilute the engine oil as outlined below.

(*a*) *Vehicles equipped with oil dilution tank.* With engine idling, depress dilution valve handle, allowing gasoline to fill dilution tank. Raise dilution handle, allowing gasoline to flow into engine oil pan. Continue this process until 1½ quarts of gasoline have been added for each 5 quarts of engine oil. (*Example:* Crankcase with capacity of 10 quarts will require 3 quarts of gasoline as an oil diluent.) Run the engine 5 to 10 minutes to mix the lubricant and diluent thoroughly. Shut down engine.

(*b*) *Vehicles not equipped with oil dilution tanks.* Check to make sure crankcase oil level is at the *full* mark on the oil level gage. Add 1½ quarts of gasoline for each 5 quarts of crankcase oil capacity. Run the engine 5 to 10 minutes to mix the oil and the diluent thoroughly. Stop the engine and note that the level of the diluted oil is above the normal full mark on the oil level gage.

(*c*) *Redilution.* The presence of a large percentage of light diluent will increase oil consumption and, for that reason, the oil level must be checked frequently and undiluted engine oil added to bring level up to normal full mark. If the engine is operated 4 hours or more at operating temperature, redilution will be necessary if it is anticipated that the vehicle will be left standing unprotected for 5 hours or more. This can be accomplished by filling the crankcase to the normal *full* mark on the oil level gage with engine oil and adding gasoline as indicated above.

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 shut-down 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 reestablish the film, bearing and gear teeth surfaces may score and fail.

(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 shut-down 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.

Section XII
SMALL ARMS MATÉRIEL

56. General

The problem of the lubrication of small arms is rather peculiar because of the fact that cleaning, lubricating, and preserving are so closely related that it often is very difficult to determine where one subject leaves off and the next begins. Most of the friction surfaces fall into two general classes—first, slide or guide bearings of various types or styles, a majority of which have reversing, intermittent motion; and second, journal-type bearings operating only intermittently and at slow speeds and generally with rotary movements of less than 360°. The result is that the lubrication problems are not severe as long as the friction surfaces are free of dust, dirt, water, rust, corrosion, etc.; but if any of these find their way between the friction surfaces they are likely to cause a malfunction. Although oil is used in the bore and chamber of small arms weapons, it is for preservative purposes only when the weapon is not in use. It always is removed before the weapon is fired because it will cause hazardous chamber pressure.

57. Detailed Lubrication Instructions

a. To provide satisfactory lubrication and protection against rust, always clean and dry all metal parts thoroughly before applying a lubricant or preservative. In damp climates, make certain that patches used for drying are truly dry and not damp with atmospheric moisture.

b. Grease is used to lubricate the surface of the bolt-actuating cam on the operating rod, the bolt-locking recesses in the receiver, the hammer-actuating cam on the rear of the bolt, and the upper and lower circular surfaces forming the receiver bridge at the rear end of the bolt of the U. S. rifles, cal. .30, M1 (series) and similar surfaces on the cal. .30 carbines. Wipe these surfaces dry with a clean, dry cloth and then coat lightly with grease. This can be done best by rubbing the grease onto the surfaces with the finger tip.

c. At temperatures below 0° F. and at all temperatures on aircraft weapons, only the slightest trace of lubricant will be applied. Thickening of a heavy film of oil or grease at low temperatures may cause malfunctioning. Apply oil by rubbing the parts with a patch which has been wet with oil and wrung out.

d. The ordinary care, cleaning, and oiling described will be depended upon only for day-to-day preservation of small arms.

e. In sandy terrain, wind-blown sand sticks to surfaces coated with a normal film of oil. This sand causes malfunctioning and rapid wear. External parts will be degreased thoroughly and left dry. Internal parts not likely to collect sand will be given only a slight trace of lubricant.

f. Points on machine gun mounts which require oilcan lubrication generally will be lubricated periodically with oil in accordance with the current applicable lubrication order. However, this interval will be reduced under extreme conditions, such as exposure to moisture, humidity, salt air, and during landing operation.

g. Points on machine gun mounts equipped with lubricating fittings (hydraulic type) will be lubricated as prescribed by current pertinent lubrication orders and technical manuals.

Section XIII

ARTILLERY MATÉRIEL

58. Basic Lubricated Surfaces

a. GENERAL. Artillery uses the same two basic types of bearings, friction and antifriction, that are used in other matériel. 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 cannon; 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 cannon. The slide bearings which permit a cannon 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 elevating 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 matériel. Lubrication of specific items of artillery will be performed in accordance with applicable lubrication orders and technical manuals.

b. IDENTIFICATION OF LUBRICATION POINTS. Oil cups, lubrication fittings, oilholes, and other lubricating points are circled in red for ready identification and location. In applying the paint circles, great care should be used not to apply paint to the fittings themselves, as it will clog them and is liable to reach the bearing surfaces and cause trouble.

59. 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 (fig. 95), 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 relubricated 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 with disastrous results.

60. Recoil Slide Rails

Recoil slide rails serve to guide the motion of the tube during recoil and counterrecoil. Two rails (fig. 96) 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, some being lubricated with oil and some with grease. 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.

61. Interrupted-Screw Breech Mechanism (figs. 97 and 98)

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 with the result that corrosion is as much a problem as lubrication. A light film of oil works best for lubricating purposes and frequent cleaning and relubrication 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.

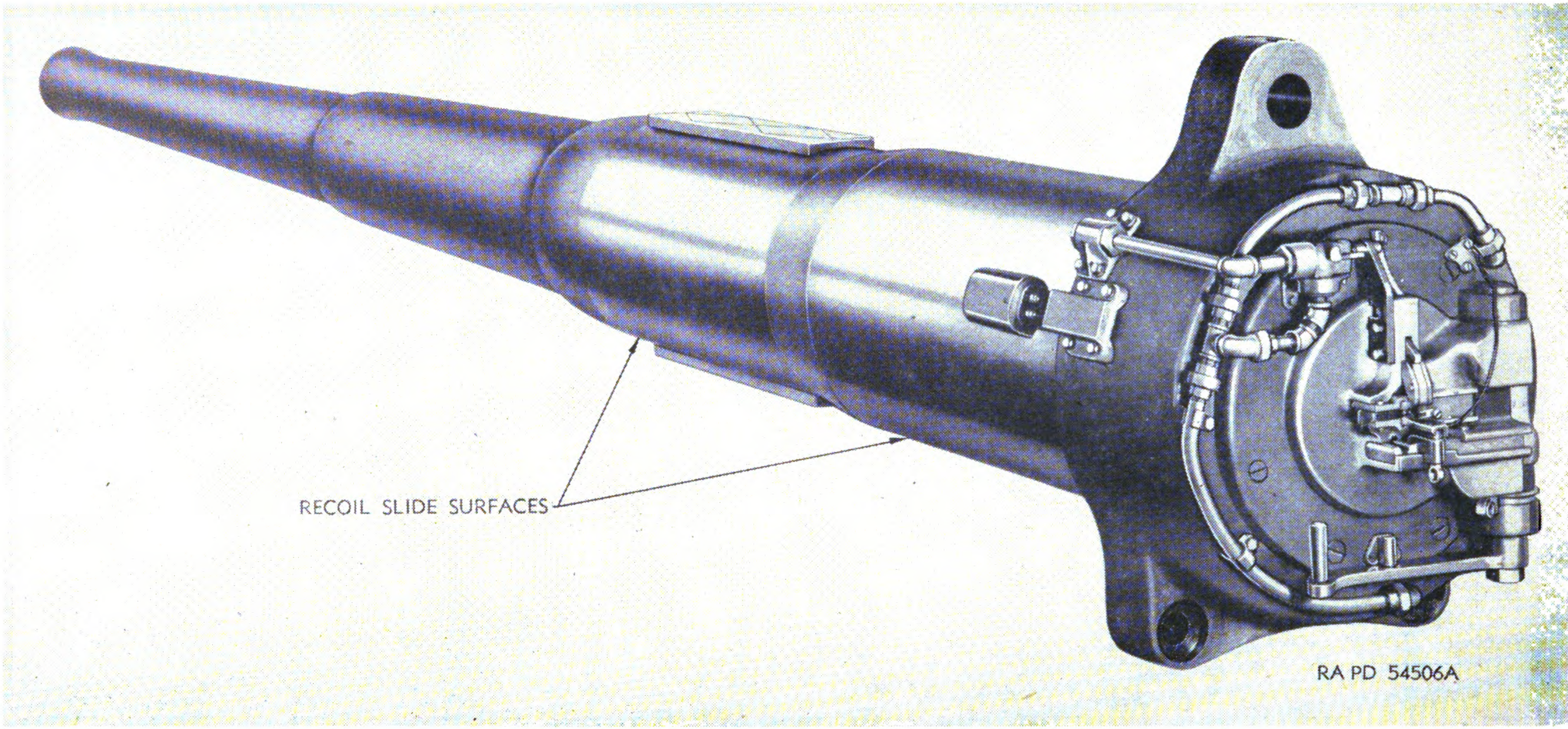

Figure 95. 6-inch gun showing recoil slide surfaces.

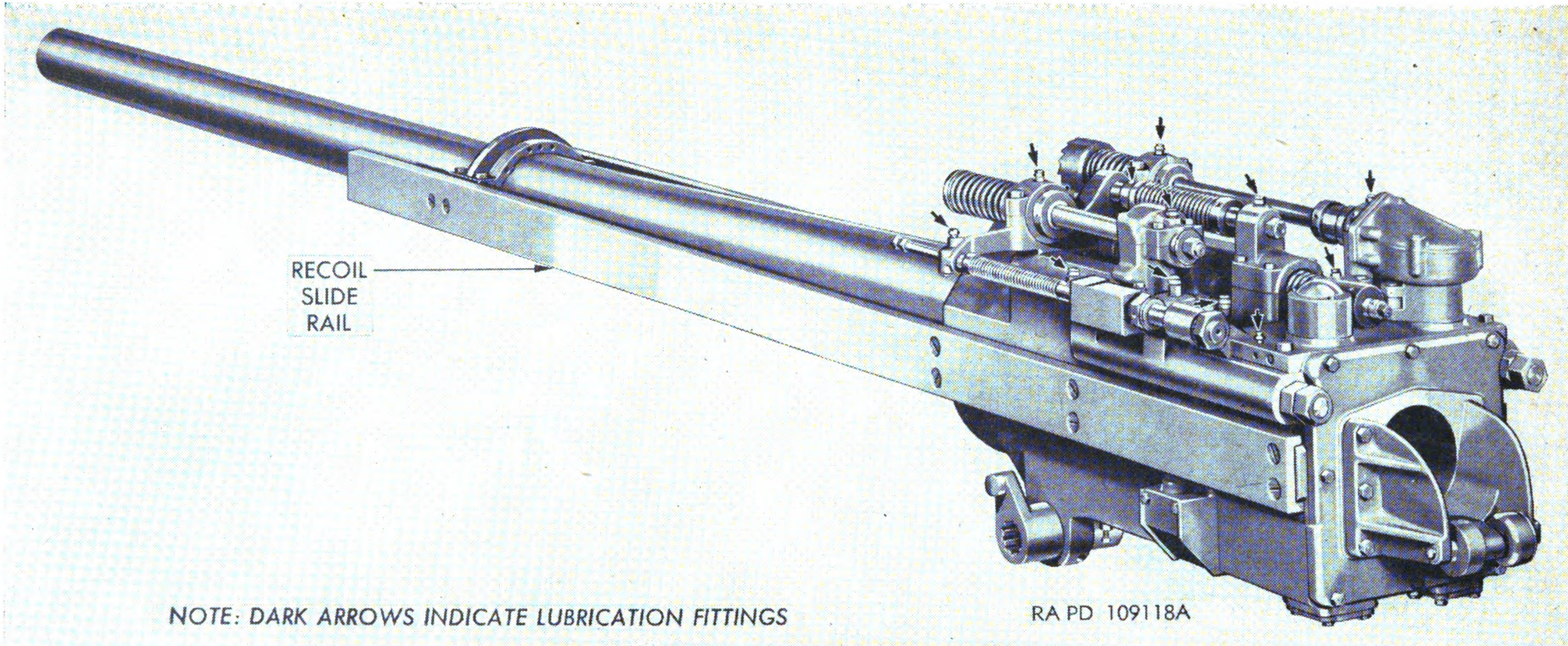

Figure 96. 90-mm gun showing slide rails.

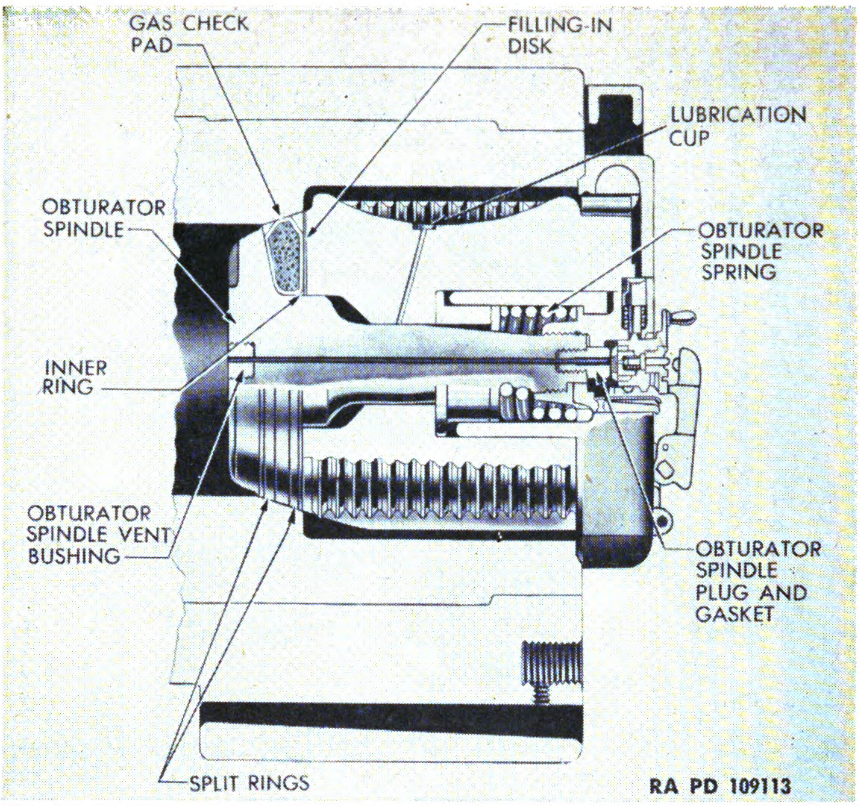

Figure 97. Section of a typical breechblock of the interrupted-screw type.

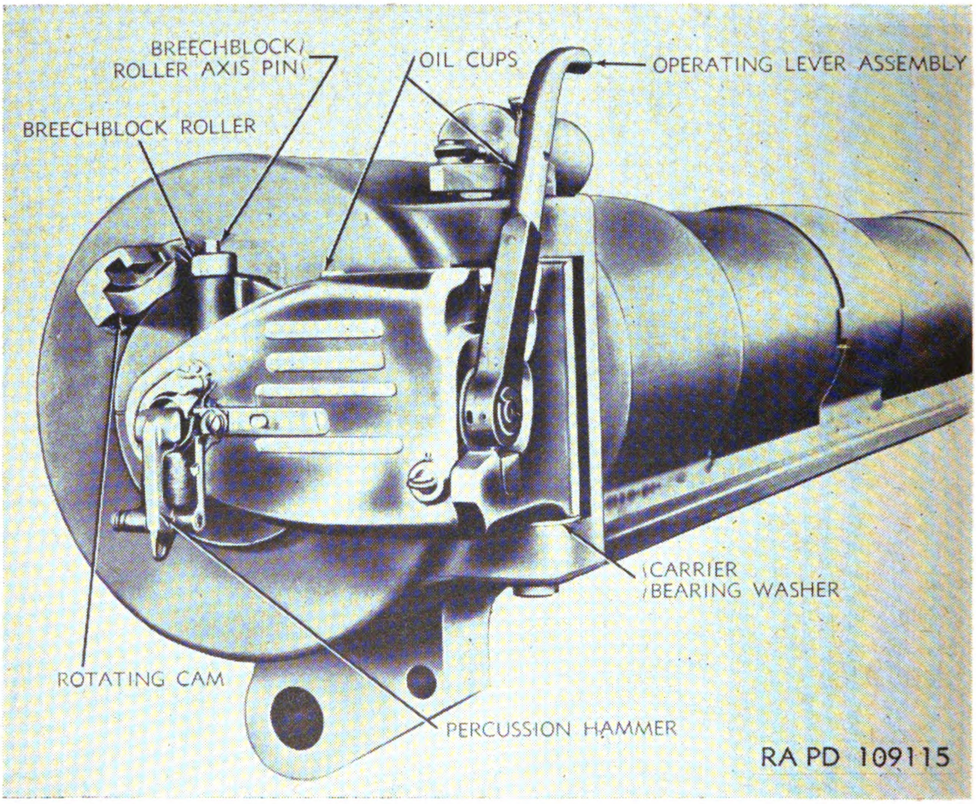

Figure 98. Operating mechanism for interrupted-screw type breechblock.

62. 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 counterrecoil. Where a sleigh is used (fig. 99), 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,

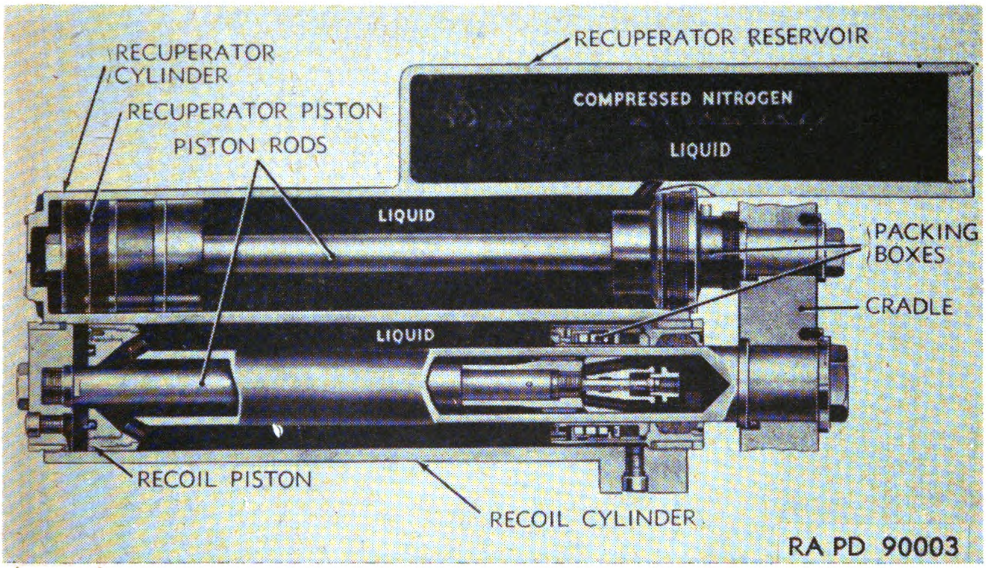

Figure 99. Recoil system with cylinders fixed in the sleigh.

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. There must be no deviation from the use of recoil oils prescribed in applicable lubrication orders and technical manuals.

63. Elevating and Traversing Mechanisms

a. Elevating Mechanisms. An elevating mechanism may be quite simple and composed of few parts as on the 81-mm mortar, or may be quite complicated with many parts such as on an 8-inch gun. The motions of most bearing surfaces are at comparatively low bearing speeds and of comparatively short duration. The result is that most

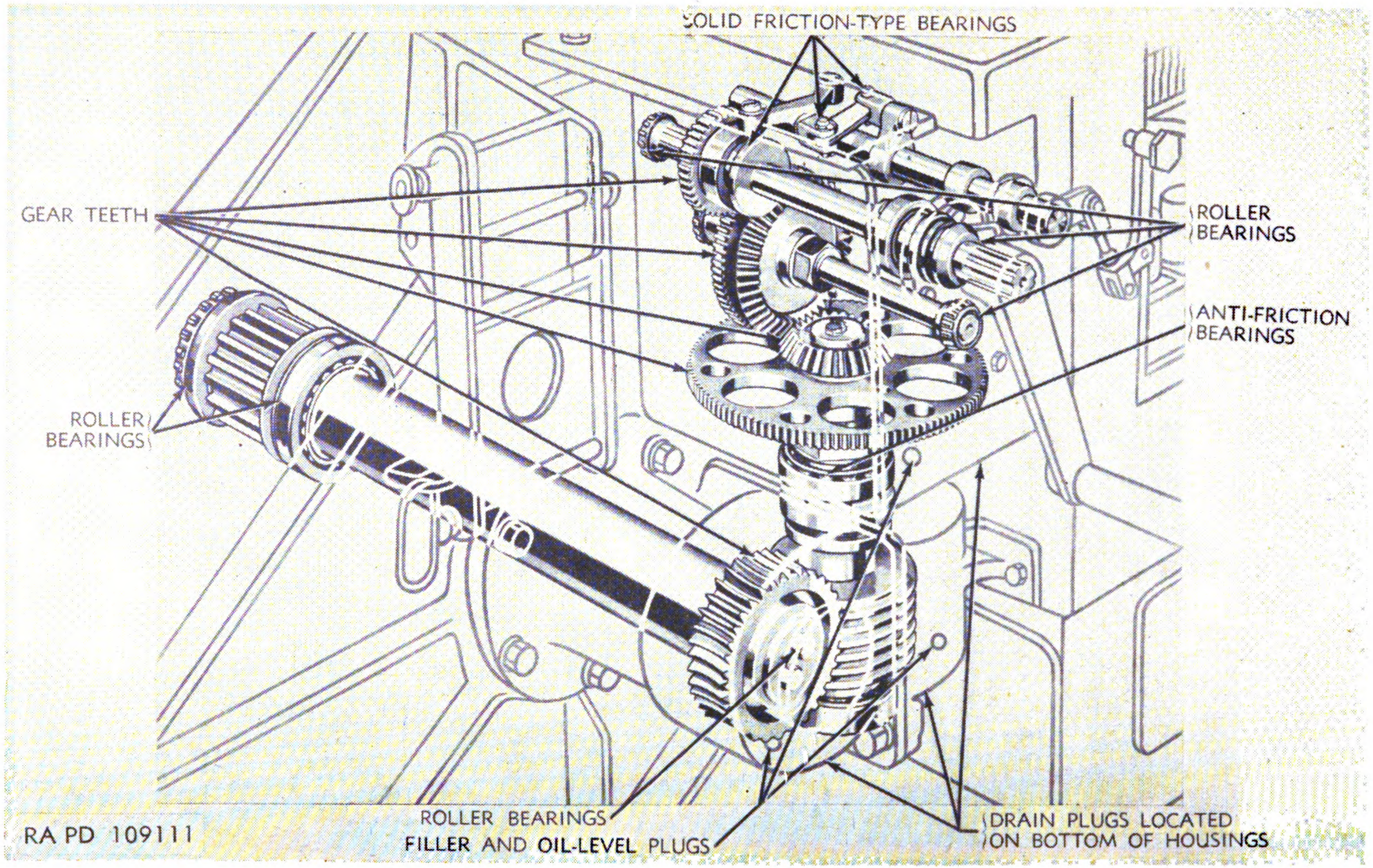

Figure 100. Elevating mechanism for a 90-mm gun.

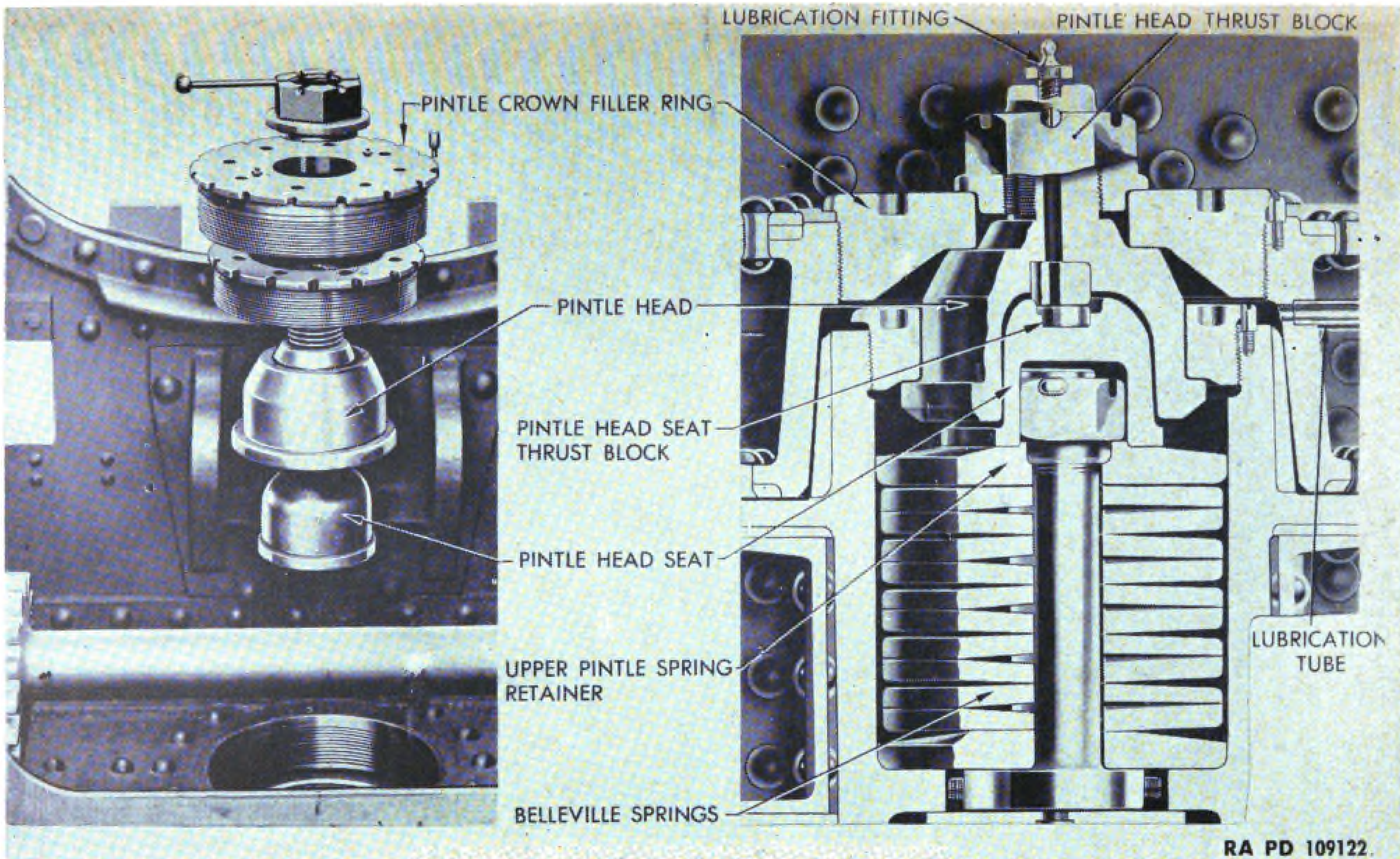

Figure 101. Pintle bearing of a 240-mm howitzer.

of the bearings are of the friction type and are lubricated with oil. Antifrication bearings are grease-lubricated, either by packing the bearings or through lubricating fittings. Gear trains which are inclosed or covered generally are lubricated with oil by the dip system or with grease. Where grease is used, only enough should be applied to furnish a proper lubricating film on the working parts and to protect the metal from corrosion. Excess grease may be difficult to remove or may create too much resistance to the movement of the gun. Trunnion bearings may be either of the journal or roller bearing type and may be either oil- or grease-lubricated. The lubrication points of an elevating mechanism are shown in figure 100, a phantom view of the gearing used for elevating a 90-mm gun either by power applied to the teeth of the power drive gear or by a hand crank.

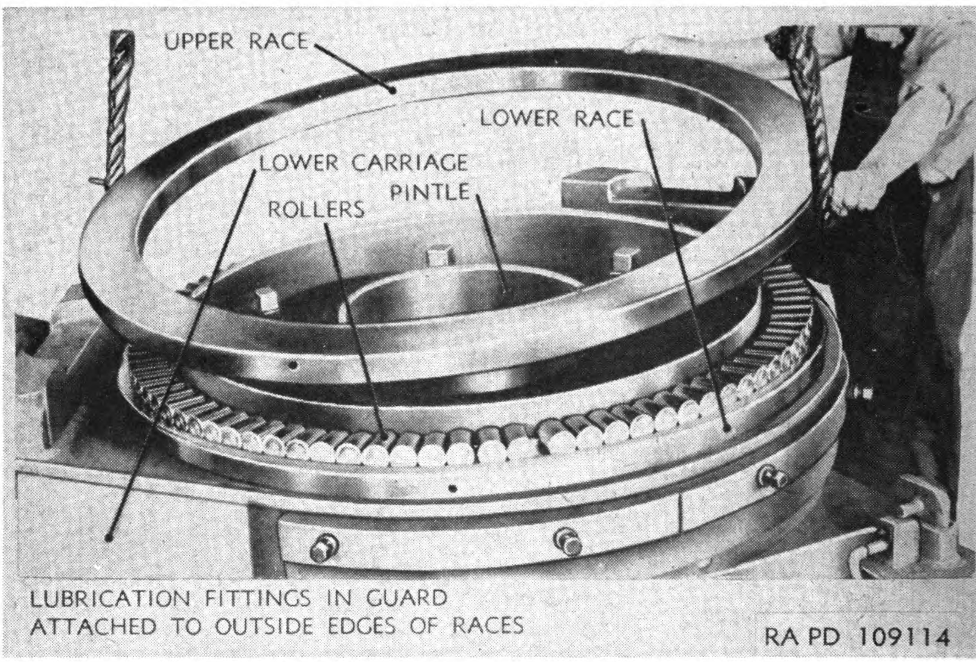

Figure 102. Traversing bearings of an 8-inch gun.

b. TRAVERSING MECHANISMS. The traversing mechanism of a weapon consists of some form of pintle (fig. 101) or a base ring (fig. 102). On large guns the base ring may be 30 feet or more in diameter with rollers about a foot in diameter, the whole assembly taking the form of a large thrust bearing. Complete disassembly usually is required for the lubrication of these parts. It is extremely important that the bearings on which a piece of artillery is traversed operate smoothly and without interference from dirt or contaminated lubricant, and it is necessary therefore that inspection, cleaning, and lubrication be performed very carefully as directed regardless of difficulty. The mechanical principles used in the operating mechanisms and the

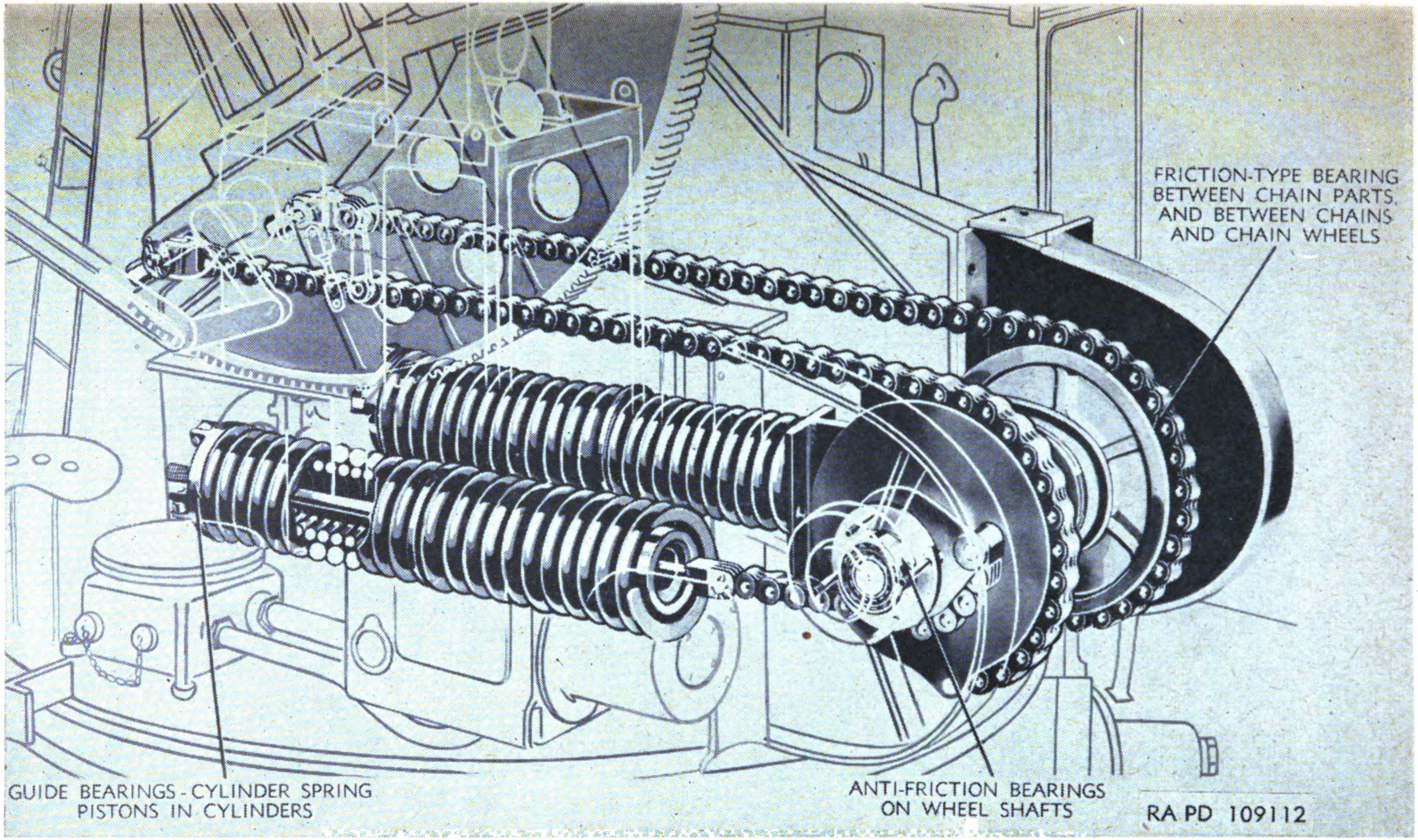

Figure 103. Spring-type equilibrator of a 90-mm antiaircraft gun.

lubrication problems presented are quite similar to those presented in the mechanisms used for elevating a gun.

64. 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 enclosed in telescoping tubular housings which ordinarily require oil lubrication of the sliding bearing between the two tubes. Other spring equilibrators (fig. 103) 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, and lubrication can 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. 104).

c. Hydropneumatic Equilibrators. In a hydropneumatic equilibrator (fig. 104), cylinders, pistons, and interior mechanisms are lubricated by the operating fluid, while the leverage adjusting mechanism and the pins or other devices used to connect the equilibrator to the cradle and carriage either are grease- or oil-lubricated.

65. Carriage

a. General. The bearing surfaces to be lubricated are incorporated in the wheels or axles on which the matériel is transported, the elevating and traversing mechanisms already mentioned, or in the various mechanisms by which the matériel 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 cases the corrosion preventive qualities of the lubri-

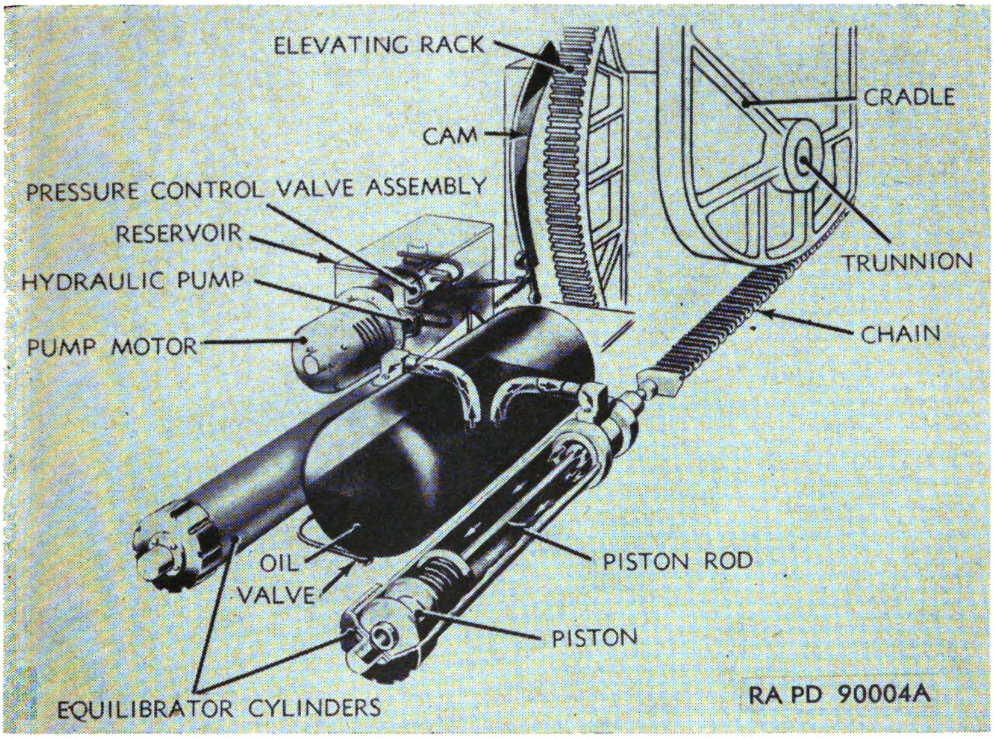

Figure 104. Equilibrator of the hydropneumatic type.

cant 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.

d. Firing Magnetos on Barbette Carriages.

(1) *General.* Two types of firing magnetos are commonly used on barbette carriages. In both types the magneto units inside the case are identical. On one type, the operating handle is on the side, and a gear train with clutch turns the rotor. On the other type, the handle is on the bottom of the case, and a rack operated vertically turns the rotor.

(2) *Lubrication.*

(*a*) To lubricate, remove the cover or case and wipe all accessible parts with a clean dry wiping cloth and apply a thin film of oil to all parts of the operating mechanism. Refer to applicable lubrication order and technical manual for instructions.

(*b*) To insure continuous maintenance of the lubricant film on all operating surfaces and to redistribute the lubricant, the firing magneto will be exercised daily by giving a few sharp pulls on the handle.

66. Hydraulic Speed Gears

On artillery using mechanical power for traversing, elevating, or loading, a hydraulic speed gear generally is used between the source

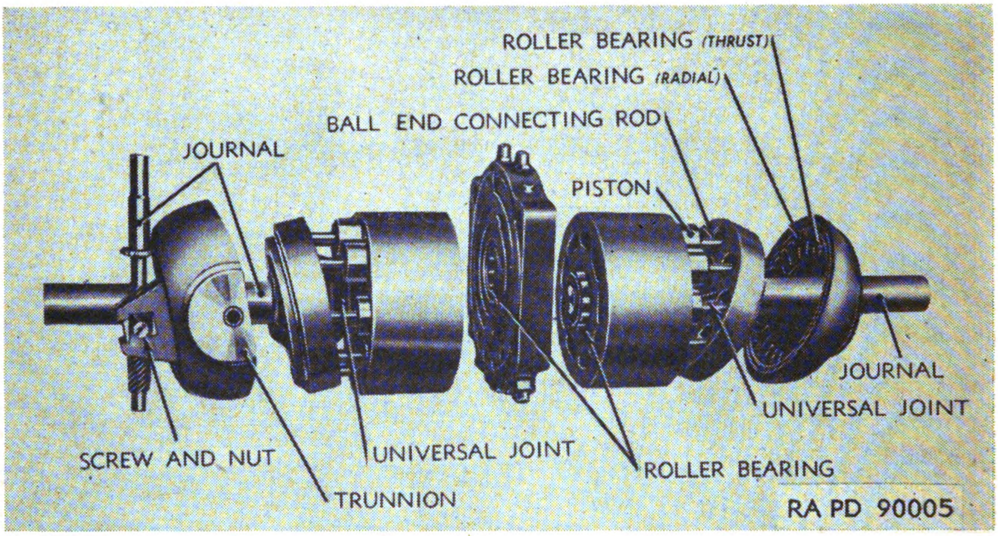

Figure 105. Moving parts of a hydraulic speed gear.

and the point of application of the power. The speed gear (fig. 105) serves to transmit the rotary power at variable speeds in either direction and without abrupt gradations. 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 current applicable lubrication order and technical manual.

67. 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.

68. Cold Weather Lubrication

a. Characteristics of Lubricants.

(1) Oils prescribed for use on artillery matériel 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 reestablish 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 matériel 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 matériel 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 relubrication, which operations must be completed before the advent of cold weather.

(2) When preparing artillery matériel 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 or 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 matériel 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 matériel 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 with rifle-bore cleaner or dry-cleaning solvent, 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 matériel 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 matériel, 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 reassembling.

(*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 that 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 reassembled 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 dry-cleaning solvent, 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 of 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 current 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.

Section XIV
SIGHTING AND FIRE CONTROL EQUIPMENT

69. General

Lubrication of most fire control matériel should be performed very carefully as even a very slight amount of overlubrication often will render an item unfit for use. Excess lubricant may creep onto lenses and obscure vision or, where subject to low temperatures, may congeal and render close fitting parts inoperative. It is very important that personnel handling fire control matériel understand that malfunctioning may result from overlubrication.

70. Optical Instruments

a. General. In the actual optical instruments used in connection with fire control matériel there are practically no friction surfaces except those required for the focusing movements of eyepieces. These friction surfaces practically always take the form of some type of screw thread, and motion is so limited that lubrication scarcely is required. It is necessary, however, to seal such points to prevent the entrance of dust, grit, or moisture; small quantities of grease are used. This grease is prepared especially for fire control systems, AA directors, 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 is 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 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 relubricated with the prescribed 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 boots or covers are used to keep dust away from ball and socket mechanisms.

d. 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 relubricating 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. Anticondensation 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

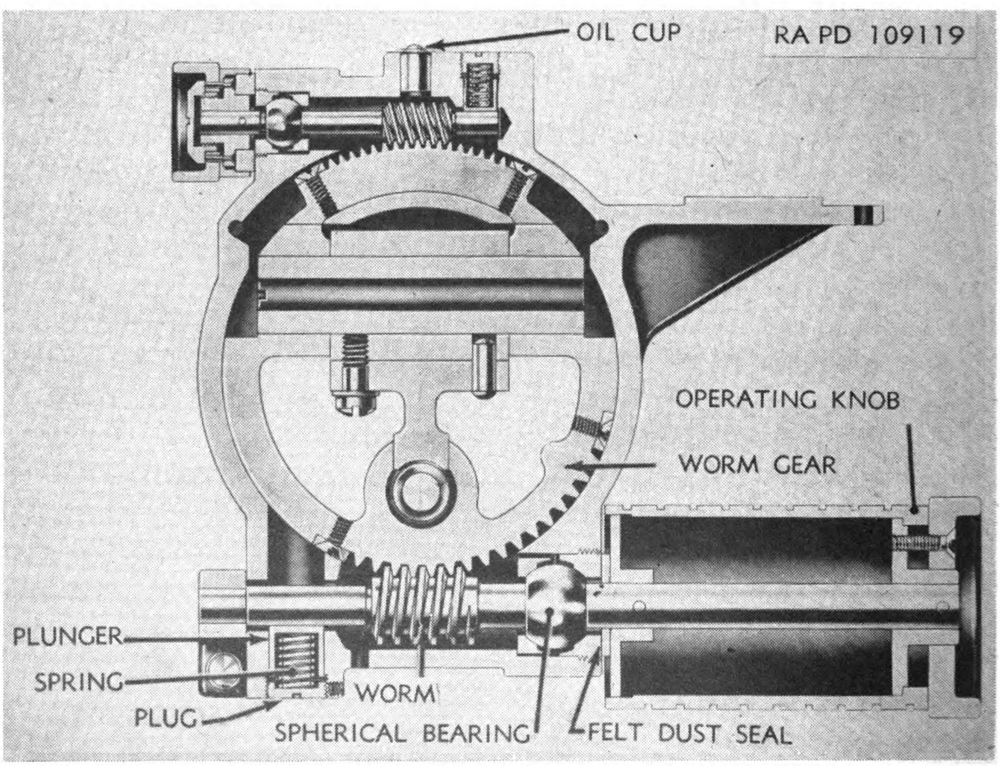

Figure 106. Typical worm and wheel measuring movement.

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.

71. Worm and Wheel Measuring Movements

Nearly all of the measuring movements incorporated in fire control matériel 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 (fig. 106). In nearly all cases the bearing surfaces including the contact between the worm and wheel are lubricated sparingly periodically in accordance with instructions in the current applicable lubrication order and technical manual. A felt seal is used to prevent entrance of dust at the point where the worm shaft 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 mechanism 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.

72. Directors and Gun Data Computers

a. GENERAL. Directors and gun data 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, backlash 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 matériel 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 shows any signs of hardening or

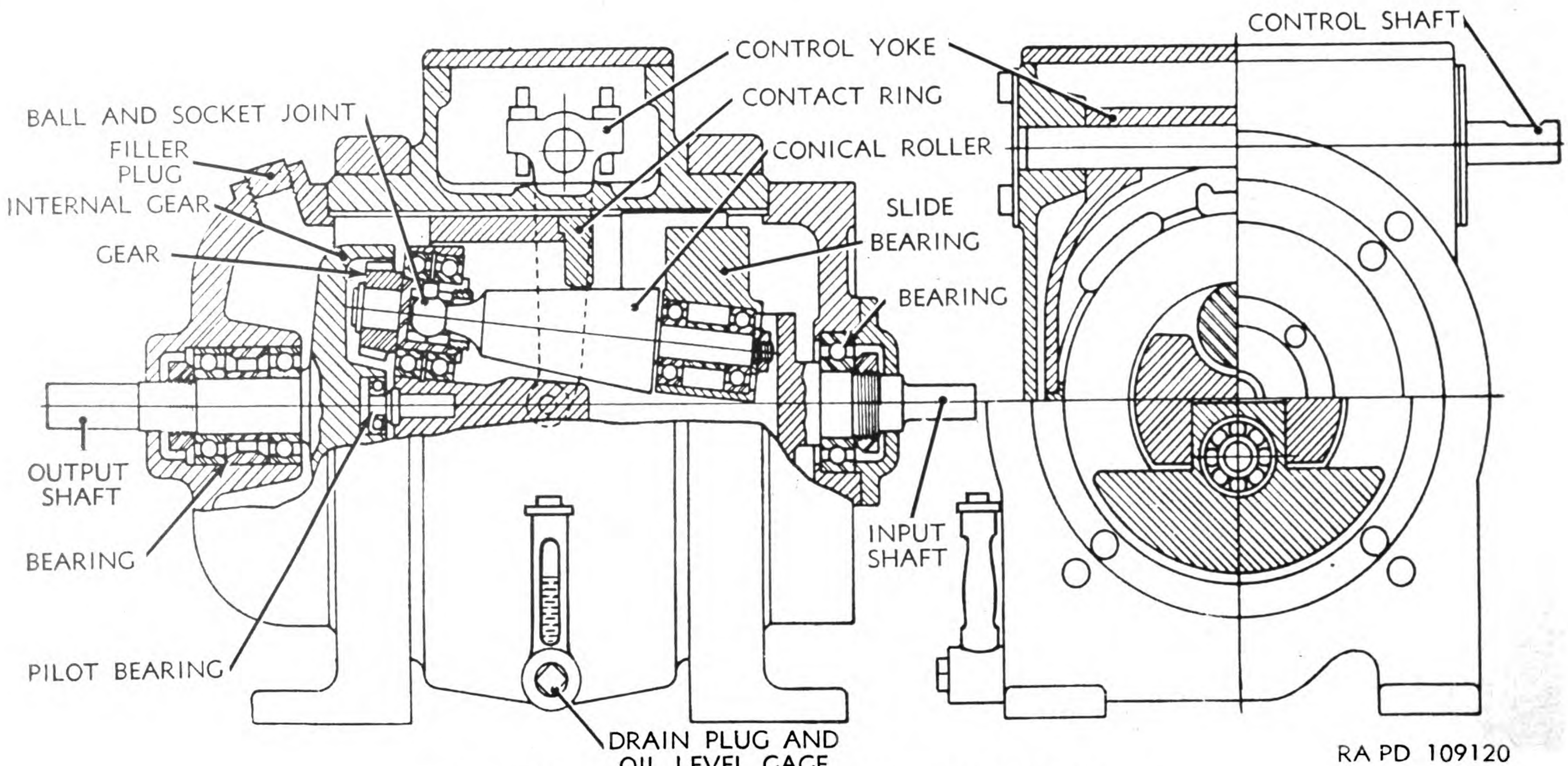

Figure 107. Variable speed drive of the conical roller type.

other deterioration, the bearing should be removed, cleaned with solvent, dried, and immediately relubricated. Units showing sluggish operation at temperatures below 32° F. should be relubricated carefully. Units which have been in storage for a considerable length of time must be completely disassembled, cleaned, and relubricated. All lubricating operations should be done in dustfree rooms.

b. Potentiometers. Surfaces to be lubricated in potentiometers 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 mechanism as well. These parts generally are installed in an oiltight housing and submerged in oil, which serves as both a lubricant and an insulating medium.

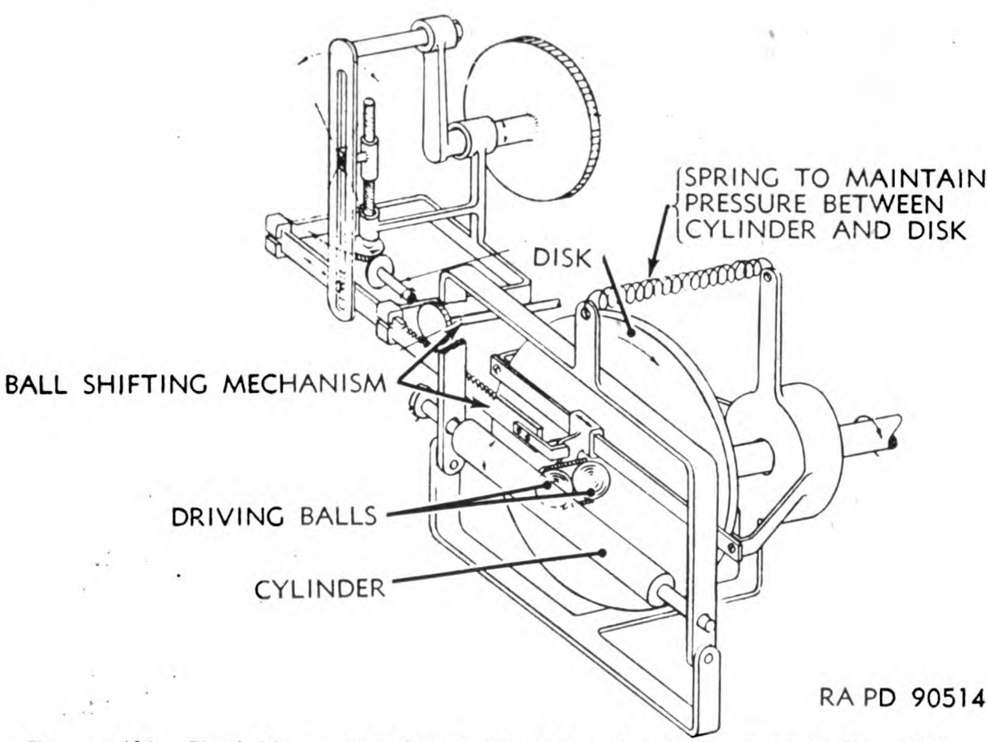

Figure 108. Variable speed drive of the disk and cylinder type (schematic).

c. Variable Speed Drives. Variable speed drives are made in a number of forms. The conical roller type (fig. 107) 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 (fig. 108) 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 for specific instructions.

73. Remote Control Systems

Remote control systems as built at the present time consist of combinations of electric, mechanical, and hydraulic equipment controlled by data received from a director and are used to position guns in both azimuth and elevation. In automatic operation, a system receives data from the director and electric power from the generator and, in accordance with this data, generates hydraulic power which is used to point the gun at the target being followed. Lubrication of the mechanical and hydraulic devices used in pointing the gun is covered in previous paragraphs. The mechanisms of oil gear transmitter and electrical differential assembly take electrical data from the director and control the oil pump and motor by adjustment of the pilot valve. They have friction surfaces of various types which are lubricated either with grease or oil where directed in pertinent technical manuals.

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

75. 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 sections VII and X 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 subzero temperature encountered.

(1) Refer to paragraph 55 *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 reassembly.

(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 relubricated 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 warm-up, the radiator should be covered to give rapid warm-up.

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APPENDIX
REFERENCES

1. Publications Indexes

The following publications indexes and lists of current issue should be consulted frequently for latest changes or revisions of references given in this appendix and for new publications relating to matériel covered in this manual:

Index to Army Regulations	AR 1-5
Introduction and Index	ORD 1
List and Index of Department of the Army Publications	FM 21-6
List of Current and Suspended Army Regulations	AR 1-10
List of Department of the Army Films, Film Strips, and Recognition Film Slides	FM 21-7
Military Training Aids	FM 21-8
Ordnance Major Items and Combinations, and Pertinent Publications	SB 9-1

2. Standard Nomenclature Lists

The following pamphlets of the Department of the Army Supply Catalog pertain to lubrication:

Cleaners, Preservatives, Lubricants, Recoil Fluids, Special Oils and Related Maintenance Materials	ORD 3 SNL K-1
Lubricating Equipment, Accessories, and Related Dispensers	ORD (*) SNL K-3

3. Other Publications

The following publications contain information pertinent to lubrication:

Basic Maintenance Manual	TM 38-650
Cleaning, Preserving, Sealing, and Related Materials Issued for Ordnance Matériel	TM 9-850

(*) See ORD 1, Introduction and Index, for published pamphlets of the Ordnance section of the Department of the Army Supply Catalog.

Decontamination ---------------------------------- TM 3-220
Dictionary of United States Army Terms---------- TM 20-205
Instruction Guide: Care and Maintenance of Ball and
  Roller Bearings-------------------------------- TM 37-265
Motor Vehicle Inspection and Preventive Maintenance
  Services ------------------------------------- TM 37-2810
Preparation of Ordnance Matériel for Deep Water
  Fording -------------------------------------- TM 9-2853

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