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January 1948

## Engineers Bulletin FT 53: Operations and Maintenance of Farm Tractors

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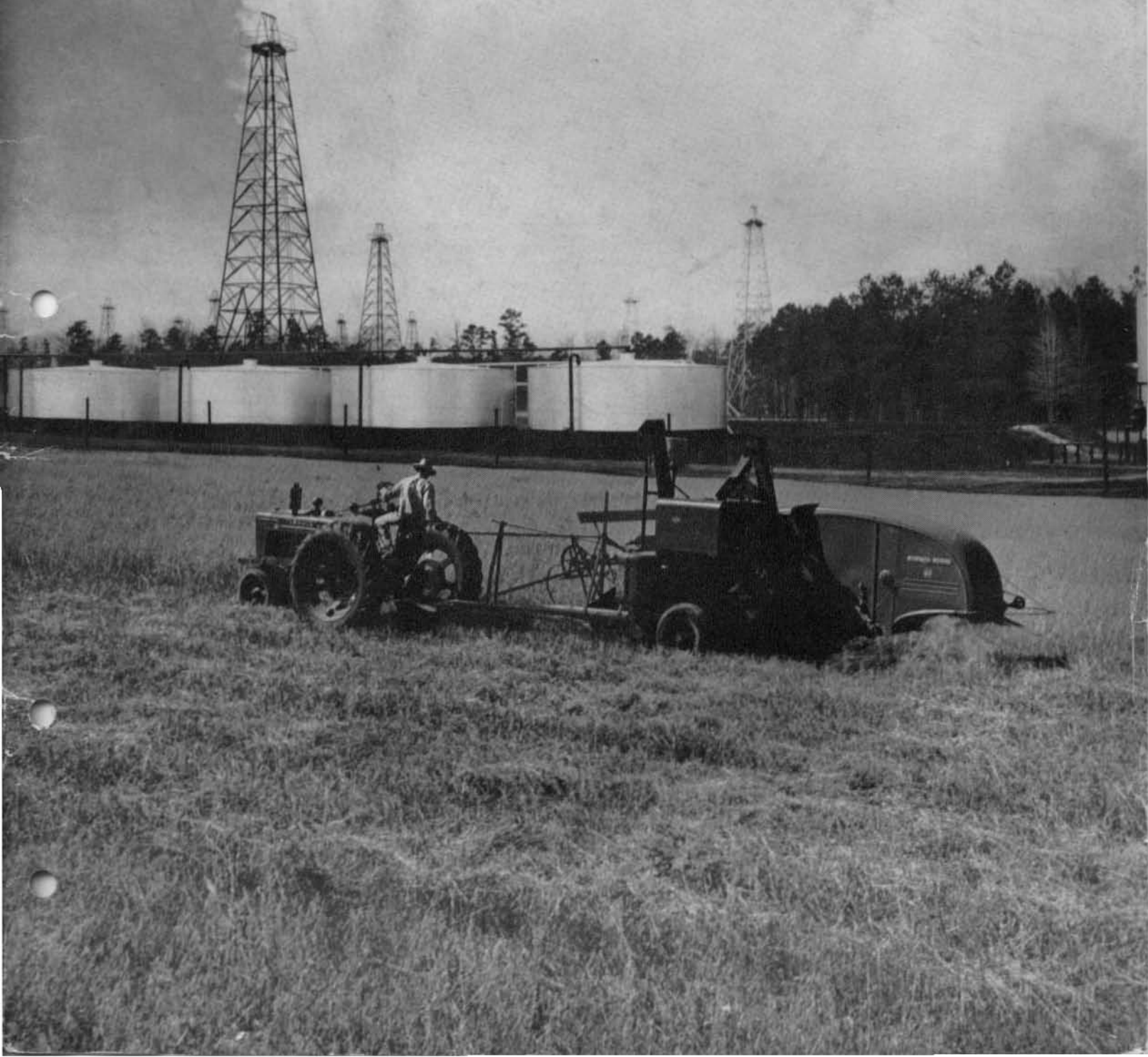
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OPERATION AND MAINTENANCE OF

# FARM TRACTORS

ENGINEERING BULLETIN FT 53



# ENGINEERING BULLETIN

## FARM TRACTORS

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STANOLIND OIL AND GAS COMPANY

TULSA, OKLAHOMA

## **FOREWORD**

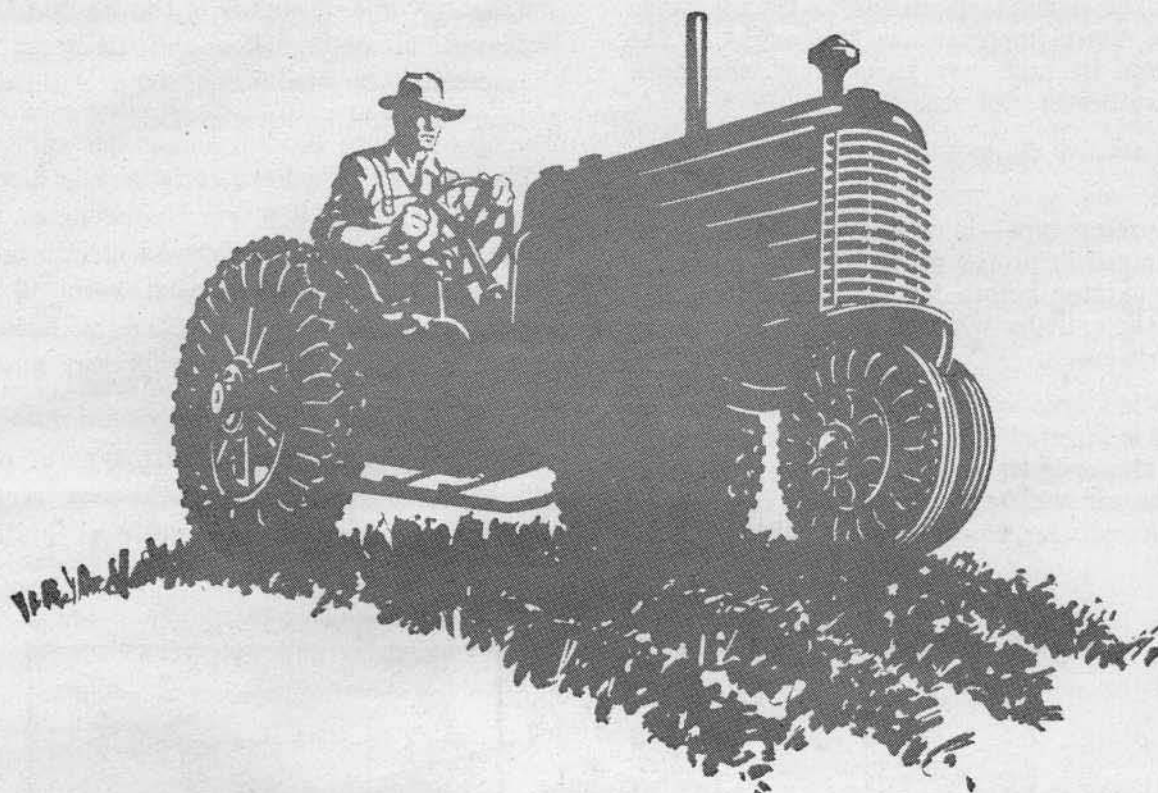
*The tractor today meets practically every power requirement on the farm and is doing almost every kind of farm work—doing it better and faster, and staying at it longer than has been possible heretofore. The contribution of the tractor to more successful farming is, therefore, one of increased productivity and lowered operating costs.*

*If the tractor is to give at all times the efficient service that it is intended to give, and which it is entirely capable of giving when properly handled, the farmer must learn to operate it with a skill that comes from a better understanding of the fundamental operating principles involved.*

*When the farmer fully understands his tractor, he may expect to obtain the most efficient operation that the tractor is capable of giving.*

*A bulletin on the subject of Farm Tractors is here offered to help train the men who shall render tractor service.*





# FARM TRACTORS

## Fuels and Lubrication

### INTRODUCTION

The elements of a farm tractor (Fig. 2) consist of a source of power (an engine), a means for connecting the power to the parts to be driven (a clutch), a means for transmitting the power at the most useful speeds (a transmission), and a means for conducting the transmitted power to the wheels (a final drive). The complete, modern tractor also usually has a belt

pulley with a means for engaging it and disengaging it as may be required. Movement of the tractor over the ground is made possible by the use of (1) wheels or (2) crawler tracks. The wheel-type tractor is turned by means of a steering gear and suitable linkage, while the crawler-type tractor is turned by momentarily slowing or stopping one or the other of the two tracks.

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Of all the elementary parts of a tractor, probably the most important is the engine. The engine and its accessory parts must, therefore, receive rather special study.

There are two distinct types of tractor engines, namely:

1. Carburetor type—in which the fuel and air are mixed in proper proportions by means of a carburetor before introduction of the fuel into the cylinder where it is later fired by an electric spark.
2. Injection type—in which the liquid fuel by itself is injected at the right moment directly into the cylinder and is ignited by the heat of the air which is very highly compressed in the cylinder.

The first type of engine is the one most often employed in automobiles and tractors. It is characterized by the use of both a carburetor and an electrical ignition system.

The second type of engine is usually described as a "Diesel." If it is a true Diesel engine, it has neither a carburetor nor an electrical ignition system, although for starting both of these accessories can be employed. One modified type of Diesel engine has no carburetor, but does employ electric spark ignition.

In this bulletin only the first type of engine will be considered, namely, the one regularly employing a carburetor and electrical ignition.

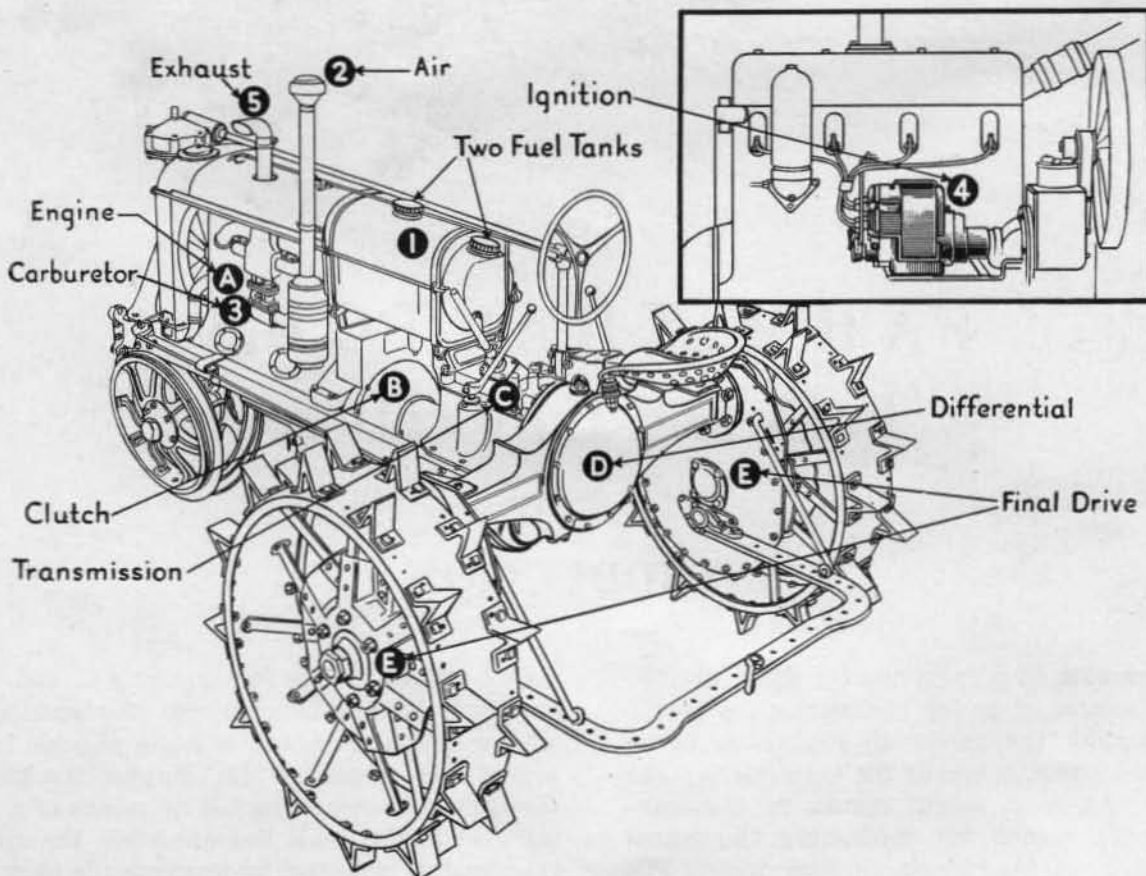


FIG. 2—The principal parts of a farm tractor.

## PART ONE

## FUNCTION AND CONSTRUCTION OF PARTS

Just as a gun propels a projectile from its muzzle by the rapid burning (explosive power) of a combustible mixture, so the cylinder of a tractor engine propels a piston (Fig. 3). The piston, fitted with rings to seal in power, is connected to a crank by a connecting rod so that its movement is converted to the turning of a crankshaft. The momentum of a flywheel keeps the crankshaft turning until the next power stroke.

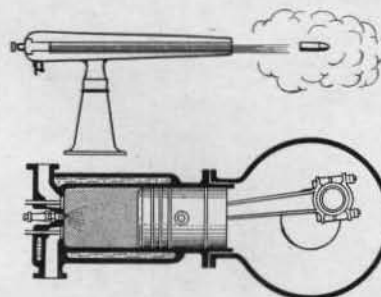


FIG. 3—The rapid burning of an explosive charge in a gun propels a projectile, while in a tractor engine it propels a piston connected to a crankshaft, thus converting straight-line motion into rotary motion.

## THE 2-CYCLE ENGINE

While the 4-cycle engine is commonly used in most farm tractors because it is usually more efficient, a 2-cycle engine is often used for small power requirements; for example, in small garden tractors as well as in washing machines,

small power mowers, etc. The 2-cycle engine (Figs. 4 and 5) requires only one revolution of the crankshaft for a complete cycle of events, during which time the piston makes just two strokes, one outward and one return. The same

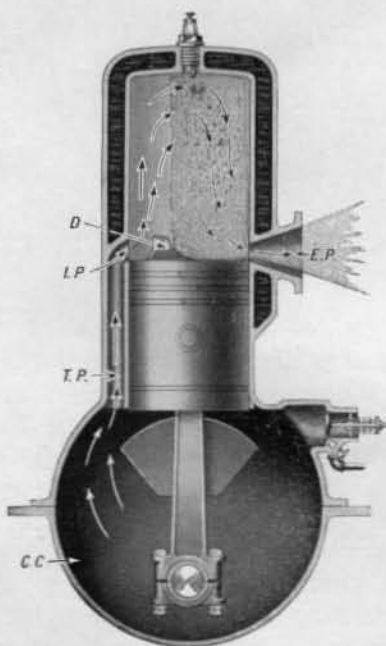


FIG. 4—Two-cycle engine. End of down-stroke and beginning of up-stroke. Exhaust from cylinder is followed by intake of compressed fuel charge from the crankcase.

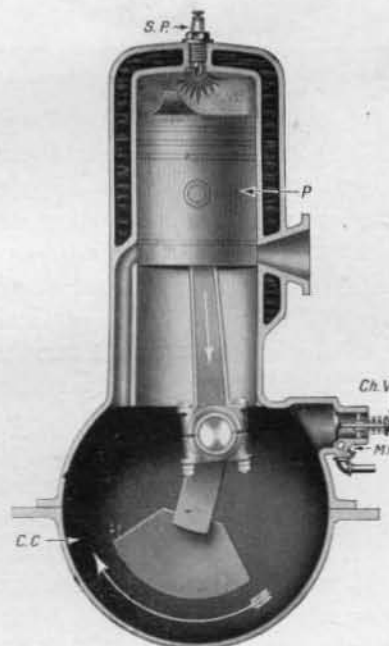


FIG. 5—Two-cycle engine. End of up-stroke and beginning of down-stroke. Compression is followed by firing. During the up-stroke a fresh fuel charge was drawn into the crankcase.



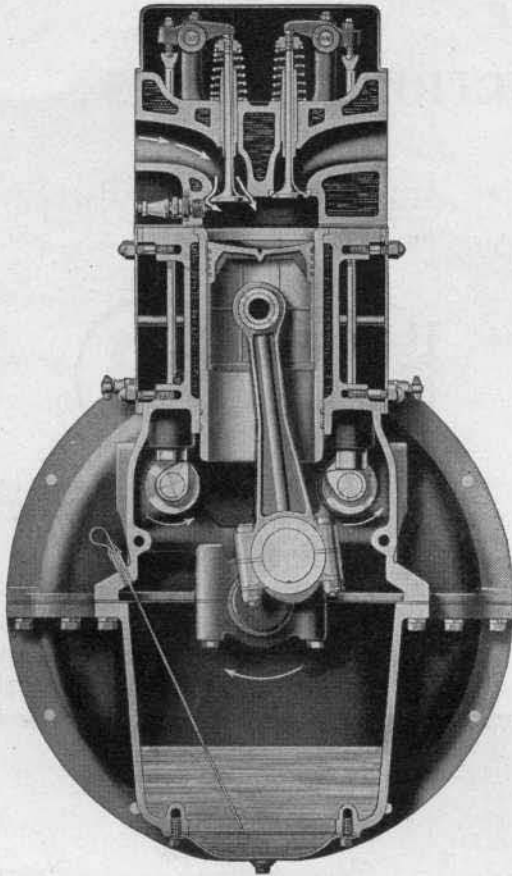


FIG. 6—Four-cycle engine. Intake stroke: piston descending with intake valve open and exhaust valve closed.

four events take place, namely—intake, compression, firing and exhaust, as in a 4-cycle engine; however, they are more closely grouped. This is accomplished by the use of an airtight crankcase in which the fuel charge is first received and compressed. The events in a vertical 2-cycle engine are divided in this way: Near the bottom of the piston stroke the piston uncovers exhaust and intake ports along the side of the cylinder bore. The exhaust passes rapidly out of the exhaust port and a new charge of air and fuel, which previously has been compressed in the crankcase by the descending piston, rapidly enters the cylinder. This compressed mixture is deflected upwards into the cylinder by a suitable deflector on the intake port side of the piston head. The intake charge flowing into the cylinder aids in scavenging the cylinder of remaining

exhaust gases. Soon after the piston commences to rise, both ports are covered by the piston and the fuel charge is compressed above the piston while another carbureted fuel mixture is drawn

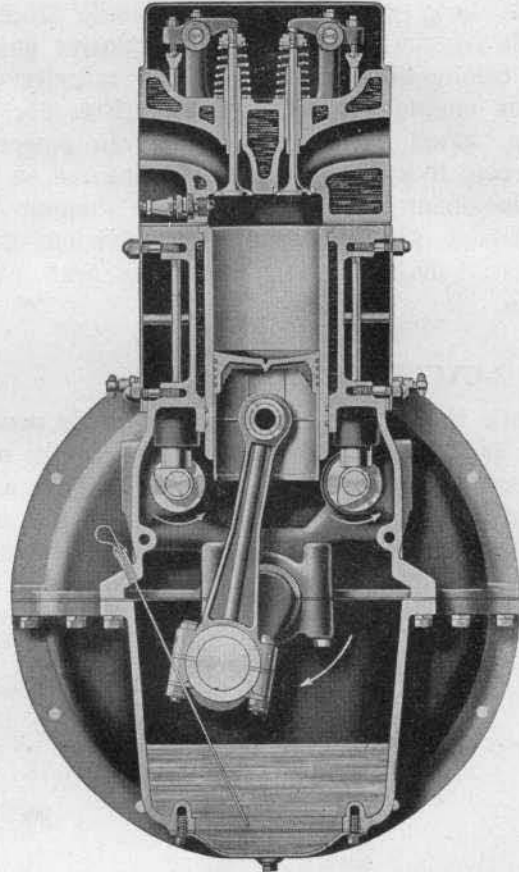


FIG. 7—Four-cylinder. Compression stroke: piston rising with both intake and exhaust valves closed

into the crankcase below. The compressed fuel charge is fired as the piston nears the top of the stroke and the expanding gases push the piston downward. As the piston nears the bottom of the stroke, it again uncovers the exhaust and intake ports and the sequence of events just described is then repeated. Since the air-fuel mixture is precompressed in the crankcase of the engine, the crankcase must be kept tight for proper functioning of the 2-cycle engine.

As the 2-cycle engine is rarely, if ever, encountered on farm tractors, this bulletin will be restricted to engines of the 4-cycle type.



### THE 4-CYCLE ENGINE

In a 4-cycle engine (Figs. 6 to 9), two valves are located in the combustion space at the head of the cylinder. One of these (the intake valve) is open as the piston moves away from the cylinder head and draws in a combustible mixture of fuel and air. Both valves remain closed while continued turning of the crankshaft returns the piston and compresses the fuel charge in the small space between the piston and the cylinder head. About 20 to 25 degrees before

Then as the power stroke finishes and the piston nears the bottom of the power stroke, the other valve (exhaust) opens and the exhaust or burned gases flow out of the cylinder as well as being pushed out by the piston on the return stroke. This is the cycle of events that is continuously repeated when a 4-cycle engine is in operation.

The piston, it will be noted, makes two outward and two return strokes for a complete cycle of events—a total of four strokes. On this account such an engine is called a "4-stroke cycle" or merely a "4-cycle" engine. A 4-cycle engine requires two complete revolutions of the crankshaft for each full cycle of events.

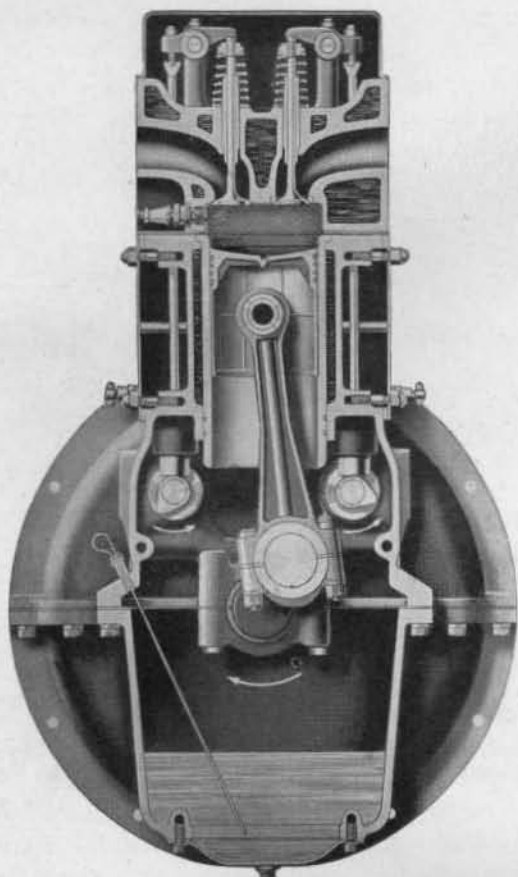


FIG. 8—Four-cycle engine. Firing or power stroke: piston descending after ignition of fuel charge. Both valves closed.

the end of the compression stroke, depending upon engine design, an electric spark ignites the compressed fuel charge. Since both valves are still closed, expanding gases force the piston down, thus giving new impetus to the flywheel.

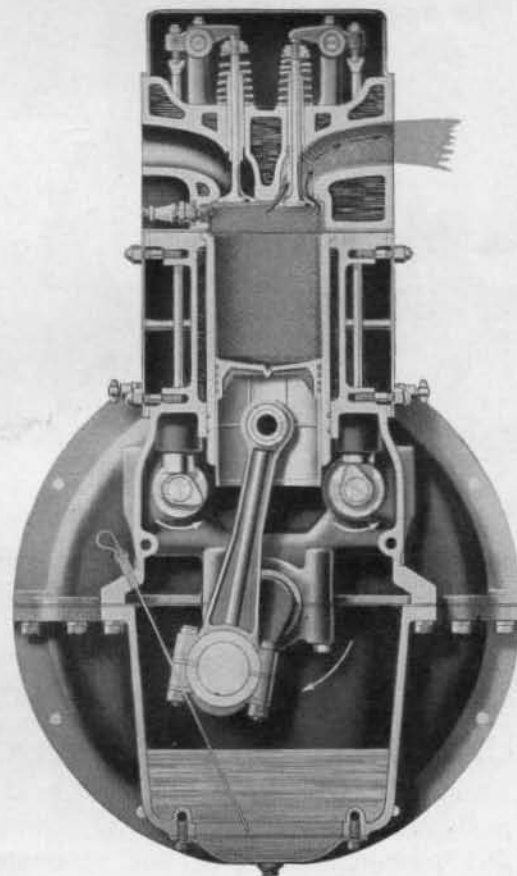


FIG. 9—Four-cycle engine. Exhaust stroke: piston rising after exhaust valve has opened. Intake valve closed.

# MULTIPLE CYLINDER ENGINES

A multiple cylinder engine consists simply of several single cylinder engines combined into one unit and usually sharing the same accessory parts. To make the flow of power smoother and overcome vibration caused by motion of the engine parts, an attempt is made to space the power impulses uniformly and counteract vibration tendencies by balancing piston and crank throw. In some multiple cylinder engines, however, a choice must be made between balanced firing and balanced piston and crank throw.

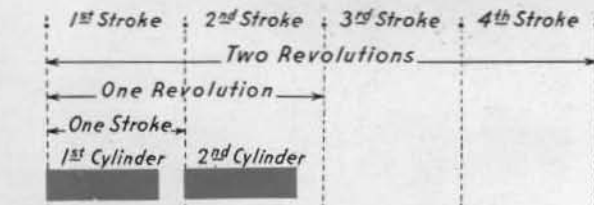
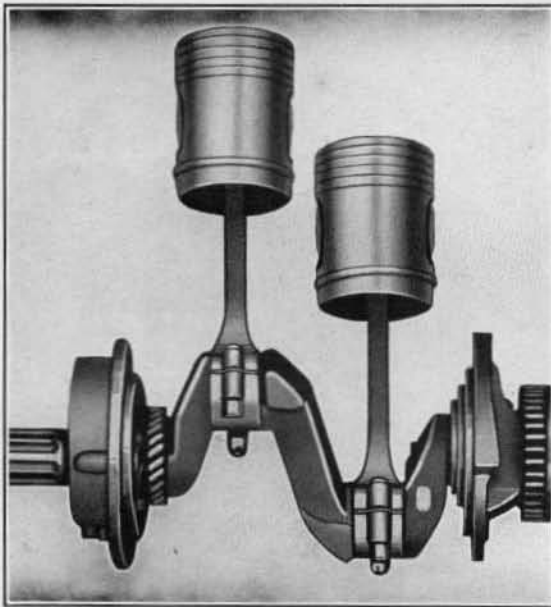


FIG. 10—Pistons and crankshafts of a two-cylinder engine as arranged for balanced piston and crank throw and uneven firing.

In 2-cylinder engines (Fig. 10), it would be necessary to have both pistons move back and forth together if the engine fired every full revo-

lution; i.e., every 360 degrees. In heavy-duty engines the moving of both pistons together might cause vibration even though the firing were balanced. Smoothness of operation in such an instance can best be obtained by balancing the piston and crank throw so that one piston is moving inward while the other is moving outward. Even though this arrangement means that uneven firing is used, it is not objectionable in heavy-duty engines as the flywheel largely compensates for the uneven impulses.

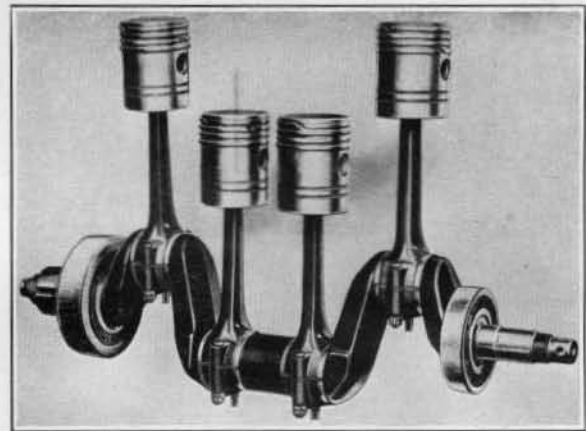


FIG. 11—Pistons and crankshaft of a four-cylinder engine as arranged for balanced piston and crank throw and balanced firing. Two possible firing orders are shown.

In 4 cylinder engines (Fig. 11), the firing is arranged so that a power stroke occurs every 180 degrees of flywheel travel ( $\frac{720}{4} = 180$ ).

It so happens in this instance that both the firing order and piston and crank throw are balanced. Usually the front and back pistons (Nos. 1 and 4) move together in one direction, while the two center pistons (Nos. 2 and 3) move

together in the other direction. It will be observed from a study of Fig. 11 that only two firing orders are possible in a 4-cylinder engine; namely, 1, 2, 4, 3 or 1, 3, 4, 2. The firing order begins with the front cylinder, the one next to the radiator. The firing order used depends upon the camshaft design.

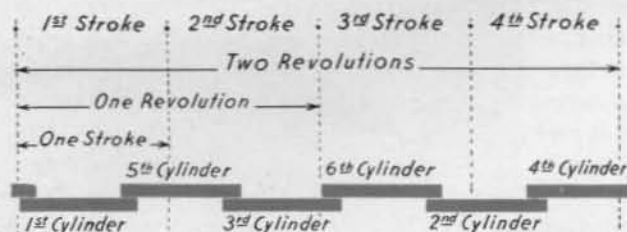
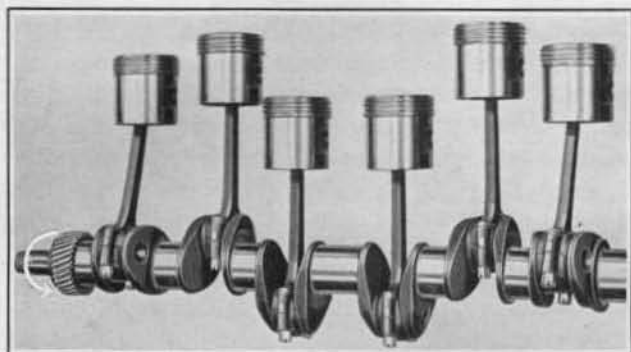


FIG. 12—Pistons and crankshaft of a six-cylinder engine arranged for balanced piston and crank throw and balanced firing. The most customary firing order is shown.

In 6-cylinder engines (Fig. 12), the firing is arranged so that a power stroke occurs every 120 degrees of flywheel travel ( $\frac{720}{6} = 120$ ).

However, there is an overlapping of power impulses which cannot be obtained with engines of a smaller number of cylinders. For example, before the first cylinder has completed its power stroke, the next cylinder in the firing order has already begun its power stroke, and so the process continues through the complete firing sequence. In the usual arrangement, pistons Nos. 1 and 6 move together, Nos. 2 and 5 move together, and Nos. 3 and 4 move together in intervals of 120 degrees of crank throw ( $3 \times 120 = 360$ ).

The latter is the arrangement shown in Fig. 12. Four different firing orders are possible in the case of 6-cylinder engines. The one most commonly used is 1, 5, 3, 6, 2, 4. This particular firing order is usually preferred as an aid to proper fuel distribution because no two consecutive power strokes occur in adjacent cylinders. When two adjacent cylinders draw on the same section of the intake manifold at nearly the same time, the second cylinder tends to receive more of the available fuel charge than the first, because of the greater inertia of the gas existing in this region of the intake manifold at that time.

### CYLINDER SIZE FACTORS

There is a rather definite relationship between the number of cylinders in an engine and cylinder size. Generally speaking, and assuming similar horsepower outputs, the greater the number of cylinders, the smaller the cylinder bore size. (Compare Figs. 10, 11, and 12.) For example, a 2-cylinder engine will have a cylinder bore size much larger than a 4-cylinder engine, and similarly, a 4-cylinder engine will have a much larger cylinder bore size than a 6-cylinder engine of similar horsepower. In the case of vertical cylinder arrangements, if the horsepower outputs are about the same, the overall lengths of the engines will, therefore, be about the same. In multiple cylinder engines, unusually long crankshafts, which would be difficult to keep from whipping, and unusually long intake manifolds, in which there is a tendency for the fuel in the mixture to settle out, are avoided by keeping the cylinder size small and thereby holding in check the overall length of the engine.

### CARBURETION

The carburetor is designed to handle liquid fuel. Its purpose is to secure an intimate mixture of the liquid fuel with air in proper proportions to form an explosive mixture. The fuel must stay liquid while in the carburetor, but upon leaving the carburetor must quickly mix with the intake air stream. To do this, the liquid fuel as it leaves the carburetor discharge nozzle is broken up into



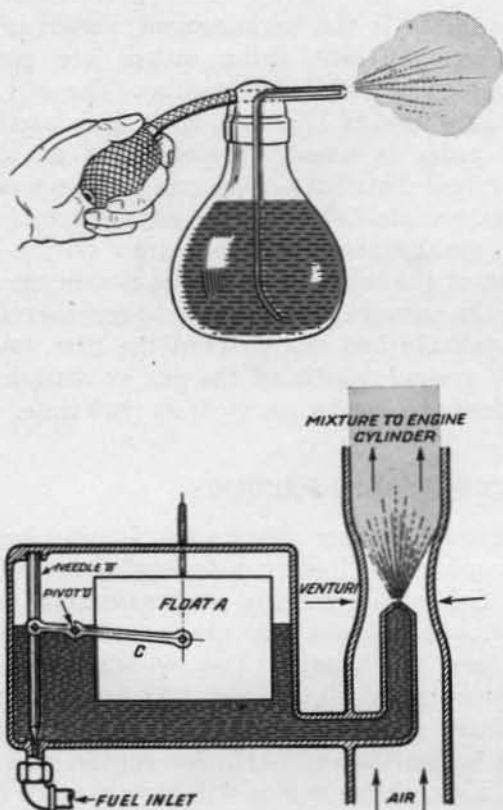


FIG. 13—Like an atomizer, a carburetor uses the principle of air rushing past an open tube to pick up the liquid and mix it with the air to form a fine spray.

a fine spray (Fig. 13). This finely atomized fuel spray readily mixes with the swirling air stream. In its course of transit through the intake manifold, from the carburetor discharge nozzle to the actual reception of the fuel charge by the cylinders, the responsibility for keeping the fuel in the mixture at a correct mixture proportion for proper burning is jointly shared by the manifold design, the manifold heat adjustment control, and the volatility of the fuel. Preliminary to discussing these factors, further details in the construction and function of the carburetor should be considered.

While early forms of carburetors drew their fuel supply directly from the fuel tank, it is now the customary practice for the carburetor (Fig. 15) to have its own local fuel supply in which the fuel can be carried at a constant level. This is accomplished by a float in the carburetor bowl

which, through suitable linkage to a valve, maintains a constant level of fuel in the bowl. In this way it is possible to maintain a uniform and carefully regulated flow of liquid fuel to the jet or jets.

In the simplest form of carburetor (Fig. 13), a single jet meters the liquid fuel from the bowl into the air stream. The jet is located centrally in a venturi tube, which is a constricted section of the intake manifold. Because the venturi has a reduced cross-sectional area, the velocity of the air travel at this point is greatly increased. This greater velocity increases the ability of the air stream to pick up fuel from the jet and atomize it.

At the beginning of the intake manifold, just beyond the jet nozzle and venturi tube, is located a butterfly valve (Fig. 15) whose degree of opening or closing controls the amount of carbureted fuel charge to reach the engine. This is the throttle plate. In automobiles it is actuated by either a foot throttle or a hand throttle. In most tractors it is controlled by a governor mechanism operating in conjunction with a hand throttle lever which regulates a spring tension in the governor (Fig. 14). Most mechanical governors use the centrifugal force of a rotating weight working against a spring tension for their operation. Such a governor maintains a uniform engine speed for any hand throttle level position.

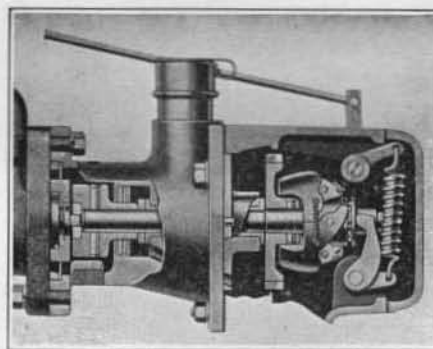


FIG. 14—A throttle governor opened up to show (right to left) spring and fly-ball mechanism, and oil fill pipe to crankcase. The engine is under governor control at all speeds from idling to maximum.

Courtesy, Tractor Division, Allis-Chalmers Mfg. Co.



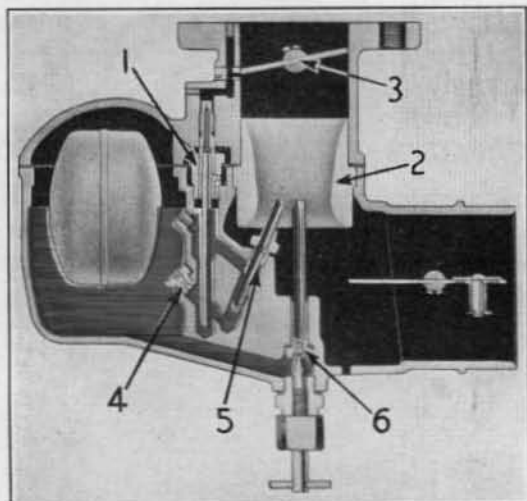


FIG. 15—An auxiliary or compensating jet type of carburetor.

1. Idling Jet.
2. Venturi.
3. Throttle plate.
4. Compensating jet.
5. Cap jet.
6. Main jet.

Courtesy, Zenith Carburetor Company

The engine speed may, of course, be increased by simply moving the lever to a higher speed position.

For starting, a damper, or choke valve (Fig. 15) is placed in the air intake opening leading to the carburetor. Ordinarily this valve is kept wide open, but when it is necessary to greatly increase the richness of the fuel mixture to enable starting a cold engine, the choke is momentarily used to restrict the passage of entering air. This restriction greatly increases the suction on the carburetor jet and causes a greater proportion of fuel to be drawn in, in relation to the air, thus greatly enriching the mixture.

Speed and load conditions also affect the mixture proportion needs of an engine. To accommodate these variable needs, several additional features are usually incorporated in carburetor designs. For example, it was early observed that in carburetors with a single jet and with a single place for air entrance, the mixture strength could not be maintained uniformly constant with different engine speeds. As the engine speed increased, the flow of fuel in response to the suction increased faster than the flow of air.

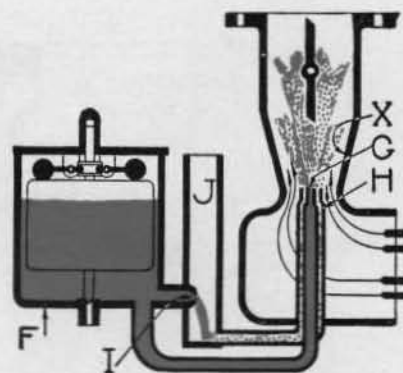


FIG. 16—Simplified drawing to explain operation of compensating jet type of carburetor shown in Fig. 15.

- F. Fuel chamber.
- G. Main jet.
- H. Cap jet.
- I. Compensating jet.
- J. Well.
- X. Venturi.

Courtesy, Zenith Carburetor Company.

Therefore, the mixture became too rich and the properly balanced mixture which the engine needed no longer existed. To overcome this enriching tendency, many different methods have been used, namely: auxiliary air valve, auxiliary or compensating jet, economizer valve and power jet, plain tube and air bleed valve, and float chamber suction control.

### AUXILIARY AIR VALVE

Fig. 17 illustrates a carburetor with an auxiliary air valve in the intake. It consists of a small spring controlled valve, calibrated and adjusted

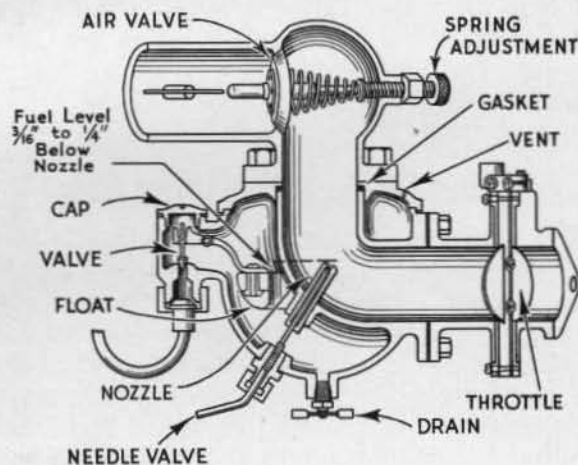


FIG. 17—An auxiliary air valve type of carburetor. Courtesy, Marvel-Schebler Carburetor Co.

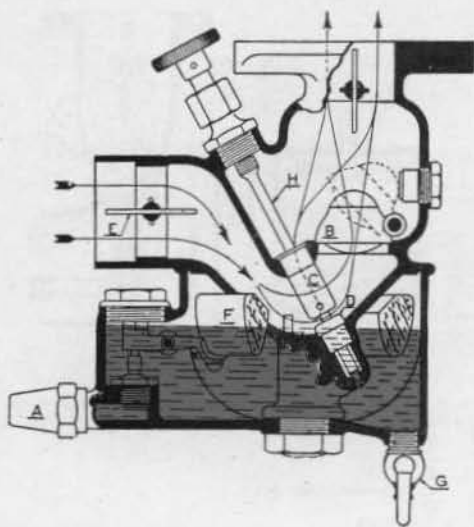


FIG. 18—A weighted, air bleed valve type of carburetor. A—fuel connection. B—air valve. C—low speed tube. D—high speed tube. E—choke. F—float. G—drain valve. H—needle valve. When the engine is idling, air valve B rests lightly on its seat and all the air passes through the low speed tube C. As the engine speed increases, the air valve rises from its seat, and the further it rises the more air passes over high speed tube D, thus compensating the mixture delivered by both tubes.

Courtesy, Kingston Products Corporation.

to admit more air to the manifold as the velocity increases beyond a certain point. At normal engine operating speeds, the valve is held wide open, but when the engine drops to idling speed, and needs a richer mixture, the valve restricts the air passage, thus enriching the mixture.

A weighted, air bleed valve type of carburetor is shown in Fig. 18. With various degrees of air velocity, the weight raises or lowers the air bleed valve, permitting more or less air to pass over the main fuel jet and, in this way, controlling the mixture strength.

#### AUXILIARY OR COMPENSATING JET

The auxiliary or compensating jet carburetor has two jets or nozzles as shown in Fig. 15. One jet operates according to the usual principle of the simple jet and delivers a mixture which increases in richness as the air speed increases. The other jet is connected to a well which is always at atmospheric pressure, and the flow of fuel into it is always at a constant rate. It delivers a mixture which decreases in richness as the air speed increases, because more air is then drawn in with

the fuel. Combining the two jets, a compensated feed is obtained.

#### ECONOMIZER VALVE AND POWER JET

Full power, for hard pulling, requires a richer mixture than part throttle operation. One way to provide this additional richness is by means of an economizer system, shown in Fig. 19,

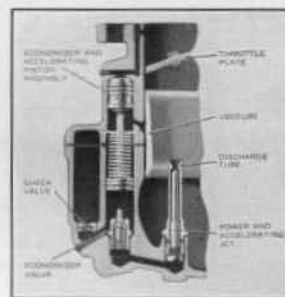


FIG. 19—Carburetor economizer valve and power jet system. Courtesy, Zenith Carburetor Company.

Under part throttle operation, the vacuum above the throttle is higher than when the throttle is fully open. This vacuum holds the economizer piston up and the check valve shown is then open and the economizer valve closed, thus shutting off additional fuel from the power jet. When the throttle is opened the vacuum falls, and so does the piston. This causes the check valve to seat, preventing a flow of fuel back into the bowl, and the economizer valve is pushed open. The fuel displaced by the falling piston is forced out through the power jet, and as long as the throttle valve is held open the piston will remain at the bottom holding the economizer valve open, permitting additional flow of fuel and enriching the mixture. The power jet, however, measures only enough additional fuel to develop full power. When the throttle is partly closed the vacuum increases above it, the piston is drawn up to the top, the economizer valve closes, shutting off additional flow of fuel so that a more economical mixture is fed to the engine.

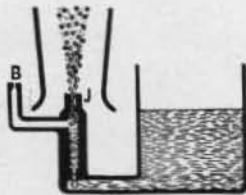


FIG. 20—Plain tube, air bleed valve type of carburetor.  
J. Jet opening.  
O. Restrictive orifice.  
B. Air bleed opening.  
Courtesy, Stromberg Carburetor Div., Bendix Products Corp.

### PLAIN TUBE AND AIR BLEED VALVE

One type of plain tube and air bleed valve carburetor is shown in Fig. 20. Both the air and fuel openings are fixed in size and compensation is brought about without any moving parts. The result achieved is similar to that of the compensating jet. In the air bleed jet, an opening to the atmosphere (through the air cleaner) is provided to the jet itself so that, as fuel flows from the jet, a small percentage of air is drawn in from the atmosphere. Consequently the jet will deliver a mixture of fuel and air, instead of liquid fuel alone, hence the tendency of the mixture to become richer is overcome. A representative carburetor of this type as employed on some tractors is shown in Fig. 21.

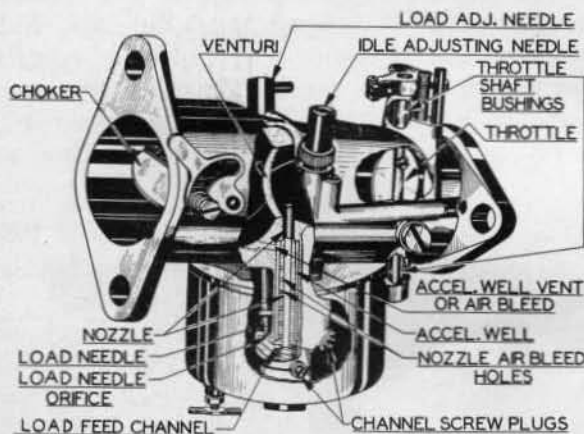


FIG. 21—Another plain tube, air bleed type of carburetor.  
Courtesy, Marvel-Schebler Carburetor Co.

Another plain tube type of carburetor with an air bleed method of compensation is shown in

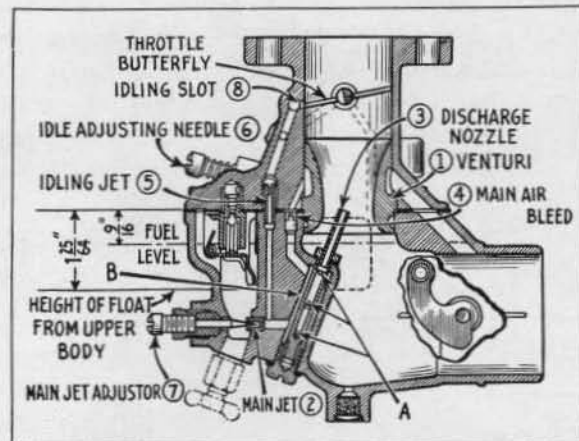


FIG. 22—Schematic section through a plain tube, air bleed type carburetor with parts identified. A. Holes through which air enters the liquid fuel from the main jet. B. Space surrounding the discharge nozzle.

Courtesy, International Harvester Company.

Fig. 22. The main jet (2) determines the maximum amount of fuel which may be obtained for full load operation. Compensating air is admitted from the space around the venturi through the main air bleed (4) and into the space (B) surrounding the discharge nozzle (3), known as the "well." The air enters the solid fuel from the main jet through the holes (A). The well vent meters the amount of air which is admitted to the fuel and allows a proportionately larger amount of air to be bled in as the suction on the discharge jet increases, thereby maintaining the fuel-air ratio fairly constant.

### FLOAT CHAMBER SUCTION CONTROL (BOWL VACUUM)

As an economizer, to reduce fuel consumption under certain load conditions, some tractor engine carburetors are designed to carry a slight vacuum in the bowl (Fig. 23). This vacuum is maintained only during operation of the engine at loads over one-fourth capacity and less than three-fourths capacity. During such operating conditions the slight vacuum maintained decreases the amount of fuel which is drawn through the main jet and thereby leans the mixture. For heavy load conditions, when the throttle is opened wide, the slight vacuum in the bowl is



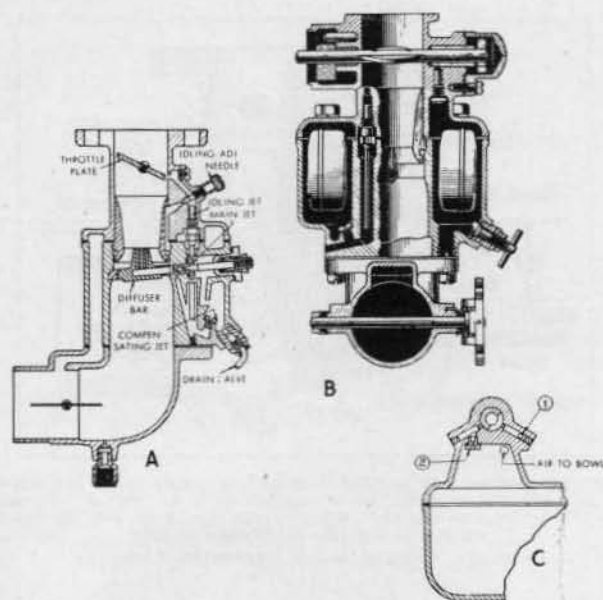


FIG. 23—Float bowl suction control economizer on a tractor carburetor. A. Jet arrangement showing diffuser bar type of nozzle. B. Partially developed cross-section of this carburetor. C. Cross-section of the economizer showing position of parts with the throttle in idling position. In this position an economizer jet is blocked off by a notched collar and no suction is transmitted to the bowl. When the throttle opens to  $\frac{1}{4}$  load position, the notched collar forms a channel between (1) and (2), thus transmitting suction to the top of the float bowl. Opening the throttle wide rotates the collar so that it closes channel (1), thus cutting off the restraining action of suction on the bowl, allowing free flow of fuel to the jets again.

Courtesy, Zenith Carburetor Company.

released, thus permitting a free flow of fuel through the jet and increasing the richness of the mixture.

### DIFFUSION BAR TYPE NOZZLES

In some carburetors the main jet and a compensating jet discharge into the air stream through a diffuser bar (Fig. 23). This is simply a means for introducing the fuel from the jets into the air stream through a number of small openings extending across the diameter of the intake throat with the object of securing better atomization of the heavier types of fuel.

### IDLING JET

At the customary idling speeds there is insufficient air velocity at the ends of the regular fuel jet or jets to raise the necessary fuel for proper operation. To provide this fuel in carburetors of other than the auxiliary air valve type, an aux-

iliary jet called an idling jet is added. This idling jet functions primarily when the throttle valve is almost closed and it then conducts fuel around the throttle valve into the intake manifold as shown in Fig. 15.

### TWO-FUEL CARBURETION

A very large number of tractor engines are so designed that they can be operated on a fuel like gasoline, a volatile tractor fuel, or a heavier distillate-type of fuel. In such cases a gasoline tank for starting and a main fuel tank are provided with suitable valves for switching from one fuel to the other. It is necessary to apply considerably more heat to the manifold when burning the heavier fuels since from two to three times as much heat is required to vaporize a heavy distillate as is required for gasoline. Additional heat for vaporizing the fuel mixture is obtained by passing the exhaust gases around a portion of the intake manifold. Some tractor engines have a damper valve that can be set manually (Fig. 24), while some others have a baffle plate that can be set either in a "hot" or "cold" position. Whenever the heavier distillates are used, heat must be applied in this way, and unless the engine has a permanently set heat adjustment for intended regular use of this type of fuel, the heat control should be kept in the "hot" position for most satisfactory operation (Fig. 25). Note, however, that in the case of manually operated heat controls when gasoline is used for regular operation, although the heat control can readily be set in the "hot" position for starting and

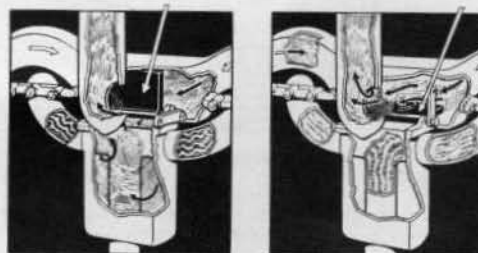


FIG. 24—A heat control manifold. (Left) Damper set in "hot" position for distillate types of fuel. (Right) Damper set in "cold" position for gasoline.

Courtesy, J. I. Case Company.



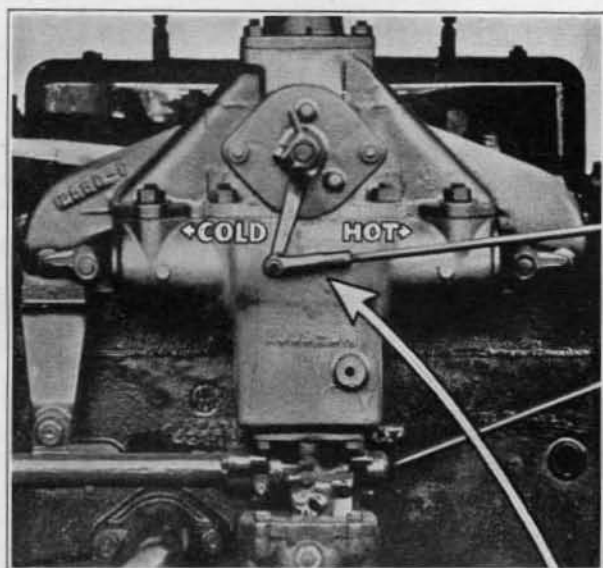
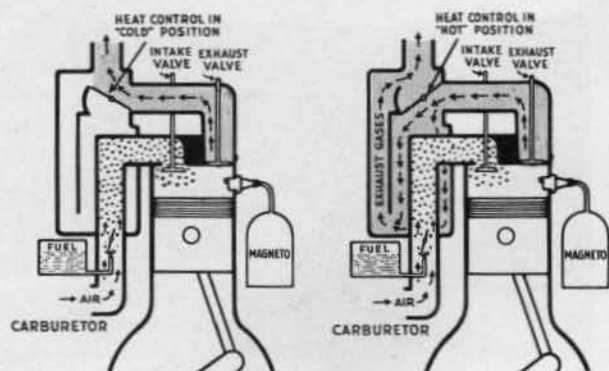


FIG. 25—(Above) Damper controlled heat adjustment regulated from the operator's seat by lever. (Below) Exterior view of the manifold.  
Courtesy, International Harvester Company.

warm-up, it should thereafter be set and kept in the "cold" position (Fig. 25). When using a volatile type tractor fuel, the adjustable manifold heat regulators should be set in the halfway to "cold" position, depending upon load and temperature conditions. Good operation when using volatile tractor fuel can also be obtained by having the heat regulator in the "cold" position and using a manifold shield.

## FUEL SUPPLY

Fuel is brought to the carburetor in most tractor engines either by gravity flow or fuel pump pressure. In the gravity system the fuel tank or tanks are located above the level of the carburetor and the fuel flows by gravity. When fuel pumps (Fig. 26) are used, they are usually driven by the camshaft. Constant pressure is maintained by a spring acting on a diaphragm piston which forces the fuel to the carburetor.

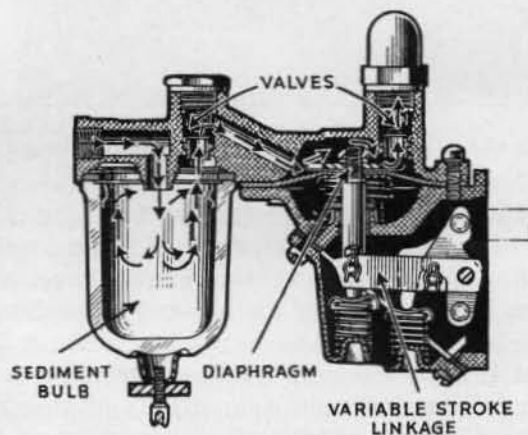


FIG. 26—Fuel pump showing, left to right, sediment bulb and cam operated linkage to pump diaphragm.  
Courtesy, International Harvester Company.

## AIR CLEANERS

The short life of many of the older makes of tractors which were used under dusty operating conditions, was probably due to the lack of a good air cleaner. The entry of abrasive dust and dirt into the engine with the intake air is responsible for much premature wear and many operating difficulties that cannot otherwise be explained. The development of efficient air cleaners has been, therefore, of very great importance in extending the useful life of farm tractors and improving their operating efficiency.

One of the first attempts made by early tractor builders to obtain clean intake air was to extend a tube vertically from the carburetor intake to a point as high as possible above the heavy dust



FIG. 27—Tractors frequently operate in dust and the engine interior must be protected against it at all times.

level usually surrounding the tractor (Fig. 27). While these intake stacks were of some benefit, fine dust found even at this higher level still entered the engine and in a short time did its destructive work. Mixed with the fuel or the lubricating oil, fine dust acts as a grinding compound and causes rapid wear of any of the frictional surfaces it reaches. Rapid wearing of top piston rings, sleeves, grooves in intake valve seats, badly worn valve stems and guides are most common evidence of dirt entering the engine.

A good air cleaner should remove the dust effectively but not restrict unduly the carburetor intake; it should operate successfully in all climates; it should require the minimum amount of attention from the operator; and it should be sturdily built to withstand vibration.

There are four common types of air cleaners used on farm tractors: (1) the dry type, (2) the oil soaked element type, (3) the water bath type, and (4) the oil bath type.

#### DRY TYPE

The dry type cleaner is most generally used at the air entry end of the intake stack as a pre-cleaner. It gives a swirling motion to the air by means of vanes and baffles, causing the heavier

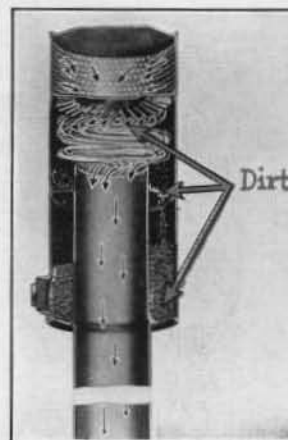


FIG. 28—A dry type of pre-cleaner used at the entry of the air intake stack.  
Courtesy, John Deere Tractor Company.

dust particles to be thrown out by centrifugal force (Fig. 28). Used in this way, it lightens the burden of the main cleaner, enabling the latter to function for a greater length of time between cleaning periods.

#### OIL SOAKED ELEMENT TYPE

A cleaner in which the intake air impinges against a fibrous element soaked in oil, is another type that in the past was commonly used on tractor engines (Fig. 29). The dust particles are held by the oil film whenever the air stream

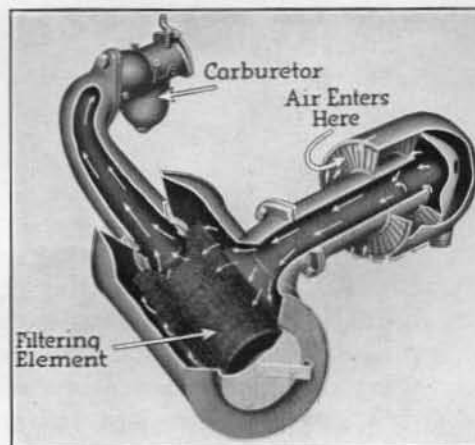


FIG. 29—An oil soaked element type of air cleaner.  
Courtesy, John Deere Tractor Company.

comes in contact with it. To prevent clogging and restriction of air flow, the filter core must be removed frequently from its retaining shell and washed clean in gasoline or tractor fuel. Then the element should be shaken free of the cleaning fuel and allowed to drain for several minutes, after which it should be dipped in fresh oil. If the element contains any traces of the cleaning fuel, a proper oil film will not be obtained.

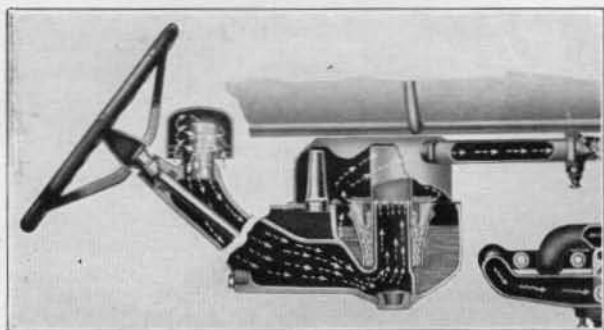


FIG. 30—A water bath type of air cleaner.

### WATER BATH TYPE

The water bath type air cleaner was developed to increase the efficiency of cleaning over that obtained with the dry type. In such a cleaner the intake air passes through a reservoir containing water. The reservoir (Fig. 30) is designed with three objects in mind: first, to give the air a relatively long travel through the water with as little restriction of the air intake passage as possible; second, to offer an opportunity for the settling out of dirt collected by the water; third, to prevent carry-over of water to the engine with the cleaned intake air. The water level must be maintained, for if allowed to become too low, a float in the reservoir drops down to a point where it covers the air intake and chokes the engine. In very dusty conditions, this type of filter requires very frequent cleaning and in cold weather there is danger of the water freezing. A later type of cleaner, which is still more efficient and is free of many of these disadvantages, is the oil bath type, next to be described.



FIG. 31—An oil bath type of cleaner. Incoming air (1) is forced through a baffle screen and oil pool (2), thence through a dense mist of oil and a fine screen (3). The oil carrying the dust removed from the air returns to the oil reservoir while the dust-free air is delivered to the carburetor (4).

Courtesy, J. I. Case Company.

### OIL BATH TYPE

In the oil bath type of cleaner (Figs. 31, 32, 33) the recommended grade (i.e., viscosity) oil

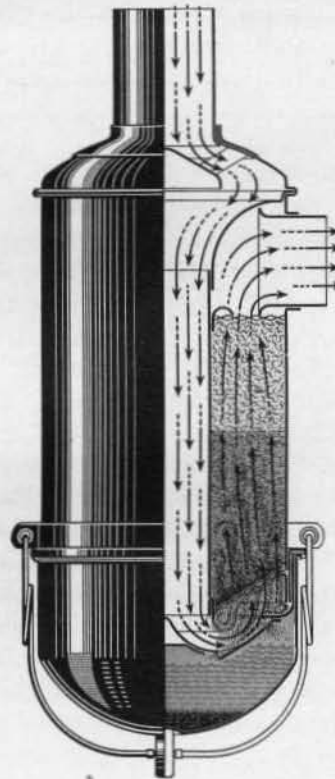


FIG. 32—Another type of oil bath air cleaner. An oil mist is formed by the swirling air, and immediately afterwards the oil and dirt are removed by the baffles of the cleaner. Courtesy, United Air Cleaner Div., United Specialties Co



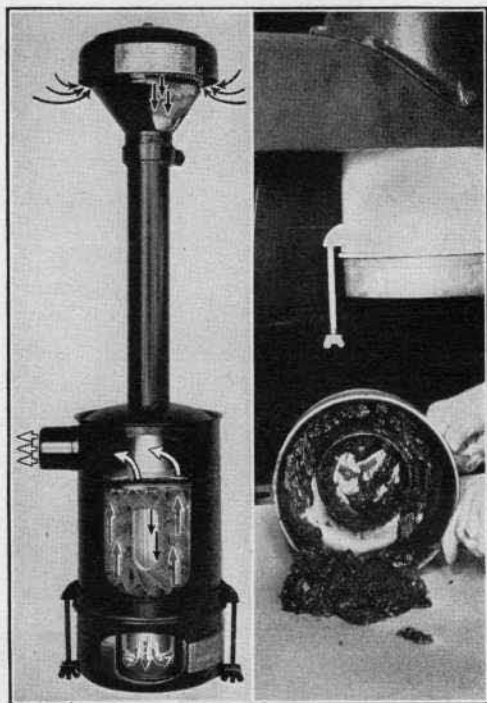


FIG. 33—(Left) An oil bath type of air cleaner in which the air first passes through a pre-cleaner and then impinges on a pool of oil, causing some of the oil to atomize at this point and mix intimately with the air. The air as it passes upwards is then freed of the dust laden oil by wire mesh baffles. (Right) Accumulated deposits in the oil reservoir must be removed periodically.

Courtesy, Donaldson Company, Inc.

is used to remove dust particles from the intake air in a novel way. The air is first made to pick up a small quantity of oil by impinging upon it with sufficient velocity to result in atomization of some of the oil. The atomized oil and air mixture is then conducted through a system of baffles and metal mesh where the excess oil and dirt collects on the mesh and drains back into the oil reservoir below. This washing down of excess oil keeps the strainer mesh fairly clean at all times. The accumulated dust and dirt settles in the oil reservoir below. Periodically, the bottom of the reservoir should be dropped down and the accumulated deposit removed (Fig. 33). Essential to a proper functioning of this unit is the maintaining of a specified oil level and the use of a sufficiently light-bodied oil. Fresh oil should be used not only to assure correct viscosity, but because used oil is likely to be dirty and considerably diluted with unburned fuel which, upon

atomization in the unit, would leave the oil too heavy to function properly and results in a lowering of the oil level.

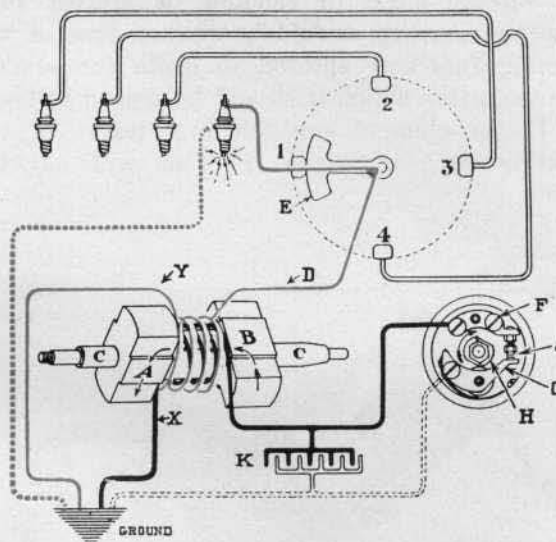


FIG. 34—The elementary parts of a magneto ignition system. A and B—rotor. C—rotor shaft. D—lead to distributor. E—rotating contact arm of distributor. F—breaker fixed arm. G—breaker movable arm. H—breaker cam. J—Breaker points. K—condenser. X—primary ground. Y—secondary ground. 1, 2, 3, and 4—high tension leads to spark plugs. Courtesy, The K-W Ignition Corp.

## IGNITION

In the type of tractor engine under discussion the high tension electric spark needed for ignition is often generated by a magneto (Fig. 36). A novel device is used on most tractor magnetos to give the armature a quick flip when cranking the engine to get it started. Ordinarily, the armature is driven from the crankshaft or camshaft by suitable gearing and shafting, and of course when the engine is being cranked by hand, the speed is hardly sufficient to generate much of a

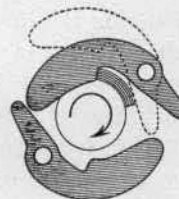


FIG. 35—Pawl arrangement on a magneto impulse starter. Dotted line shows pawl disengaged by throw of weighted arm.

Courtesy, Elsmann Magneto Corporation.



spark. The magneto is, therefore, equipped with an impulse starter (Fig. 35). This consists of a pawl and spring arrangement which winds up as cranking commences. Shortly afterwards the spring releases, and the armature is given a quick flip which generates a hot spark. When the engine starts, centrifugal force causes the pawl to disengage the spring, and thereafter the magneto drive is direct in the usual fashion. The impulse starter also retards the spark for hand cranking, thus lessening the danger of a kick-back that might injure the operator. As soon as the engine starts, the device automatically advances the spark for normal operation.

The distributor (Fig. 34) of the ignition system contains a revolving head that contacts in

correct firing sequence, the high tension wire leads extending to each of the spark plugs. In this way the current generated by the magneto is directed to the spark plugs at precisely the right time. The degree of spark advance or retard is determined by the position of the breaker case (Fig. 34) which contains the magneto points.

When a battery is used to supply current for ignition, it is accompanied with a high tension coil, a condenser, and a circuit breaker, the same as on most automobile engines.

Each spark plug consists of (1) a threaded outer shell which screws into the cylinder head and contains the outer electrode, (2) an insulated core which is made of heat resistant material and contains the inner electrode, (3) a bushing for holding the insulator in place, and (4) a copper gasket. The width of gap between the points of the two electrodes needs to be very carefully adjusted, for it is here that actual ignition of the fuel charge takes place when the high voltage current sent to the plug causes a hot spark to jump across the gap. Point settings vary from about .020 of an inch for typical high compression engines to about .030 of an inch for typical low compression engines, the exact gap width always being specified by the tractor manufacturer.

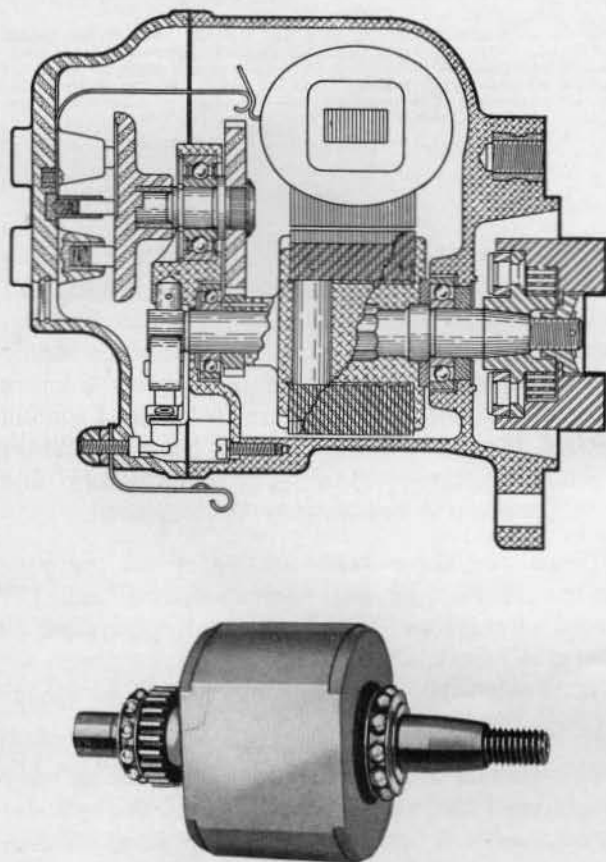


FIG. 36—(Above) A magneto which differs from the conventional type in that it has a magnetic rotor. (Below) The magnetic rotor.

Courtesy, Fairbanks-Morse Company.

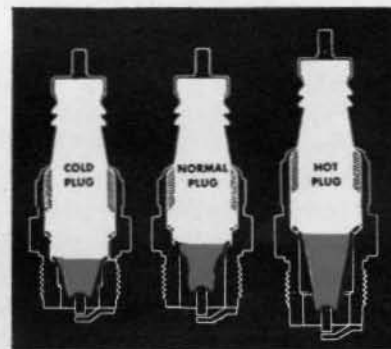


FIG. 37—Illustrating the difference between "cold," "normal," and "hot" spark plugs. The length of heat travel determines the rate of heat conduction from the core to the seat and then to the engine cooling system. A plug with a short heat travel runs relatively cool, while one with a long heat travel runs hot.

Courtesy, Champion Spark Plug Company.

The length that the plug insulator extends below the gasket shoulder controls the temperature at which the plug operates (Fig. 37). This temperature of operation is important. The plug must be hot enough during operation to prevent fouling, and cool enough to avoid pre-ignition and rapid wearing away of the electrodes. The requirements of different engines vary in this respect, probably in accordance with their respective operating temperatures. In general, a "hot plug" should be used in a cold running engine or when burning a volatile tractor fuel or a heavy fuel, and a "cold plug" should be used in a hot running engine or when burning only gasoline.

### EXHAUST SYSTEM

The exhaust gases from each cylinder are usually conducted into a gathering manifold and piped away to a point where exhaust flames will not constitute a fire hazard, and where the exhaust gases will not subject the operator to unpleasant fumes or health hazards. As already explained, the hot exhaust gases are often piped around a portion of the intake manifold to aid in vaporization of the fuel charge. A muffler may be used to quiet the sound of the exhaust but the type used must be such as not to cause undue back pressure in the exhaust system.

### COOLING SYSTEM

As the temperature reached in burning the fuel charge is from 3000 to 4000° F., and nearly one-third of this heat is transmitted through the cylinder walls, ample means for cooling the engine must be provided. Without such cooling extremely high temperatures would be reached, particularly around the cylinder head and exhaust valves, possibly causing pistons to stick, and subjecting many other engine parts and the lubricating oil to undue punishment. Moreover, high temperatures may cause pre-ignition of the fuel and result in loss of power.

Cooling, however, can be carried too far and in any internal combustion engine the operating efficiency, is, after all, dependent upon the best

means of utilizing heat. In general, the most efficient cooling water temperature for gasoline engines is 165 to 185° F., and for engines operated on heavier types of fuels, 190° F. or more, (Fig. 176, page 76).

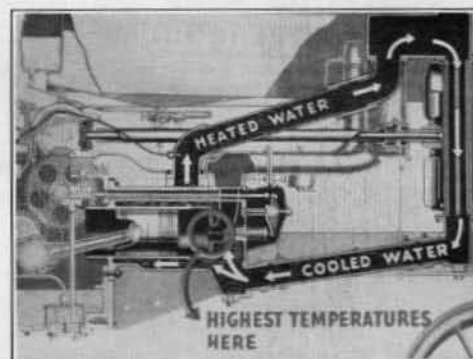


FIG. 38—A thermo-siphon cooling system (no water pump employed). Also shown is a geared-shaft-driven fan. A wartime innovation on some models is a thermo-siphon pressure cooling system, obtained by sealing the radiator filler opening, thus raising the boiling temperature of the water (at sea level) from 212° F. to 230° F.

Courtesy, John Deere Tractor Company.

There are three general methods for cooling internal combustion engines: (1) air cooling, (2) water cooling, and (3) oil cooling. The first requires a strong air blast directed over finely fluted cylinders and is used on garden tractors and smaller power units. The third named cooling method is now seldom used on tractors. Water cooling has been found very satisfactory and most tractor engines employ that method.

There are three types of water cooling systems: (1) hopper, (2) thermo-siphon, and (3) forced circulation. The first usually employs an integrally cast large open hopper type reservoir, located above the water jacket, and is no longer used on tractors.

The thermo-siphon system (Fig. 38) is very widely used in tractors. As water in the cylinder jacket heats it expands and, becoming lighter, moves upward. As the water in the radiator is cooled, it contracts, becomes heavier, and moves downward. Since the jacket and radiator are con-

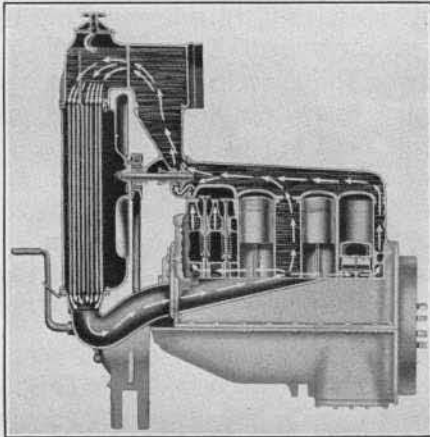


FIG. 39—A thermo-siphon cooling system which employs an impeller to aid water circulation.  
Courtesy, Harry Ferguson, Inc.

nected at the top and bottom, circulation results. A fan is usually employed behind the radiator to pull air through the core openings, and aid in

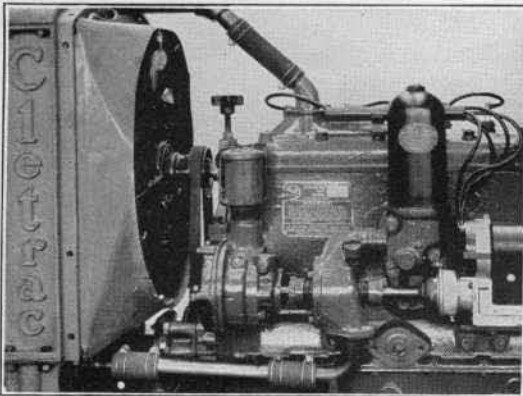


FIG. 40—A forced circulation cooling system showing a centrifugal type of water pump.  
Courtesy, The Cleveland Tractor Company.

cooling the radiator water. In a modification of this system an impeller (Fig. 39) in the water line connecting the jackets to the radiator is driven by the fan and assists circulation of the water mechanically.

The forced circulation system (Fig. 40) is a further step from the impeller-assisted, thermo-siphon system. A pump, usually of the cen-

trifugal type, is used to insure positive circulation of the water. The pump provides more rapid circulation and, if the radiator is left covered, such a system has the further advantage of introducing the water to the engine block with less temperature difference than is likely to be the case with the thermo-siphon system.

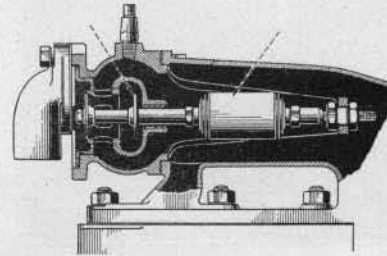


FIG. 41—Thermostat in cooling system showing valve at left and thermostat element at right.  
Courtesy, International Harvester Company.

Most forced circulation systems are equipped with a thermostat (Fig. 41) which, when the water is cold, blocks the flow of water to the radiator. This permits the jacket water to warm up quickly and hastens bringing the engine up to a proper operating temperature. As soon as the jacket water warms up sufficiently, the thermostat opens and the water circulates through the radiator.

Forced circulation systems may be open to the atmosphere or operated under moderate pressure (6 to 7 lbs.), thus increasing the boiling point of the cooling water to about 230° F. (Fig. 41a).

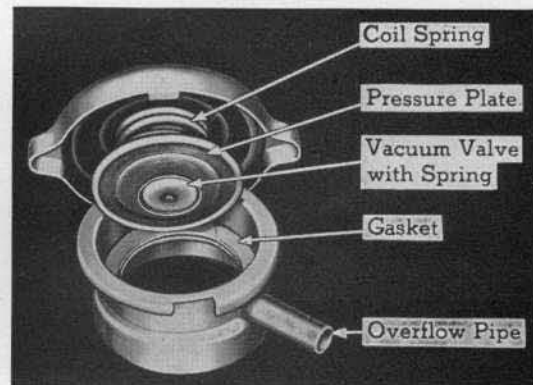


FIG. 41a—Spring loaded, sealed radiator cap used on a pressure cooling system. Be sure the gasket fits tightly and never remove the cap when the tractor is hot.  
Courtesy, John Deere Tractor Company.





FIG. 42—Adjustable radiator curtain  
Courtesy, J. I. Case Company.

The radiators of most tractors are equipped with a curtain (Fig. 42) or shutter arrangement (Fig. 43) so that operating temperatures can be better controlled. When starting and warming up an engine, it is always advisable to raise the radiator curtain and operate the engine with the cur-

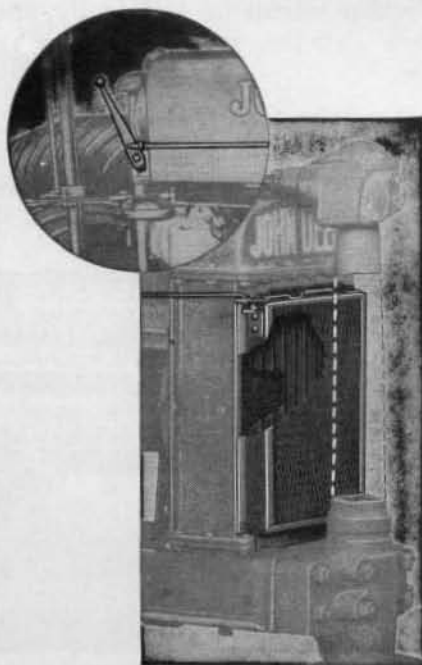


FIG. 43—A radiator shutter showing, in the inset above, a manual control lever.  
Courtesy, John Deere Tractor Company.

tain in this position until full operating temperature has been reached. Thenceforth it is advisable to lower the curtain only as much as may be necessary to maintain the desired operating temperature (165-185° F. for gasoline, 190-200° F. for fuels heavier than gasoline). In cooler weather, closer attention needs to be given to the use of the radiator curtain, or shutter, than at other times, although attention to this operating detail ought to be given at all times.

Radiator fans are friction driven, gear driven, or belt driven. Most fan belt drives (Fig. 40) are equipped with a take-up adjustment for regulating proper tension. The right tension avoids undue slippage without imposing an unnecessarily heavy loading on the fan bearing. A badly slipping fan belt, or a broken belt, often results in engine overheating because of insufficient cooling air being brought through the radiator core.

## LUBRICATION

In a tractor engine the principal parts requiring lubrication are:

1. Piston, piston rings, and cylinder wall.
2. Main bearings, connecting rod bearings, and piston pins.
3. Valve mechanism, camshaft and timing gears, valve stems and guides, and governor.

In most tractors one oil, carried in the crankcase, lubricates all of these parts. However, some of the very earliest models of tractor engines, usually those of few cylinders of large bore and operated at relatively low speeds, employed direct oil feed from a mechanical oiler to many of these parts (Fig. 44). Cylinder walls and bearings had individual pipes feeding oil to them. Sight feeds on these lines were incorporated in the mechanical lubricator unit, and individual adjustment was possible on each feed. This was strictly a fresh-oil, all-loss system. The used oil dropping off the lubricated parts collected in the bottom of the crankcase and from there it overflowed onto the gears and then onto the ground.

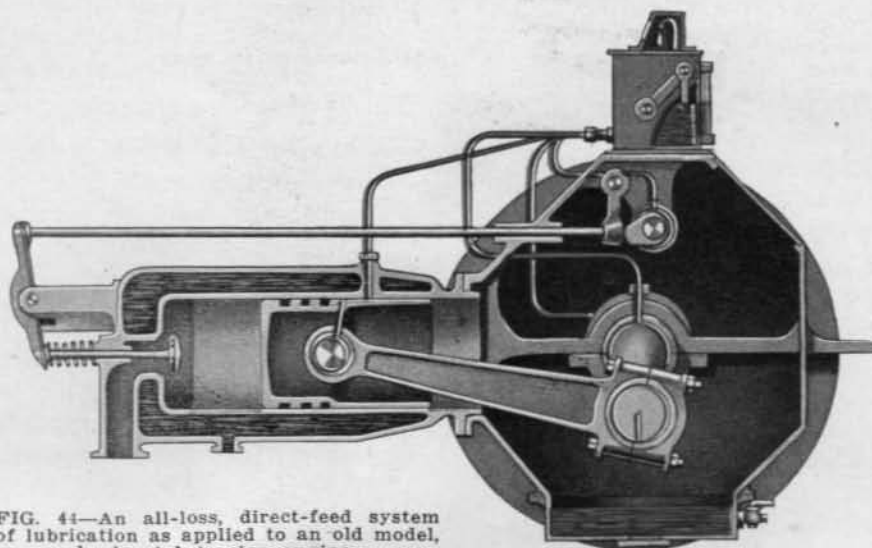


FIG. 44—An all-loss, direct-feed system of lubrication as applied to an old model, horizontal tractor engine.

Few of the older models of tractors were equipped with efficient air cleaners. On that account, a fresh-oil, all-loss, direct-feed lubrication system was very satisfactory in spite of a large consumption of oil because the dust and dirt that entered the engine were continually washed away by the fresh oil.

The two most common lubrication systems employed in modern tractor engines are:

1. Circulating-splash.
2. Pressure circulation.

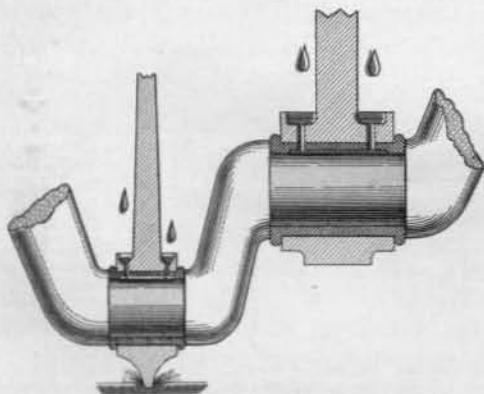


FIG. 45—Splash method of supplying oil to the connecting rod and main bearings.

The general principle employed in the circulating-splash system (Fig. 45) is that of permitting the bottom of the revolving connecting rods to splash oil from troughs located below the crankshaft, which continually receive oil from a circulating system—either pump or gravity. Oil enters the bearings through oil gathering holes, properly located in the bearing region of the connecting rods, and the balance of the oil is splashed to the other parts of the engine. Channels and piping are usually provided to gather and conduct oil by gravity to the main bearings and to remotely located accessory parts. The lubrication of the upper portions of the cylinder and piston, and the wrist pins, is actually supplied more by oil mist, or finely atomized oil than by splashing of the oil in the usual sense. Since the oil must splash readily, an oil pump, or the flywheel of the engine, is employed to carry oil from the crankcase to the oil trays and to continue the circulation process, too heavy an oil will not function properly in the circulating-splash system. This requirement must be kept definitely in mind in selecting a proper lubricating oil for cold weather operation.

A pressure circulation system (Fig. 46) employs a pump in the crankcase to constantly cir-

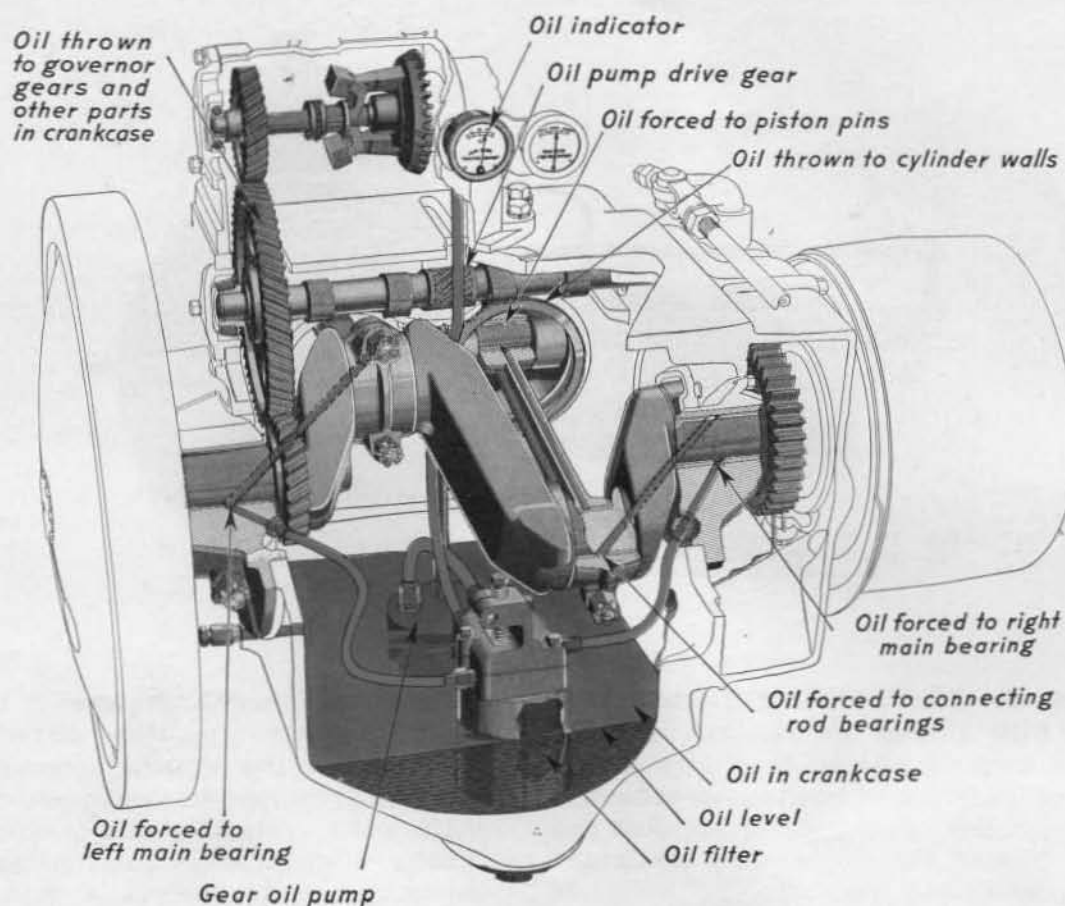


FIG. 46—A pressure circulation system of lubrication on a 2-cylinder horizontal engine. The oil is pumped through an oil filter to the principal parts of the engine. Courtesy, John Deere Tractor Company.

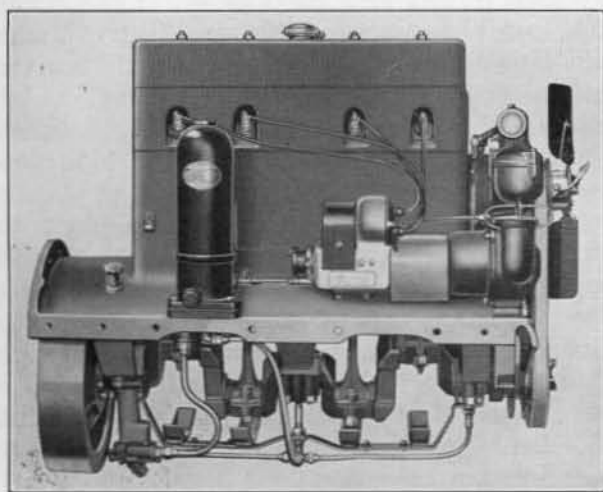


FIG. 47—Showing the circulating system oil lines and the splash system oil dip pans in an engine with the two systems combined (crankcase and oil pan removed). Courtesy, The Massey-Harris Company.

culate oil under pressure through oil lines and drilled passages in the crankshaft to the main bearings and connecting rod bearings, and then through drilled connecting rods, to the wrist pins. Oil escaping from the connecting rod bearing ends is thrown to the cylinder walls and furn-

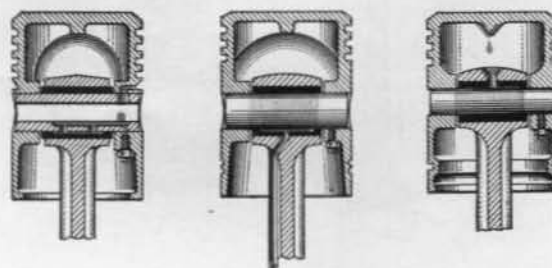


FIG. 48—Three types of wrist pin lubrication: (left) oil collected off of the cylinder wall, (center) oil pumped from the engine circulating system, (right) oil splashed against the underside of the piston top drops into an oil pocket above the pin.



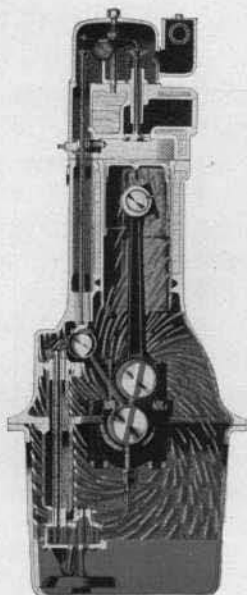


FIG. 49—A circulating-splash system of lubrication showing how a continuous spray from the surplus oil thrown out by the connecting rods lubricates many of the moving parts within the engine.

Courtesy, J. I. Case Company.

ishes lubrication for this part of the engine.

In circulating-splash systems, the cylinder walls and wrist pins are lubricated by splash or

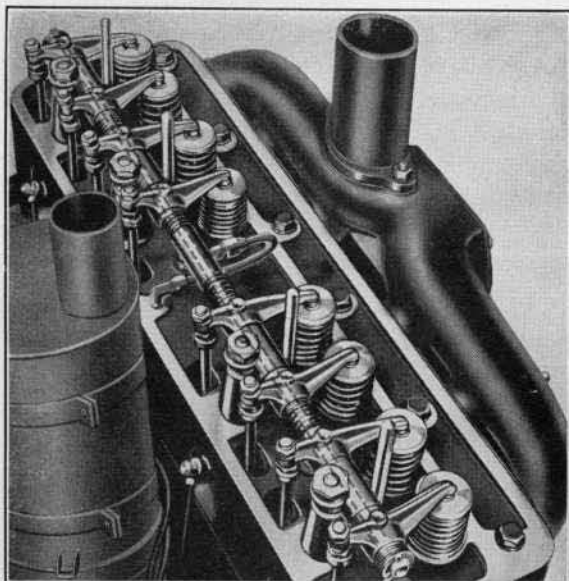


FIG. 50—Showing how oil reaches the valve rocker arms by pressure lubrication direct from the oil pump through a rocker arm shaft that is drilled full length and has communicating holes to each rocker arm bushing.

Courtesy, The Massey-Harris Company.

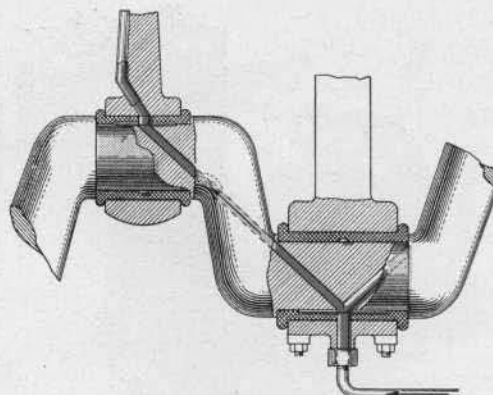


FIG. 51—Pressure circulation system of supplying oil to the connecting rod, main, and wrist pin bearings.

throw-off from the connecting rod bearings, while the rest of the engine is lubricated by pressure circulation.

## OIL FILTERS

Many tractor engines are today equipped with oil filters to help keep the crankcase oil free of abrasive contamination and to aid in removing other impurities that normally collect in the

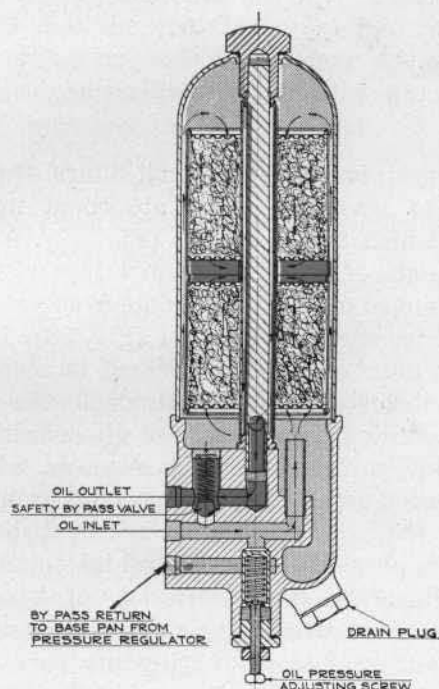


FIG. 52—A replaceable waste-packed type of oil filter with the waste pack in the form of a removable cartridge. Courtesy, Duo-Flo Filter, Michiana Products Corp.

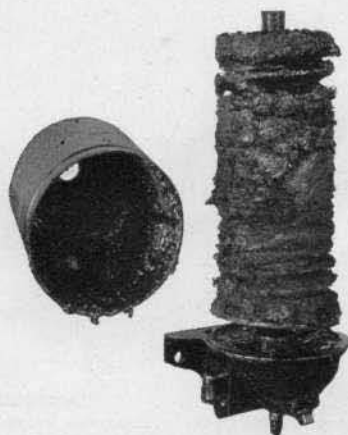


FIG. 53—A cloth bellows type of oil filter with cover removed to show deposit which has rendered the filter partially, if not wholly, inoperative.

crankcase oil. Tractor builders, however, do not always agree that the addition of oil filter equipment is effective. Some claim that it merely adds one more chore to the servicing of the tractor and that, in spite of recommendations for periodic cleaning of the filter or replacement of the element, it is too often neglected. On this account, such tractor builders prefer to equip their tractors with oil filters only when especially ordered.

There are several types of oil filters. One type consists of waste or other absorbent material through which the oil passes (Fig. 52). Another type consists of a felt or flannel type cloth element arranged over a wire frame to offer a large area of filter surface to the oil (Fig. 53). In such units the filter element is enclosed in a chamber so that oil flows from the outside to the inside, the impurities taken from the oil collecting on the outside surfaces. A by-pass valve, which is spring loaded so as to by-pass the oil around the filter in the event the filter element becomes clogged, is placed between the oil inlet and outlet lines. Whenever the restriction of the filter reaches a point where the oil inlet pressure becomes greater than the spring pressure of the by-pass valve, oil will pass around the filter and not be filtered.

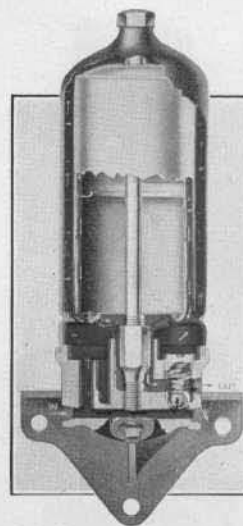


FIG. 54—An edge-type oil filter.  
Courtesy, International Harvester Company.

Another type of oil filter operates on the same principle as that just described except that the filter element is different. This type uses an extremely fine metal strainer or edge-type metal filter (Fig. 54). It is made by winding a flat wire edgewise around a cylindrical cage with a three-thousandths of an inch spacing between the edges. This element will remove only the larger particles until it becomes covered with a filter bed. As this bed continues to build up, the filter becomes more efficient in removing extremely fine materials. When the thickness of the material accumulated on the element restricts the flow of oil through it, the element should be re-

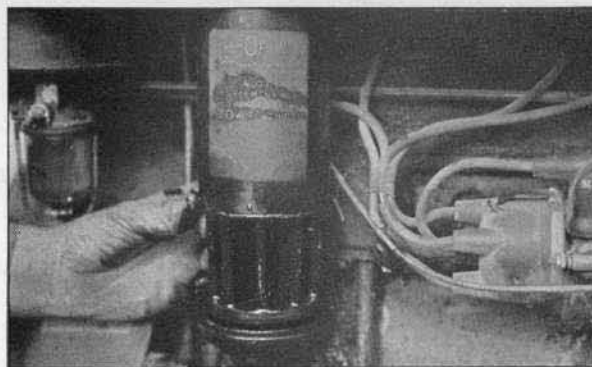


FIG. 55—A star type paper-element filter with cover raised to show the element. The cross-section of the element is in the form of multi-pointed star.

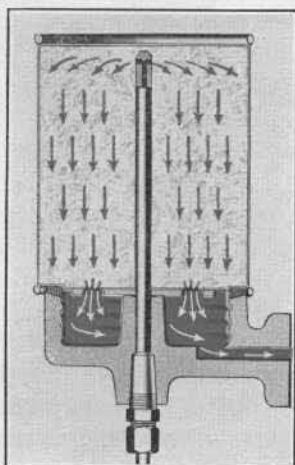


FIG. 56—A replaceable waste packed type oil filter. Courtesy, Tractor Division, Allis-Chalmers Mfg. Co.

moved and cleaned. In case the filter is neglected and becomes plugged, a by-pass valve in the base of the filter opens and allows the oil to continue circulating to the engine parts.

"Star" paper filter elements (Fig. 55), which have several times the filtering area of the metal elements and smaller openings, are now generally used on the later model tractors. When the paper element has been used for the specified length of time, it should be removed and replaced with a new element.

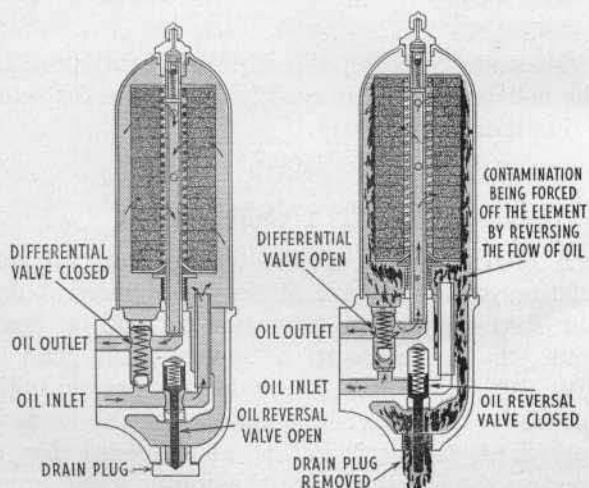


FIG. 57—Felt disc type of oil filter. (Left) Filter in normal operation. (Right) Filter with flow reversed for cleaning. Air pressure may be employed to aid cleaning by connecting air line to fitting at top.

Courtesy, H-W Filters, Michiana Products Corp.

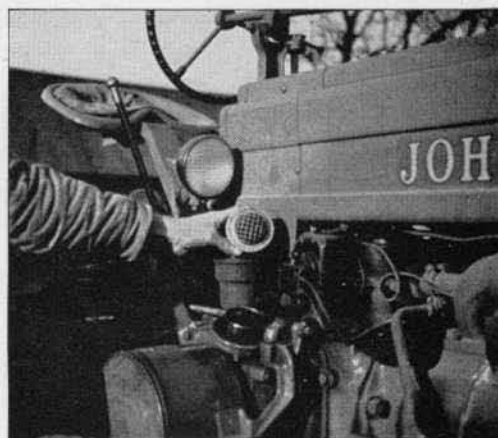


FIG. 58—Showing the oil-soaked air cleaner element on the air intake of a crankcase ventilator system.

Another filter, known as the by-pass type, (Fig. 56) simply takes about 10% of the oil in a by-pass circuit of its own and returns the filtered oil to the crankcase. Most of these filters have a cartridge-type, waste pack element. The cartridge is so designed that when it becomes dirty it must be entirely replaced with a new one.

Crankcase ventilation is used to carry unburned fuel vapors and moisture products of combustion out of the crankcase before they condense and contaminate the crankcase oil. A small amount of moisture will often cause the lubricating oil to acquire a milky color when carbon black is absent or cause the formation of dark-colored water sludge. Oil-soaked air cleaner elements are used in the air intake openings of crankcase ventilator systems (Fig. 58) to prevent dust and dirt gaining access to the crankcase interior. These elements must, of course, be kept clean and well oiled.

## THE CLUTCH

A tractor engine must be able to run free of load for starting, idling, and to permit shifting gears. It is not only necessary for the engine to be running before a load is applied, but it is desirable to have some means of applying the load gradually through the mechanism of a clutch



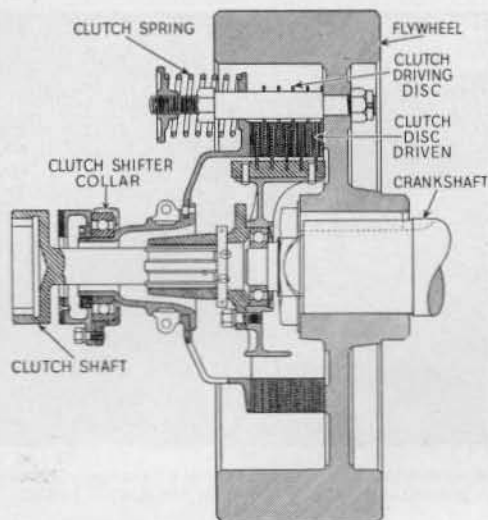


FIG. 59—A multiple disc type of clutch.

(Fig. 62). A clutch permits the load to be picked up gradually and smoothly without undue strain on the engine or power transmission parts.

There are two types of friction clutches used in tractors: (1) multiple disc and (2) single disc.

Multiple disc clutches (Fig. 59) are of two types, one operating in an oil bath, and the other operating dry. The discs are of steel, faced with asbestos or fibrous material that will withstand wear and heating.

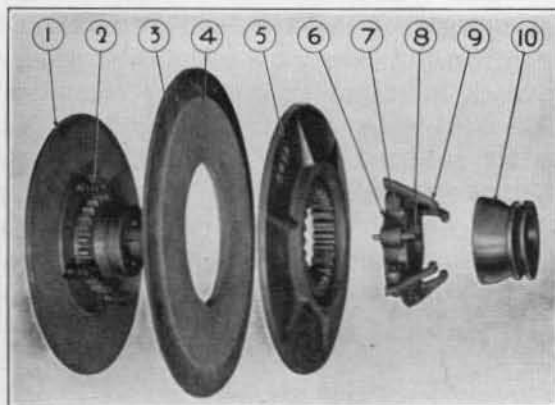


FIG. 60—Parts of a single disc clutch:

1. Hub and back plate.
2. Release spring.
3. Driving plate.
4. Friction disc.
5. Floating plate.
6. Finger assembly.
7. Finger pin.
8. Adjustable lock pin.
9. Finger.
10. Cone.

Courtesy, The Massey-Harris Company.

Single disc clutches (Fig. 60) operate dry, but otherwise are similar in construction to multiple disc clutches except that the disc diameter is usually larger. They usually have a grease fitting for lubricating the throwout bearing and clutch pilot bearing. The clutch pilot bearing is often lubricated through a fitting in the flywheel. To apply the gun, it is necessary to turn the engine so that the fitting on the flywheel registers with a hole in the housing. This bearing requires very little pressure gun grease, and care must be taken not to over-lubricate it. A slipping or grabby clutch is often caused by the use of a poor grease or the use of too much grease.



FIG. 61—A clutch within a belt pulley. Also shown is a pulley brake.

Courtesy, John Deere Tractor Company.

On some tractors, the clutch is located within the belt pulley and is readily accessible for minor adjustments (Fig. 61).

## THE TRANSMISSION

A characteristic of the tractor internal combustion engine is that at very low speed it does not develop sufficient torque to pull a heavy load. On this account, a transmission gear set (Fig. 62) is required to provide the proper engine speeds as well as vehicle speeds for the loads involved. A transmission is also needed for reversing the tractor, since the engine itself cannot be reversed, but always revolves in the same direction. Several speeds forward are usually provided, but only one speed in reverse.

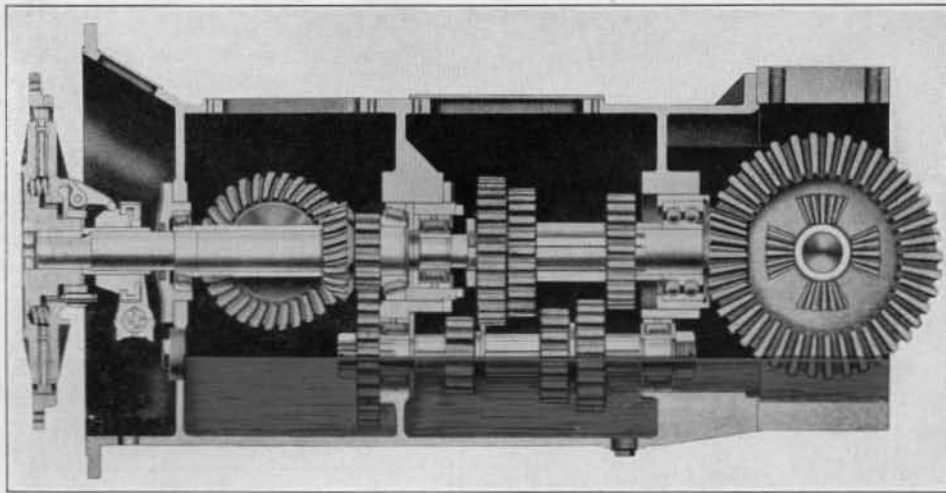


FIG. 62—Transmission system beginning, at left, with a clutch, followed by belt pulley drive, transmission gears, and final drive, including differential pinions within the ring gear.

Courtesy, The Huber Manufacturing Co., Inc.

The gear ratio when driving through high gear on most tractors, including the final drive, will usually be of the order of 25 to 1 up to 50 to 1, while for passenger automobiles it is about 3.5 to 1. Because the gear reduction and rolling resistance are so high, a tractor under load does not coast when the clutch is released. Hence a tractor is customarily started in the particular gear ratio selected for the prevailing operating conditions without first going through the lower gears, as is the practice in automobile operation.

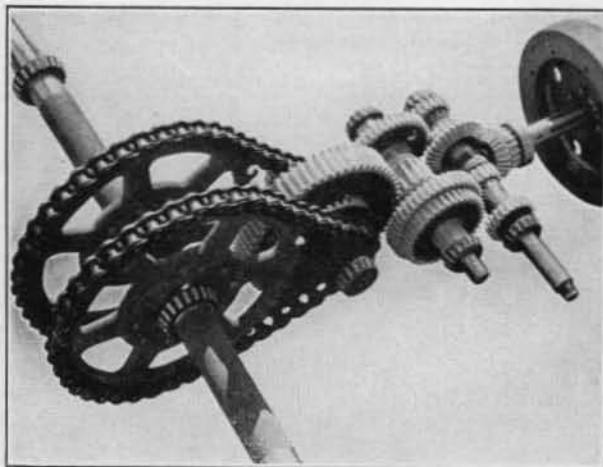


FIG. 63—The elements of a transmission with transverse gear shafts and roller chain final drive.

Courtesy, J. I. Case Company.

Selection of gears is customarily made with a gear shifting lever mounted above the transmission gear case. The gear case usually contains a number of sets of spur gears, with one gear of a set running on the main shaft and the other of the same set running on a counter shaft. A number of these are sliding gears, keyed to the shafts with splines. Engagement and disengagement of the particular gear sets wanted is made by sliding the corresponding mating gear along its splined shaft.

The gears of modern tractors are of machined and hardened steel, fully enclosed and running in a bath of lubricant. The gear shafts are usually supported in ball or roller bearings, lubricated by splash or throw-off of the gear lubricant.

## THE DIFFERENTIAL

The drive from the transmission to the rear wheels is made through a differential (Fig. 62). Except for the problem of turning the tractor, this drive could be made simply through a right-angle bevel gear set or a worm gear set, with the large ring gear driving the wheel axle directly, or driving pinions or sprockets connected to the wheels by further gearing or chains. When the

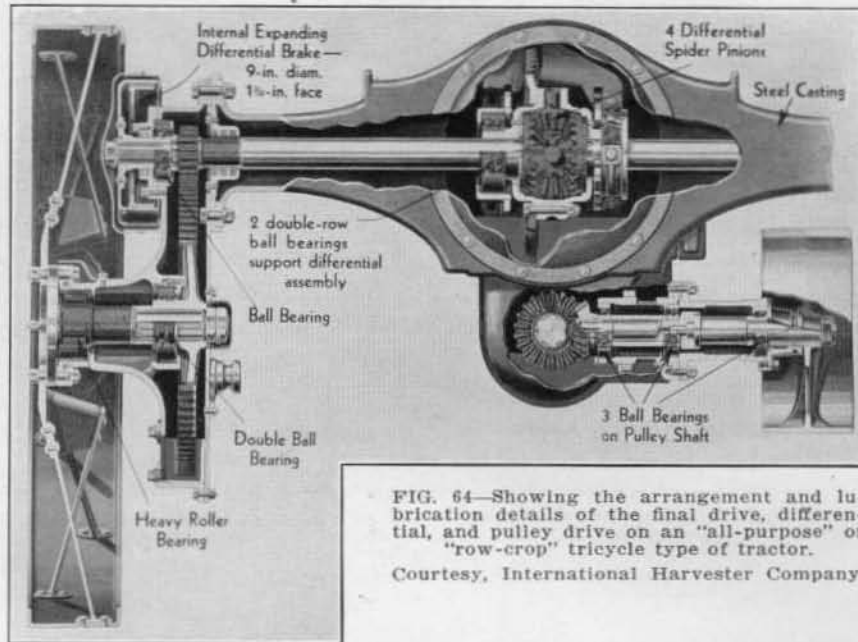


FIG. 64—Showing the arrangement and lubrication details of the final drive, differential, and pulley drive on an "all-purpose" or "row-crop" tricycle type of tractor.  
Courtesy, International Harvester Company.

tractor is driven straight forward, both rear wheels naturally revolve at the same speed, but when the tractor makes a turn, it is clear to see that the inside wheel must turn slower and the outside wheel faster. Some sort of compensating mechanism must be provided to accommodate this difference. Such a mechanism is the differential, so named because of what it does. With

this mechanism, instead of the drive being direct to a single axle, the drive is divided into two halves and both are driven through a cluster of small bevel gears arranged as shown in Fig. 65. The bevel pinion differential gears have bronze or steel bearings and turn on steel pins.

### THE FINAL DRIVE

A chain drive (Fig. 63) is employed on some tractors. The chains in these drives are usually

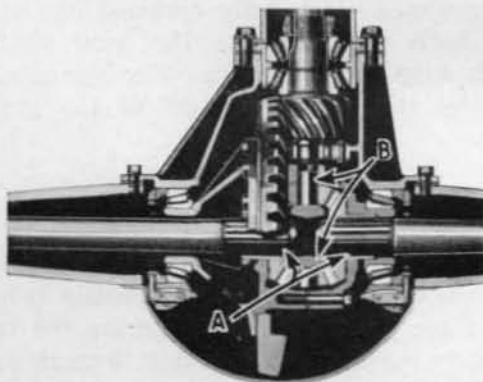


FIG. 65—The principal parts of a differential assembly showing (A) side gears attached to left and right halves of the axle, respectively, and (B) pinions attached to ring gear spider and free to rotate on their own pins.  
Courtesy, Tractor Division, Allis-Chalmers Mfg. Co.

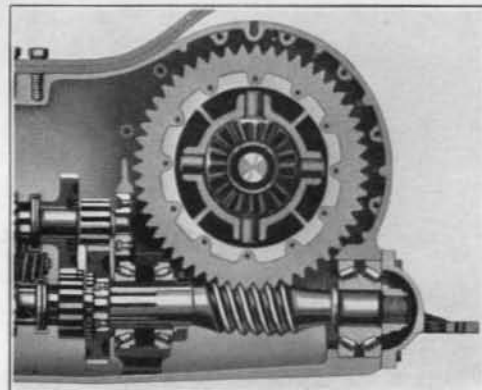


FIG. 66—Worm gear final drive.  
Courtesy, Harry Ferguson, Inc.



of the roller type, with rollers of finely finished hardened steel. Their proper operation and long life depend very largely on keeping the rollers free-turning on their pins. Other tractors often use a large spur gear set for the final drive to each wheel (Fig. 64). One make of tractor (Fig. 66) uses a large, high-reduction worm gear set in combination with a differential for the final drive itself without supplementary gear reduction.

### CRAWLER-TYPE TRACTORS

Crawler-type tractors have transmissions which resemble those already described for

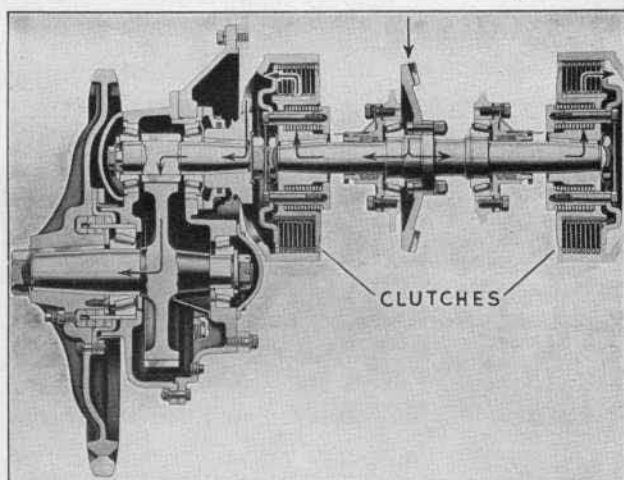


FIG. 67—Clutches (one for each track) are used in the final drive of one type of crawler tractor. Arrows show the flow of power.

Courtesy, Tractor Division, Allis-Chalmers Mfg. Co.

wheel-type tractors, but also incorporated with them is a steering mechanism. While a wheel-type tractor is steered by its front wheels, a crawler-type tractor has only two traction members, and these control steering by being individually slowed down, or stopped and started, or driven independently. In one type, the drive to the two crawler tracks is simply through clutches (Fig. 67), one for one side and another for the other side, and no differential is required. Each clutch, which is hand operated, is, in addition,

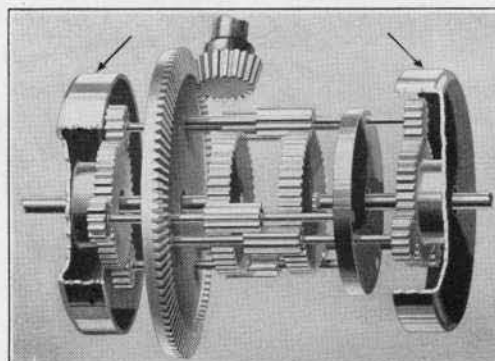


FIG. 68—A differential drive and brakes (shown by arrows) are used for steering on another type of a crawler tractor. Courtesy, The Cleveland Tractor Co.

equipped with a foot operated brake which acts on the driven part. For a quick, sharp turn, one of the clutches is not only released, but the brake for that side is also applied.

Another make of crawler-type tractor uses a differential drive and a brake on each crawler for steering instead of special clutches (Fig. 68). A spur gear type of differential, differing somewhat in design from that previously depicted, but similar in operation, is used.

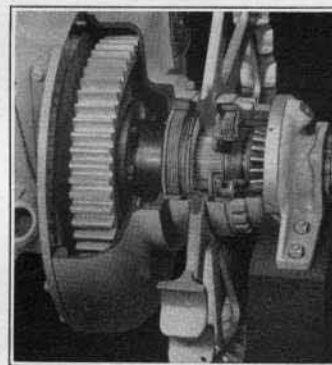


FIG. 69—Cut-away view of hub of final drive sprocket on a crawler type tractor, showing (at center) a metal, bellows type, flexible dust seal.

Courtesy, Caterpillar Tractor Company.

### THE BELT PULLEY

Tractors are rated in horsepower capacity as 8-16, 10-20, 15-30, 20-30, etc., the first number representing the drawbar horsepower, and the

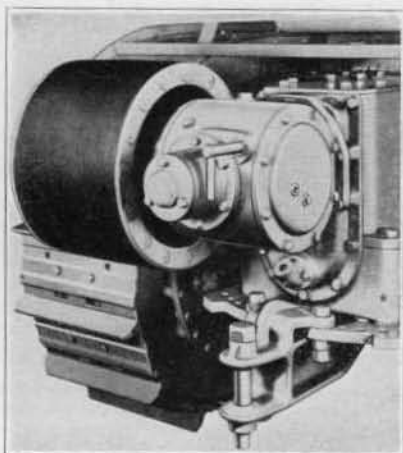


FIG. 70—A belt pulley which is located at the rear on a crawler type tractor. The lever shown is for engaging and disengaging the pulley drive.

Courtesy, Tractor Division, Allis-Chalmers Mfg. Co.

last number the belt horsepower. The difference of 30% to 50% between belt horsepower and drawbar horsepower is partly accounted for by (1) the power absorbed in propelling the tractor itself or lost in friction, and (2) the use of different factors in calculating the respective horsepower.

The belt pulley on most tractors is located on the right-hand side, although in crawler-type tractors it is generally located at the rear. If the engine is set lengthwise in the chassis, the pulley is driven by a bevel gear set at the back of the engine (Fig. 64). Gear driven belt pulleys are customarily designed to have a peripheral speed of about 2650 feet per minute. If the engine is set crosswise, the pulley is mounted on one end of the crankshaft (Fig. 46), or driven through a spur gear set. With this arrangement the pulley, although smaller, is customarily designed to have a peripheral speed of about 3250 feet per minute, thus requiring a larger pulley on the driven machine to give the same speed as obtained by a tractor with the lower belt speed. In some tractors the pulley is driven whenever the engine is in operation, while in others there are means for engaging and disengaging the pulley drive either through the main clutch or a special pulley clutch.

The belt pulley drive is lubricated by a bath

of oil, either sharing the same reservoir as the transmission gear case or having a reservoir of its own. In the latter case, the special reservoir either carries its own supply of lubricant, or is lubricated by the regular transmission oil carried to it by the movement of the transmission gears.

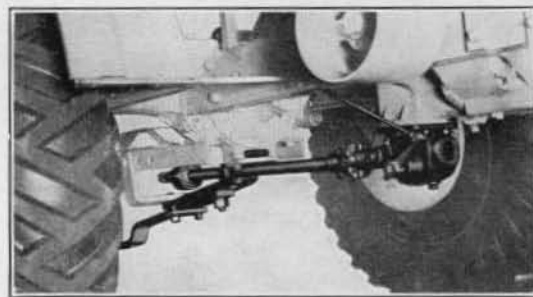


FIG. 71—A power take-off for transmitting power to the pulled equipment. The lever for engaging and disengaging the unit is also shown.

Courtesy, Tractor Division, Allis-Chalmers Mfg. Co.

#### POWER TAKE-OFF AND POWER LIFT

Many tractors are now equipped with a power take-off drive (Fig. 71) leading from the transmission to a generally standardized location above the drawbar so that any type of equipment needing to take power from the tractor can be coupled on readily. Power take-off drives on farm tractors always turn in a clockwise direction (viewed from the rear) and at about 535 r. p. m. at governed engine speed. Combined with this



FIG. 72—A power lift, controlled by dual foot lever, for raising or lowering the working equipment.

Courtesy, John Deere Tractor Company.

unit there is sometimes a power lift (Fig. 72), which needs but a touch of a foot lever to raise or lower the implement attached. A power lift enables the operator to keep his hands on the wheel at row ends when making a turn.

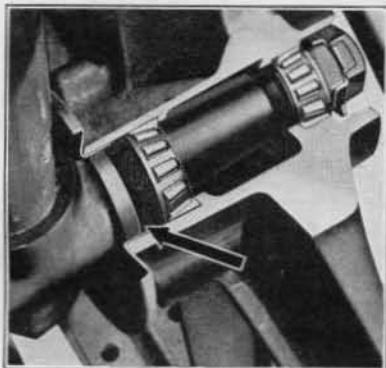


FIG. 73—A dust seal (shown by arrow) on a front wheel hub bearing.  
Courtesy, J. I. Case Company.

### WHEEL BEARINGS

Most tractors now use tapered roller bearings on both the rear and front wheels (Fig. 73). These bearings are sealed to guard against entry of dust and dirt and to minimize leakage of lubricant. The rear wheel bearings may receive lubrication from the oil carried in the differential or final drive, although sometimes grease fittings are installed.

### TRACK ROLLERS

Crawler-type tractors, instead of the usual wheels, have a sprocket or driving wheel and an idler wheel for each track, and in between these two main wheels a number of small rollers supporting the load on the track (Figs. 74-76). Lubrication of the driving and idler wheel bearings is much the same as for the rear and front wheels of wheel-type tractors, roller bearings being generally used. The track rollers may have roller bearings or specially constructed bushings designed with special seals to retain the lubricant and keep out dust, dirt, and water (Figs. 74 and 76). The latter type of bearing usually receives oil from a reservoir directly above the bearing. Periodic filling of the reservoir is made from a special dispenser and fitting.

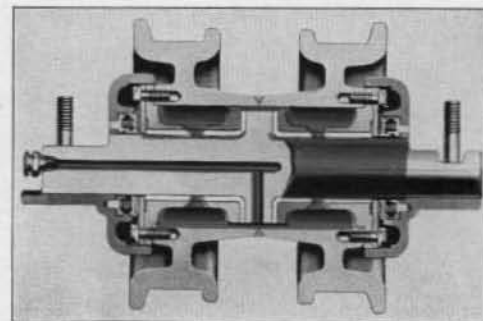


FIG. 74—Large oil reservoirs within this track roller supply lubricant to the bronze sleeve bearings (backed by cast iron sleeves). Thrust loads are carried by a forged flange in the middle of the shaft. Bellows type seals keep oil in and dirt and water out.  
Courtesy, Caterpillar Tractor Company.

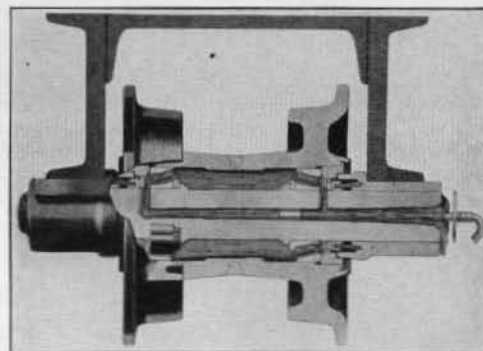


FIG. 75—Roller bearings and neoprene and steel seal-rings are lubricated from large oil reservoirs which contain a fluid lubricant. This type of track roller is lubricated only once every 200 hours (requiring about 3¼ gallons of lubricant per tractor). The lubricant is changed as shown by forcing the old oil out around the lubrication nozzle as the new oil enters.

Courtesy, Tractor Division, Allis-Chalmers Mfg. Co.

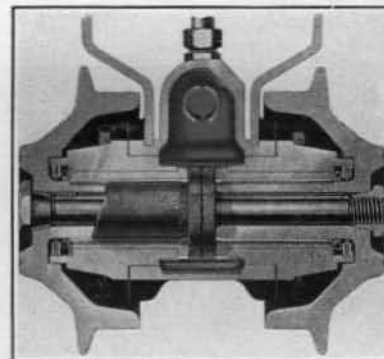


FIG. 76—Another type of oil lubricated track roller. This one has an oil supply line to a central reservoir. Leather oil seals at each end keep oil in and dirt and water out.  
Courtesy, The Cleveland Tractor Company.





FIG. 77—Foot controlled rear-wheel brakes are used on tractors of wide wheel tread to aid in making extremely short turns.

Courtesy, John Deere Tractor Company.

### THE STEERING GEAR

Steering of wheel-type tractors is accomplished very much in the same way as is customary for automobiles. A steering gear, usually of the worm-and-sector or worm-and-nut type, is enclosed in a lubricant-tight case, the lever arm being connected to the front wheel knuckles by the usual cross arm and tie rod linkage (Fig. 78). Three-wheel tractors may employ simply a worm

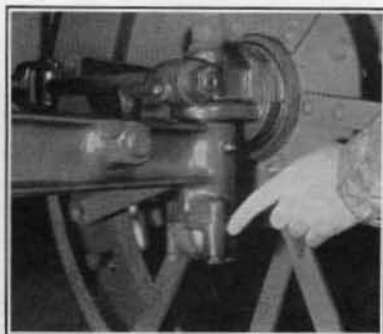


FIG. 78—Front wheel steering knuckle on a 4-wheel tractor.  
Courtesy, International Harvester Company.



FIG. 79—Steering spindle and axle shafts of a "3-wheel" type of tractor. (Above) Steering worm and sector. (Below) Note dust seals at inner ends of the axle shafts.  
Courtesy, Minneapolis-Moline Power Implement Co.

and sector directly connected to the turning spindle (Fig. 79).

To aid in turning tractors having wide wheel treads, turning brakes are usually employed, one on each rear wheel (Fig. 77), so that, in making a sharp turn, the inside wheel can be braked. The brakes may be operated by hand, or foot, or automatically by being connected to an arm on the steering spindle.



FIG. 80—Phantom view of steering gear used on a 4-wheel type of tractor.  
Courtesy, The Massey-Harris Company.



FIG. 81—(Left) Air filled rubber tire with cast iron weight added to the wheel to improve traction. (Center) Tire filled three-fourths full with water (calcium chloride solution in winter) to improve traction, without addition of wheel weights, and reduce bounce. (Right) Tire filled 100% with liquid is the latest practice which further improves traction and reduces bounce and eliminates any need for checking air pressure.

## RUBBER TIRES ON TRACTORS

Rubber tires have come into wide use on tractors, because it has been found that they decrease the rolling resistance and thereby lower fuel consumption somewhat. For example, a three-plow tractor was found to take 6.4 more horsepower just to move the tractor when equipped with steel wheels than when equipped with rubber tires. In general, the maximum drawbar pull of a rubber tired tractor is equal to about half the weight on the rear wheels. Therefore, to increase the traction, it is desirable to add extra weight to the rear wheels. This is done either by attaching weights to the wheels or by filling the tires three-fourths full with water (or in freezing weather, water and calcium chloride solution.) A tire so filled with water (or calcium chloride solution) will add about 250 pounds weight to each rear wheel. If rubber tired tractors can be operated at full load, they may show

fuel savings over steel wheels ranging from 10% to 25%.

TABLE I  
SIMPLIFIED SCHEDULE  
TRACTOR TIRE INFLATION DATA

### FRONT—ALL SIZES

- |                      |         |
|----------------------|---------|
| 1. 4 ply tires ..... | 28 lbs. |
| 2. 6 ply tires ..... | 36 lbs. |

### REAR—ALL SIZES

- |  |         |
|--|---------|
| 3. Minimum inflation pressure .....  | 12 lbs. |
| 4. When plowing, increase pressure in tire on furrow wheel by .....  | 4 lbs.  |
| 5. When special heavy wheels are used, or heavy implements, such as corn pickers, bedders, etc., are carried on the tractor, inflation pressure must be increased. |         |

Adopted by Tire and Rim Association.

Having now completed a detailed discussion of the function and construction of the various parts of a farm tractor, a further step can be taken toward an understanding of operating theory and practice with the object of helping operators attain better operating efficiency from their tractors. The following section on Tractor Operation and Maintenance will, therefore, take such a step and deal particularly with means for obtaining good operating efficiency, especially through the proper functioning of well-selected fuels and lubricants.

## PART TWO

## TRACTOR OPERATION AND MAINTENANCE

## POWER CONSIDERATIONS AND TRACTOR RATINGS

Scientists have proved that heat is a form of energy. Not only can energy be converted into heat, but heat can be converted into energy. Friction is an example of energy converted into heat, while power from the burning of a fuel, as in a tractor engine, is an example of heat converted into energy.

The unit of heat used for this evaluation is the British thermal unit, which is usually abbreviated, B. t. u. One B. t. u. is defined in Mark's Mechanical Engineers' Handbook as "the 1/180th part of the heat required to raise the temperature of one pound of water from 32°F. to 212°F. It is substantially equal to the heat required to raise the temperature of one pound of water from 63°F. to 64°F." For example: 1000 B. t. u.'s will raise the temperature of 1000 pounds of water one degree, or 100 pounds of water 10 degrees.

The unit of power is called "horsepower." It is defined as "the rate of doing work equivalent to raising 33,000 pounds one foot in one minute.

To convert heat (B. t. u.) to power (h.p.), tests have been conducted which show that 42.44 B.t.u.'s are equivalent to one horsepower.

Just as a matter of interest, Bulletin No. 174 of the Department of Agriculture states that if a horse exerts a pull of 150 pounds on his traces, and walks 220 feet in one minute (a rate of approximately 2½ miles per hour), he has done work at the rate of one horsepower (220 feet per minute x 150 pounds = 33,000 foot-pounds per minute). If the horse continues to pull the same load 2½ miles in one hour, he has done "one horsepower hour of work."

A "horsepower hour" means, in other words, that one horsepower has been exerted continuously for 60 minutes.

Engines are rated by their horsepower. A 25 horsepower engine will deliver 25 horsepower continuously.

Whenever heat or energy is converted from one form to the other, or transmitted from one place to another, a considerable portion of it undoubtedly will be lost. Fig. 82 illustrates approximately where the different losses may occur in a typical tractor engine.

Note that, in the typical tractor engine 75% (34+41) of the potential heat energy in the fuel is lost in the exhaust and through the cooling water. The remainder, or 25% (100-75), can be called the "indicated horsepower" of the engine.

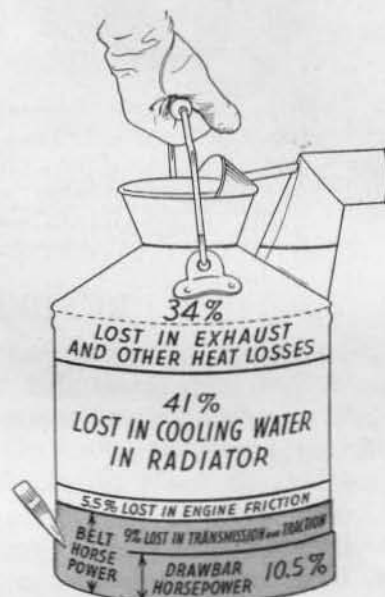


FIG. 82—Illustrating the approximate potential heat-energy losses in a typical tractor engine.

As depicted in the illustration, an additional 5.5% is lost in engine friction, leaving only 19.5% available for belt work.

But when the tractor is used for drawbar work, an additional 9% of the original potential heat energy is wasted in friction introduced by the transmission and traction conditions, leaving only 10.5% available for drawbar work.

It should be noted in passing that, while "indicated horsepower" is a measure of the energy developed by the ignited mixture acting on the pistons of the cylinders within the engine, it does not take into account friction or other mechanical losses.

"Brake horsepower," on the other hand, is a measure of the power developed by the engine actually pulling against the load of a brake or dynamometer. There are several different forms of such power absorbing and measuring devices, some operating with friction block, others with water, or air, and others electrically.

The simplest form of device for measurement of brake horsepower is the Prony brake, illustrated in Fig. 83.



A simple example of the details of calculating brake horsepower may be helpful. First, to find horsepower, it is necessary to determine the number of foot-pounds per minute being developed. Using the definition of horsepower previously given, foot-pounds per minute divided by 33,000 equals horsepower. With the Prony brake, the weight reading in pounds on the scale arm is observed and recorded, after making a correcting deduction for the weight of the arm. To determine "feet per minute" it is then necessary to calculate how far point "P" (Fig. 83), where the scale is attached, would travel in one minute if it were free to rotate. Since the distance in feet travelled in one revolution is the circumference of a circle whose radius is R feet, or  $2\pi R$ , this distance multiplied by the counted revolutions per minute will give the feet per minute. Hence,  $\text{h.p.} = \frac{2\pi R \times \text{r.p.m.} \times W}{33,000}$ , with W the net weight reading of the scale. As a short cut to this calculation, the brake arm (R in the formula) can be made 5.25 feet in length. The circumference of the presumed circle of travel will then be 33 feet, which when divided by 33,000 gives the simple figure of .001, so all that it is necessary to do in calculating the horsepower in this case is to count the revolutions per minute, mark off three places, and multiply by the corrected weight reading of the scale (W).

"Drawbar horsepower" cannot be determined as easily or as accurately as brake horsepower, since so many variables are introduced by the condition of the ground, the adhesion of the driving wheels to the ground, the size of the driving wheels, and the packing of the ground. Ground packing and rolling resistance vary with different tractor types and depend a great deal on weight distribution.

The drawbar horsepower of a tractor must be determined by actual measurement of the power exerted at the drawbar in pulling (Fig. 84); for example, when plowing or hauling. It is found that a tractor drawing two plow bottoms, each cutting a furrow 14 inches wide and 8 inches deep, requires about 600 pounds pull for each bottom. With the tractor speed at  $2\frac{1}{2}$  miles per hour, which is 220 feet per minute, the drawbar horsepower would be  $\frac{600 \times 2 \times 220}{33,000}$  or 8 drawbar horsepower. The drawbar horse-

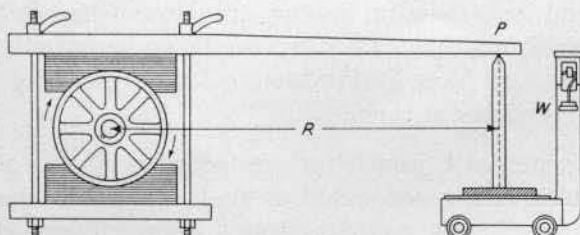


FIG. 83—The elements of a Prony brake.

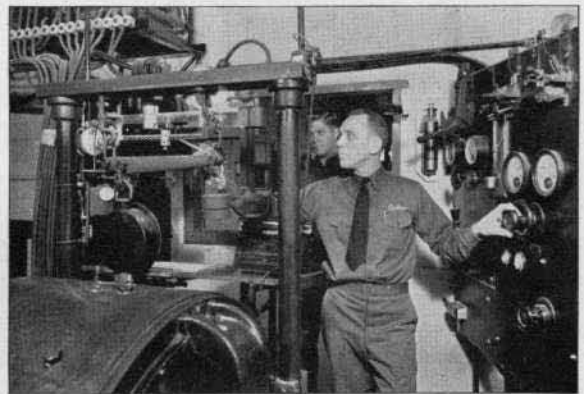


FIG. 84—Equipment used in tractor horsepower testing. (Above) Determining drawbar horsepower. (Below) Determining belt horsepower.  
Courtesy, Department of Agricultural Engineering, The University of Nebraska.

power will generally be from  $\frac{1}{2}$  to  $\frac{2}{3}$  of the brake horsepower.

A rough way to estimate the speed of a tractor is to walk beside it for 20 seconds, taking 36-inch steps, and count the number of steps taken. This number, divided by ten will give the approximate speed in miles per hour. For example, 30 steps in 20 seconds =  $\frac{30}{10} = 3$  m.p.h.

The drawbar horsepower may be approximated in this way: Observe or estimate the speed of the tractor and, likewise, the load the tractor is pulling. (A quite common load is that imposed by two plows as used in a previous example. This figured 600 pounds pull per plow bottom.) Then, since one mile an hour equals 88 feet per minute, if the speed of the tractor is 3 miles per hour, the drawbar horsepower will be approximately  $\frac{(3 \times 88) \times (2 \times 600)}{33,000}$  or 9.6 h.p.

## PROPER FUEL COMBUSTION

All petroleum fuels are composed almost entirely of just two elements in only slightly varying proportions, the usual composition being about 85% carbon and 15% hydrogen. On complete combustion the carbon unites with oxygen

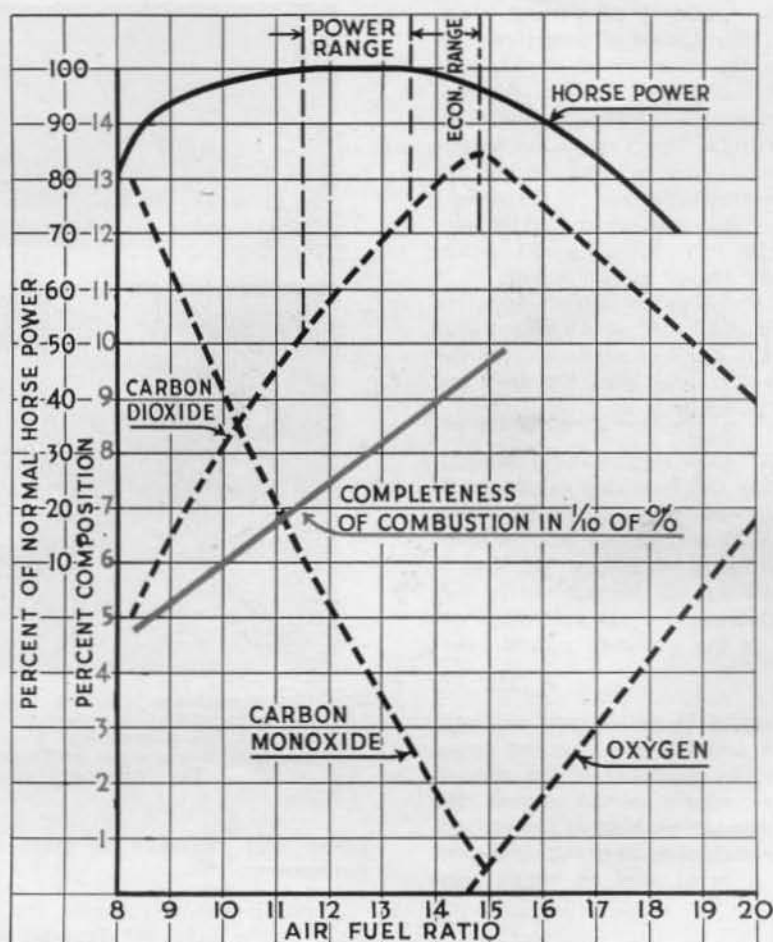


FIG. 85—Chart showing relation of air fuel ratio to (1) horsepower, (2) per cent composition of exhaust gases, and (3) completeness of combustion.

from the air to form carbon dioxide and, similarly, the hydrogen burns to water vapor. For complete combustion, one pound of liquid fuel requires about 15 pounds of air, or one gallon of liquid fuel to about 9000 gallons of air. It happens, however, that this perfect mixture is rarely used. Instead the so-called "maximum power" mixture of about one pound of gasoline per 12.5 pounds of air is more generally employed in order to obtain maximum possible performance from the engine. The exhaust gases from this mixture contain about 70% nitrogen, 14% water, 11% carbon dioxide, and 5% carbon monoxide. The large proportion of nitrogen is due, of course,

to the fact that it comprises nearly 80% of the intake air. It is worth noting that approximately one gallon of water is formed in the combustion process for each gallon of fuel burned. This is one of the sources of the water that may be found occasionally in the crankcase, especially in cold weather, since vapor laden combustion gases may blow by the pistons into a cool crankcase and there condense.

A mixture proportion range of  $11\frac{1}{2}$  to 13 pounds of air per pound of fuel, commonly used for maximum power, gives a completeness of combustion ranging from 70% to 82%. A mix-

IN A COLD ENGINE, WHEN STARTING, a 2 to 1 ratio of Air to Liquid Fuel is supplied by the choke, but only a portion of the fuel is instantly vaporized:

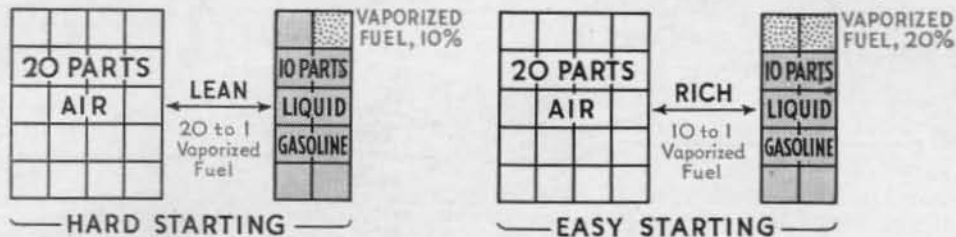


FIG. 86—How the "front end" volatility of a gasoline affects ease of starting a cold engine.

ture ratio of from 13 to 13½ pounds of air per pound of fuel gives a completeness of combustion of from 82 to 86%. The latter mixture ratio affords a good balance between maximum power and best economy with no very appreciable loss in engine power. These and previously mentioned relationships are depicted in graph form in Fig. 85.

There is a general tendency among tractor operators to use a very rich carburetor setting. This is done so that the engine when cold will not stall when put under load. These very rich mixtures result in greater fuel consumption and, if excessive, may result in black exhaust smoke. Such mixtures are also likely to cause excessive carbonization in the engine and thinning of the crankcase oil from excessive quantities of unburned fuel.



FIG. 87—A tractor does not tire; it can stay on the job hour after hour, day and night if need be. Courtesy, Oliver Farm Equipment Sales Company.

A mixture containing more than the required amount of air is known as a lean mixture. Too lean a mixture burns so much slower than normally that under heavy loads it can result in burned exhaust valves. In addition, an excessively lean mixture may burn so slowly that the combustion gases are still aflame when the intake valve opens to take in the next fuel charge. When this happens the fresh, incoming charge is ignited, causing "back-firing" or "popping" in the intake manifold and through the carburetor.

The leanest mixture that will fire in the average tractor engine is about 20 to 1, and the richest is about 8 to 1. This has reference to the mixture strength of the fuel charge that actually reaches the cylinder. To start a cold engine, for example, it may be necessary to use temporarily a 2 to 1 ratio at the carburetor by manipulating the choke, in order to get a rich enough mixture to fire (Fig. 86). This is because only vaporized fuel will burn and at sub-normal temperatures, only a small part (possibly 10%) of the fuel may vaporize at first. As soon as the engine takes hold and warms up, the choke must be reduced gradually in order to return eventually to the normal carburetor mixture ratio.

## FUEL KNOCKING

In the transforming of the available energy in a fuel into useful work through the process of combustion, one of the stumbling-blocks is "knocking" (Fig. 88). When a fuel charge knocks, power and economy are sacrificed, hence the



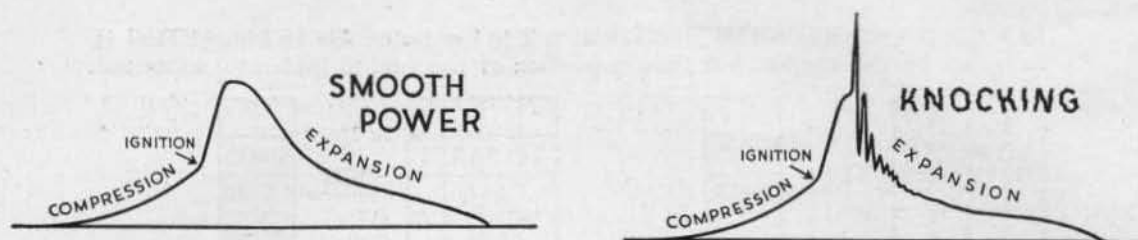


FIG. 88—Time-pressure indicator diagrams depicting what happens in the cylinder of a tractor engine during the compression and power strokes, (left) when there is no "knocking"; (right) when "knocking" occurs.

elimination of fuel knocking is essential to efficient tractor operation.

It should be recognized, however, that there are a number of kinds of knocking that are not related to the fuel, and these should not be confused with fuel knocking. For example, if the engine is operating under very heavy loads with the spark advanced too far, a spark knock will result. This is not a fuel knock. An advance in spark is often an unsuspected cause of spark knock. In other cases, spark plugs of too long a base may be used. These plugs may run too hot and cause a pre-ignition knock. Pre-ignition may also result from other causes, most of which are essentially some form of overheating. Overheated engines have sometimes been observed to continue running even after the ignition spark has been turned off, the firing of the fuel charge probably resulting from incandescent carbon in the combustion space. Operators can avoid this by allowing the engine to idle and cool down before switching off the ignition.

True fuel knocking often does occur in an engine operated at near full throttle and under a very heavy load. Under these conditions, a greater volume of fuel charge is taken into each cylinder per engine revolution, and higher than normal compression pressure results. The higher temperatures resulting from this increased compression pressure may be sufficient to cause knocking. In this case, the knock is not the result of pre-ignition since it occurs after ignition by the spark plug. Part of the combustible gases do not burn in the usual manner. Instead, after combus-

tion has progressed part way, the remaining portion of gases detonates violently (Fig. 89) with an accompanying pounding or "knocking" noise and intense radiation of heat to the combustion chamber surfaces. It has been noticed that the presence of carbon tends to induce this kind of knocking by its heat-insulating effect. This promotes higher combustion space temperatures than would be attained with clean surfaces.

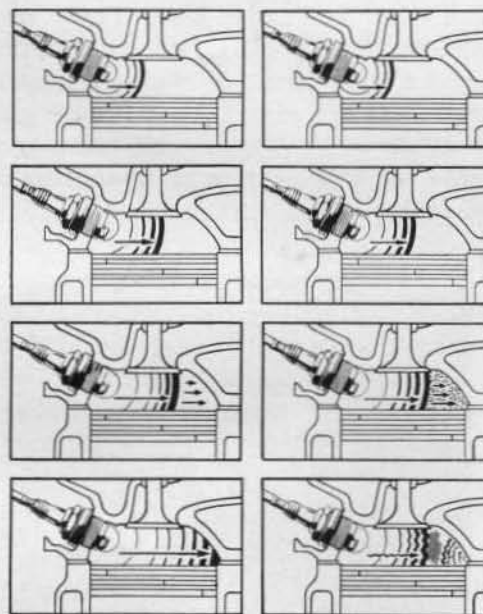


FIG. 89—With a "non-knocking" fuel, burning of the air-fuel charge proceeds as shown in the first vertical row. The whole fuel charge burns smoothly from beginning to end. With a "knocking" fuel, however, burning proceeds as shown in the second vertical row. The last part of the fuel charge to burn is self-ignited, and immediately afterwards detonation, or "knocking," occurs.

Courtesy, General Motors Corporation.

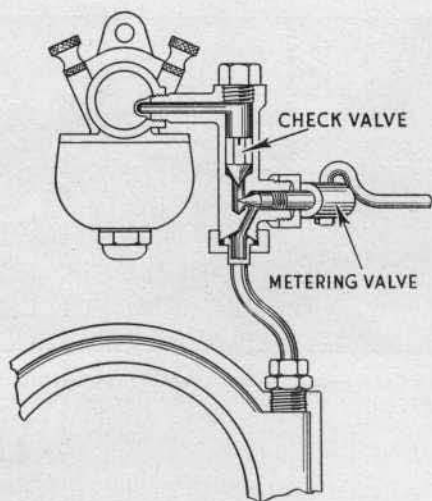


FIG. 90—On some of the older models of tractors, water injection (with the fuel in the intake manifold) is used to control fuel knock. Shown here are (1) brass check valve; (2) metering valve with control rod.  
Courtesy, John Deere Tractor Company.

While fuel knocking is occasionally encountered in most tractor engines under the conditions described, in engines of relatively high compression ratios, ordinary fuels are likely to knock most of the time, even under regular operating conditions, unless they possess sufficiently high antiknock properties, or unless special cooling facilities for the compressed fuel charge are provided in the engine design.

A very old practice, first used on kerosene burning tractors that knocked badly, is to inject a small amount of water into the intake manifold. This prevents knocking possibly by its cooling effect in the combustion process and possibly by its dampening effect on flame propagation. Water is taken from the cooling system supply and introduced into the manifold through a brass needle valve with a check valve (Fig. 90) to prevent the water from entering under light load conditions. The water is fed very sparingly because too much would seriously cut down the power development of the engine.

## REQUIRED FUEL PROPERTIES

American tractor operators are more fortunate than they often realize in having available to them at relatively low cost the practically pure

hydrocarbon liquid fuels derived from petroleum. Of more than 400,000 known chemical compounds, none have as high or as useful heat energy content as those derived from petroleum.

It has now been determined that an altogether suitable power fuel must have (1) properly balanced volatility and (2) properly selected anti-knock characteristics with respect to both the engine and the operating conditions under consideration.

## VOLATILITY

Volatility determines how readily the liquid fuel may be vaporized to form a combustible fuel mixture with air. It also is closely related to the ease with which a high degree of completeness of combustion may be obtained. Opposed to this is the relationship that the lower the volatility, the higher is the total heat-energy content of the fuel (Fig. 91).

With further respect to volatility, and with the above factors in mind, the object of good fuel design is to get the flexibility and ease of performance desired without too great a sacrifice in best possible economy. A good power fuel, therefore, represents a proper balancing of these vola-

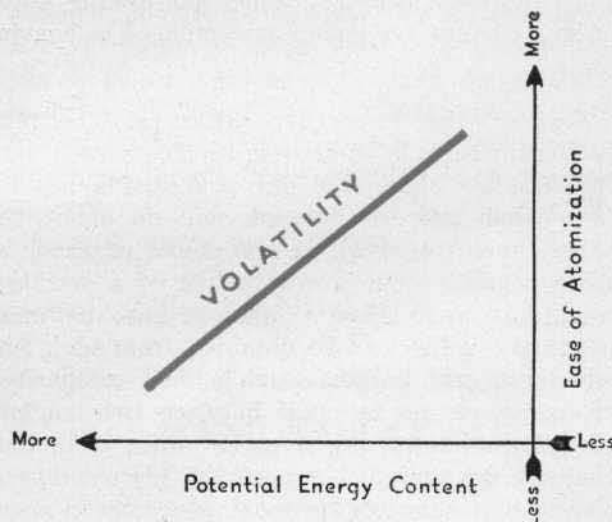


FIG. 91—A graphic presentation of the relation of petroleum fuel volatility to its ease of atomization and potential energy content. The latter two properties are shown to be opposed in nature.

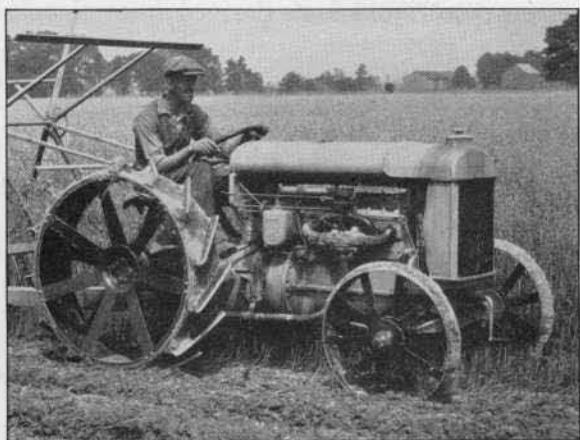


FIG. 92—An early model 2-fuel tractor designed (before the introduction of distillate and other special types of tractor fuels) for operation on kerosene.



FIG. 93—A late model 2-fuel tractor, typical of those today which may operate on either gasoline or the heavier type fuels.

Courtesy, J. I. Case Company.

tility requirements. Tractors designed to burn fuels heavier than gasoline have a lower operating efficiency due to the higher manifold temperatures and lower compression pressures. This, however, is intended to be more than offset by the greater energy content per gallon of the heavier fuel. Gasoline burning tractors, on the other hand have a higher compression ratio and also higher operating efficiency due to operating with a colder manifold and less manifold restriction, which permit greater volumetric efficiency. This, however, is offset somewhat by the lower energy content per gallon as compared to heavier fuels.

One of the important differences between petroleum fuels is their weight. Tests with two-fuel tractors show that one pound of a heavier fuel, when properly burned, will do about the same amount of work as one pound of gasoline. Since a gallon of a power fuel or of a distillate would be heavier than a gallon of gasoline, more power per gallon can be obtained from such fuel when properly burned. Such a fuel comparison of course, cannot be made between two tractors of different compression ratios since it is true that the higher efficiency of the high compression engine operating on gasoline results in about the same amount of work per gallon as can be obtained from a two-fuel tractor operating on a heavier fuel.

If a two-fuel tractor is to be operated continuously on gasoline, better economy could be obtained by increasing the compression ratio and converting the engine to a gasoline job. When this is done, several other changes with respect to spark plugs, valves, valve lubrication, manifold, etc., should be made.

Obviously, the tendency to dilution of the crankcase oil with unburned portions of the fuel, and the washing down of the cylinder walls during periods of poor combustion, is less for gasoline than for heavier types of fuels, but in either case if the volatility of the fuel is substantially correct for the type of engine concerned, and proper control of manifold heat and engine cooling temperatures is made, there should be no

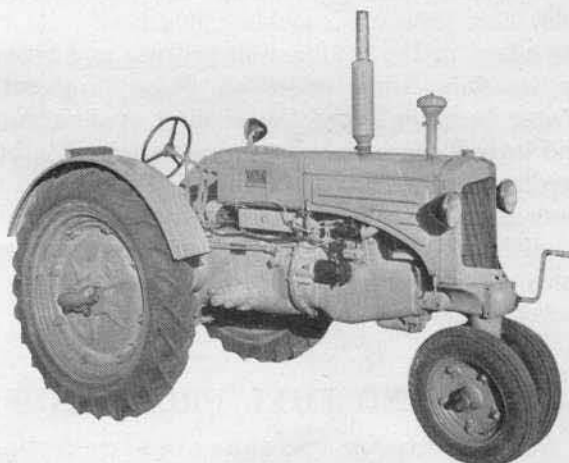


FIG. 94—A late model gasoline burning tractor (designed solely for the use of gasoline).

Courtesy, Minneapolis-Moline Power Implement Co.



trouble from excessive dilution. Excessive dilution may result, however, from the use of fuels that are much too heavy in the final portions of their composition.

## ANTIKNOCK

Antiknock characteristics, the second property required of a tractor fuel, determine the ability of a fuel to keep from knocking, the causes of which have already been explained. The reason why one fuel will knock and another not knock under the same operating conditions is simply due to a difference in antiknock property. This property in any tractor fuel must always be high enough to prevent knocking under the prevailing operating conditions.

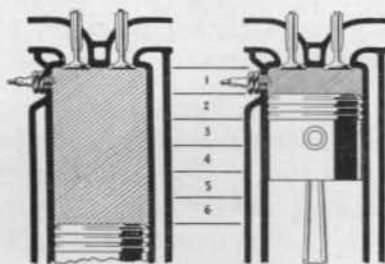


FIG. 95—Illustrating what is meant by "compression ratio." (Left) Piston at beginning of compression stroke. (Right) Piston at end of compression stroke. Comparing the two, six volumes in the space above the piston have been compressed into one volume, a ratio of 6 to 1.

Courtesy, Ethyl Corporation.

Tractor engines differ in their antiknock requirements just as they do in volatility requirements, but in this case it is compression temperature resulting from compression pressure that makes the difference. Still, if the fuel selected, whether gasoline or a heavier type of fuel, has the right antiknock property for the type of engine in which it is used, and engine operating temperatures are properly controlled, there should be no troublesome knocking.

When knocking occurs, the valves and other engine parts are subjected to severe punishment from excessively high temperatures and pressures, and bearings, pistons, spark plugs, and the cylinder head gasket are likely to be damaged

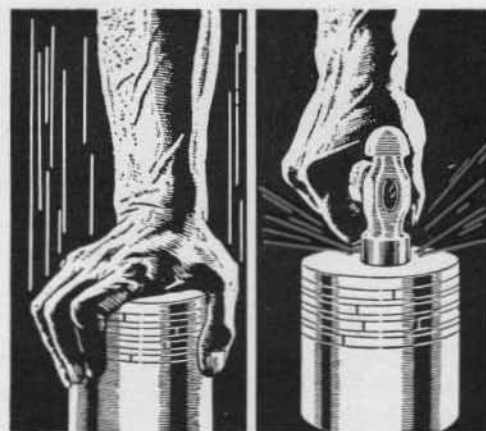


FIG. 96—Antiknock quality makes this difference in a tractor fuel: Power that pushes instead of power that pounds.

from the violent pounding they receive (Fig. 97). As shown in Fig. 96, power is wasted because the piston receives a sudden, hammer-like blow which has less thrusting power than the smooth push of a nonknocking fuel.

## IMPURITIES

Impurities which are seldom encountered in reputable fuels, but which probably should be

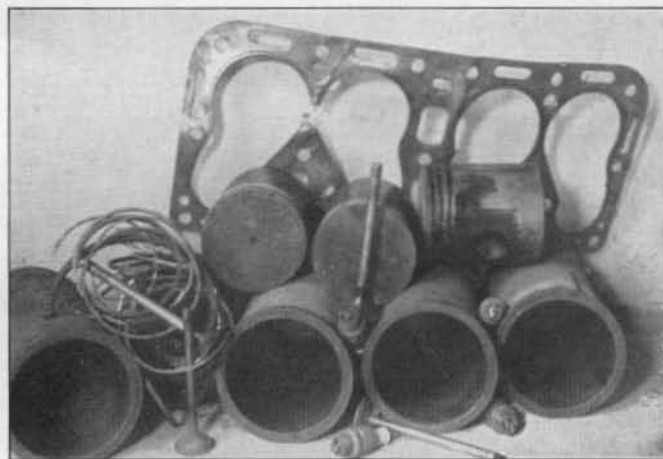


FIG. 97—Damage to these engine parts has resulted from continued operation of a badly knocking engine.

guarded against, in cheap fuels of unknown origin, are:

1. Sediment and water.
2. Sulfur, not to exceed reasonable limits.
3. Gum, not to exceed reasonable limits.

In the case of the more volatile, low-viscosity fuels, like gasoline or special tractor fuel, sediment and water contamination are readily removed by settling and ordinarily, with proper storage and handling and periodic cleaning of the sediment bulb, there is very little likelihood of difficulties from this source. Anyone familiar with carburetor operation can readily surmise how quickly sediment or traces of water will clog the small passages and metering jets and thus render the carburetor incapable of functioning properly. Before efficient operation can again be restored, the carburetor must be taken apart and cleaned.

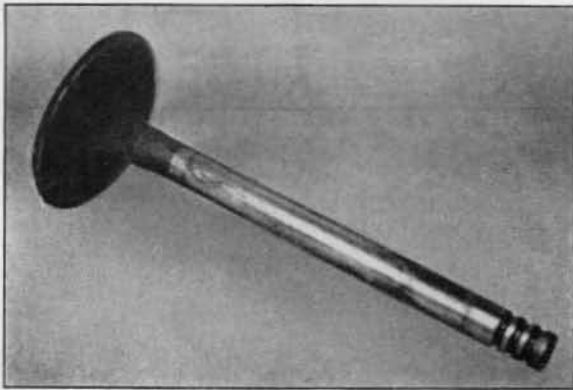


FIG. 98—A corroded valve stem. Some of the newer stainless steel valves are of improved resistance to valve stem corrosion and rusting.

Cheaper fuels of any type, particularly those offered by very small refineries or "skimming plants" with inadequate refining facilities, are sometimes found to contain harmful amounts of sulfur and gum-forming products. It is not necessary that tractor fuels be entirely free of all traces of sulfur if the sulfur is of the non-corrosive kind, and if the amount is kept below dangerous limits. In the past, however, much more rigorous standards have been applied than really



FIG. 99—Wrist pin corrosion caused by moisture and excessive fuel impurities.

is necessary. Moderately low sulfur assumes importance when the weather is sufficiently cold to cause low-temperature engine operation for prolonged periods, or when the engine is worn, causing excessive blow-by. Under such circumstances, a small portion of the products of combustion may find its way into the crankcase and remain in the cylinders when the engine is stopped. If the fuel contains much sulfur, and if water from the condensed products of fuel combustion is present, a dilute solution of sulfurous and sulfuric acids is formed which may cause serious corrosion of important parts, such as cylinder walls, anti-friction bearings, wrist pins (Fig. 99), cams and tappets.

Corrosive sulfur products must, of course, not be permitted in the fuel. It is, therefore, required that the fuel pass a test for corrosion to make sure that it will not attack the metal surfaces with which it is in constant contact in the fuel tank, lines, and carburetor. From what has been said about sulfur as a fuel impurity, it is not difficult to see how low-priced fuels, in which proper treatment has been slighted to keep the cost down, may actually be expensive to use in the long run.

Improperly and cheaply refined fuels are those most likely to cause difficulties in engine opera-

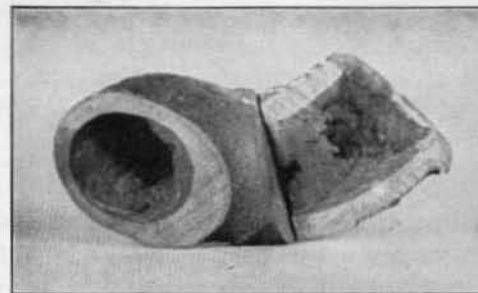


FIG. 100—A section of an intake manifold cut away to show build-up of deposits from the use of a poor quality fuel of extremely high gum content.

tion from gum formation. Proper refining methods remove or render ineffective those unstable portions of the fuel which may cause gummy deposits to collect in the carburetor mechanism, in the manifold (Fig. 100), on the inlet valve guides, or in the piston ring grooves. Sluggish or stuck valves and piston rings, resulting from poor quality fuels, can add to the cost of tractor operation and maintenance sufficiently to offset any supposed advantage in lower price per gallon. On the other hand, it is undoubtedly true that, much the same as for non-corrosive sulfur, more rigorous standards have been applied in the past than really is necessary.

### CARBURETOR ADJUSTMENTS

Field surveys show that the average tractor owner wastes from \$8.00 to \$15.00 worth of fuel each year just because he doesn't have the carburetor of his tractor properly adjusted. Putting the tractor under load before it is properly warmed up is the principal cause of so many over-rich carburetor adjustments. While operators should not constantly tinker with the tractor carburetor, they should adjust it as needed for the various fuels and load conditions encountered.

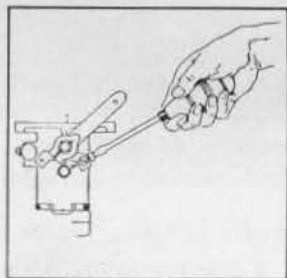


FIG. 101—A throttle-stop set screw constitutes the idling speed adjustment of the carburetor.  
Courtesy, Zenith Carburetor Company.

Before making these adjustments, the operator should refer to his instruction booklet to be sure he understands exactly what to do. Most tractor engine carburetors have three adjustments: idling speed adjustment (Fig. 101), idling speed mixture adjustment (Fig. 102), and high speed or load mixture adjustment (Fig. 103). No

adjustment should be made until the engine is up to proper operating temperature.

The idling speed adjustment is nothing more than a stop screw which regulates how far the throttle will close when the governor control lever is set in the idling position (Fig. 101). This is set properly at the factory, but, after a tractor has been in service for a few years, wear occurs permitting the throttle to close so far that the tractor dies when idling. Idling trouble is very noticeable whenever the operator changes from a very volatile to a less volatile fuel. Such trouble can easily be corrected by merely screwing in the idling speed stop screw about a turn or more—enough to make the engine idle at a speed of from 350 to 450 r. p. m. When using heavy fuels, adjust the engine to idle at a somewhat higher speed so that the engine temperatures will not drop off too rapidly.



FIG. 102—Making the idling speed mixture adjustment of a carburetor.

### ADJUSTING IDLING NEEDLE VALVE

When adjusting the idling mixture valve (Fig. 102), set the throttle in the idling position and turn the needle valve screw in until the engine begins to "roll," then back off until satisfactory idling is obtained. On the carburetors illustrated, the idling mixture adjustment screw controls the air and, when turned "in," the mixture becomes richer. If the running of the engine is not affected when this idling needle valve screw is opened a turn or two, it indicates that the carburetor float level is too high for best operation or that the float valve is leaking or that the area around the throttle valve is restricted by intake manifold carbon.





FIG. 103—Adjusting the carburetor high-speed or load mixture needle valve.

### ADJUSTING LOAD NEEDLE VALVE

One of two methods may be used for adjusting the load, or high speed needle valve (Fig. 103). Either have the tractor under load, or have the engine running at full speed with no load, and the spark retarded if possible. Turn in the load, or high speed, needle valve screw until the engine begins to lose power due to too lean a mixture; then open it slowly until the engine picks up speed and runs smoothly. When the high speed adjustment is made without load, it is often necessary to open the needle valve a little (not over  $\frac{1}{8}$  turn per trial) if the tractor tends to stall when the load is applied. Never try to adjust the carburetor in the field unless you have someone on the seat to stop the tractor in case you stumble.

Tractor carburetors have no accelerating pumps such as used on automotive equipment; hence tractor engines should not be expected to have as much accelerating ability. However, when pulling a power-take-off machine such as a combine, pick-up baler, or field ensilage cutter more responsive pick-up for suddenly encountered loads can be obtained if a slightly richer mixture adjustment is used.

Running a tractor with too lean a carburetor mixture causes loss of power and high exhaust valve temperatures. In some cases, this may cause valve burning. Therefore, excessively lean mixtures should always be avoided.

### KEEP CARBURETOR GASKETS TIGHT

On most tractor carburetors a partial vacuum is maintained in the float chamber when the engine is running. On some carburetors, this vacuum is regulated by the throttle shaft and so arranged that it is applied during  $\frac{1}{4}$  to  $\frac{3}{4}$  loads. It is, therefore, always good practice to examine the carburetor gaskets and make sure that they are tight.

### KEEP FUEL SCREENS CLEAN

Occasionally the strainer screen in the carburetor should be cleaned. In some tractors this screen is so located that it is not easily noticed, but it will always be found where the fuel line enters the carburetor bowl (Fig. 104). A badly

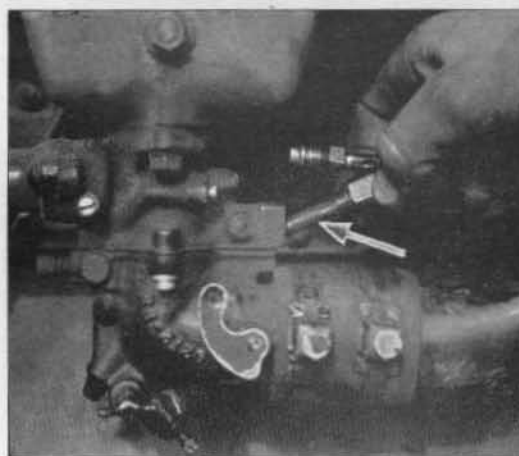


FIG. 104—The fuel screen on this carburetor is located by removing the fuel line as shown. It should be taken out and cleaned once in a while.

plugged screen often causes faulty engine operation, especially when changing from a volatile to a heavier type of fuel.

When cleaning the screen in the sediment bowl, remove the glass bowl with a twisting motion to avoid breaking the gasket (Fig. 105). Fuel residues which cannot be removed by washing in fuel can be dissolved in acetone. To eliminate the formation of such residues, always drain the entire fuel system before storing the tractor.

If the tractor is being used on a cornpicker or hay buck, it should have a metal sediment bowl

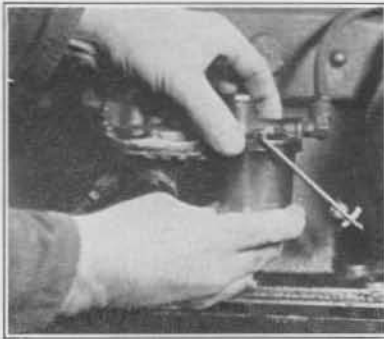


FIG. 105—Before removing the fuel sediment bulb, give it a twist to prevent breaking the gasket.

so that if a fire is started, the bowl won't crack and allow all the fuel to run from the tank and make a big and serious fire out of a small one. Also, always check the fuel system for leaks and shut off the tractor when filling the fuel tank.

### CHECKING FUEL LEVEL

A simple means of checking the fuel level in the carburetor is to use a short piece of rubber tubing connected to a glass tube. Attach this to the carburetor drain and measure the height of the fuel in the carburetor bowl, as shown in Fig. 106. In measuring the height, be sure to do so from the top of the bowl, which is easily noted by the gasket where the cover and bowl join. A check of this kind helps to determine if the float is sticking.

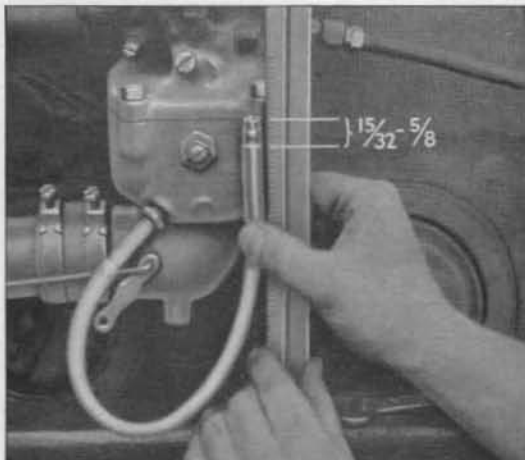


FIG. 106—A simple method of checking fuel level in carburetor bowl.

### CARE OF AIR CLEANERS

Air cleaners and stacks require periodic attention and servicing for proper operation. The inlet cap sometimes becomes jammed or bent from bumping (Fig. 107), in which case it cuts off the proper flow of air and should be bent back into its correct position. Accumulations of bits of grass, straw or husks, should be removed periodically from the guard screen or from the deflector fins. If the intake is not high enough to avoid much of this restricting accumulation, it should be raised to a higher level, taking care to make airtight connections and to use a stack diameter no smaller than the original. If long stack extensions were originally provided and have since been taken off for any reason, see that they are put back on.

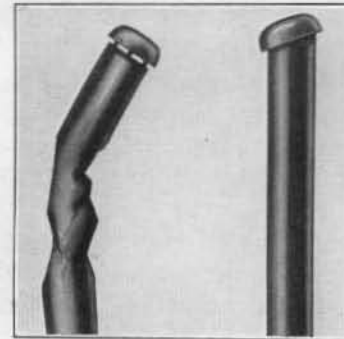


FIG. 107—Bent or dented air stacks, or jammed caps at their intakes, can cause enough reduction in the volume of air reaching the engine to result in uneconomical operation.

### CENTRIFUGAL PRE-CLEANER

Centrifugal pre-cleaners are used on many of the newer tractors to throw out the heavier dust particles and help to prevent overloading of the air cleaner. In some cases, screens or perforated sheet metal units are used as pre-cleaners to keep out leaves, straw, chaff and small sticks. These screens should be cleaned regularly, and the air intake stack removed occasionally, to make sure that they are free from dirt.



FIG. 108—To make sure that dirty air does not reach the engine interior through the crankcase ventilator intake, clean and re-oil the oil soaked element of the cleaner every 10 hours of operation.

### OIL SOAKED ELEMENT TYPE AIR CLEANER

If servicing of the oil soaked element type air cleaner is neglected, the filter becomes heavily coated with dust, especially along the paths of least resistance through the filter. On loosely packed elements, when all the oil has been absorbed, the cleaner does not clog excessively, but the incoming dust and fine sand wear off the incrusted dust from the fibers, carrying this dirt into the engine with resultant engine wear. If the element is neglected too long without re-oiling, the abrasive action of the fine dust may also cut out the fibers in the element and make larger channels, and thus ruin the filter.

Where the fiber elements are packed very tightly, a build-up of dust on the unit closes the air passageways and restricts the flow. This restriction or choking action of the intake air may cause the engine to run excessively rich and result in dilution of the crankcase oil. An operator may blame either the fuel or the engine for this condition, but actually it is the result of his own neglect. Thus the most important precaution to observe with this type of cleaner is to clean it regularly and keep it well oiled.

When cleaning the oily fiber type air cleaner, the element should be washed in fuel, swung vigorously to throw off excess fuel, and allowed

to drain for a few minutes. Then the element should be dipped in new oil. Since the oil film on the fiber is so important, the element should always be soaked long enough to flush off any remaining fuel and allow the fibers to become entirely coated with the new oil. "Soak it in Oil" is a slogan that should be adopted for servicing this type of filter element.

### WATER BATH TYPE AIR CLEANER

The water type of air cleaner works quite satisfactorily when clean, but on some installations it requires a great deal of cleaning because the air intake is located directly over the tractor housing. At this point, dirt, carried by the wheels, is blown by side winds directly onto the housing where it is drawn into the air cleaner. Under extremely dusty conditions it may be necessary to clean the air cleaner every one or two hours to keep it functioning properly. Relocating the intake removes a tremendous burden from the air washer and makes it possible for it to function more satisfactorily.

### OIL BATH AIR CLEANER

In normal service, the oil bath air cleaner should be inspected at least once a day and cleaned

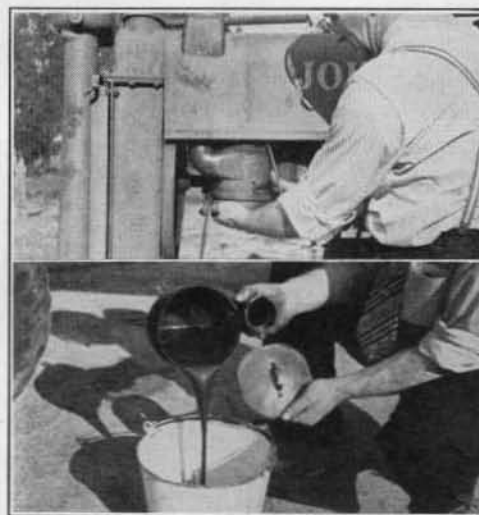


FIG. 109—(Above) The oil reservoir of an oil bath type of air cleaner should be checked at least once a day during regular operation. (Below) At each such inspection, the oil, if very dirty, should be discarded, the reservoir cleaned, and fresh oil of correct grade reinstalled.  
Courtesy, John Deere Tractor Company.



whenever dirt ( $\frac{1}{8}$  to  $\frac{1}{4}$  inch) has collected in the bottom of the cup or the oil begins to thicken.

Many tractor operators use too heavy an oil in the cup of the oil bath air cleaner. As most air cleaners depend upon oil atomization to remove fine dust particles from incoming air, the oil must be light enough to mix with the air. The use of a heavy oil may even restrict the air passage to the engine, causing a rich fuel mixture and smoky exhaust when under heavy loads, often wrongfully attributed to poor carburetor adjustment.

To encourage the use of lighter oils in the air cleaner, some manufacturers have recommended used motor oil. Field experience has proven this an unsatisfactory practice as the actual viscosity of a used oil is never known. The used oil may have oxidized and thickened or become highly diluted with unburned fuel. Atomizing a highly diluted oil in the air cleaner may drive off the diluent, thus thickening the oil, washing the needed oil film from the separating screen, and causing the oil level to drop unduly.

### CRANKCASE VENTILATION

Crankcase ventilation is obtained on most tractor engines by air actually circulated through the engine or by use of a tube or a special ventilator cap, usually located on top of the valve cover, or over the oil fill tube. Care must be exercised to keep the ventilating system open.

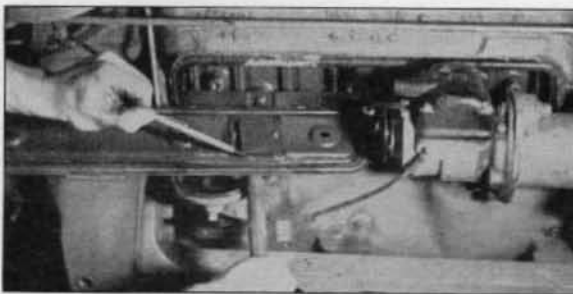


FIG. 109a—Above the pointing pencil on the side plate is a moss type cleaner covering the ventilator tube inlet. Below this may be seen a small hole that allows condensed oil vapors to drain into the engine. Excessive oil consumption can be caused by this hole becoming plugged.

### SERVICING FILTER SCREENS

In service, corn husks, silks, soybean leaves, straw, etc., accumulate on the under side of the separating screen of the air cleaner (Fig. 110). When the cup is removed for servicing, inspect the separating screens be removed and thoroughly any such accumulations. Some air cleaner manufacturers recommend that at least once a year the separating screens be removed and thoroughly flushed with fuel so as to remove any fine dust or other accumulated material.



FIG. 110—Inspect the underside of the separating screen, when the cup of the oil bath type air cleaner is removed, and clean it of accumulated materials if necessary.

### PREVENTING AIR LEAKS

#### WORN CHOKE SHAFT AND BEARING

In time, the carburetor choke shaft and bearing will wear. This creates an opening, as shown in Fig. 111, which may become so large that even a pencil point can be passed between the bearing and shaft. An opening like this will let in an excessive amount of dirt, and unless the parts are replaced or repaired, a rapid rate of engine wear may result, soon followed by a loss of engine power and efficiency. Failure to service such parts is one of the reasons why so many engines wear prematurely and become sluggish. Tractors operating in dusty air with a worn choke shaft

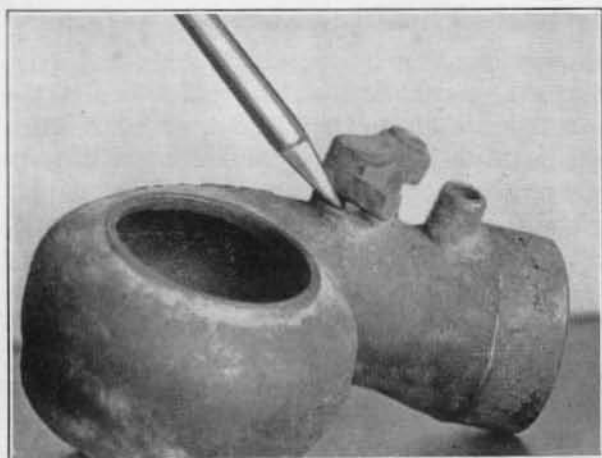


FIG. 111—Dirt laden air can enter an engine through the enlarged clearance of a worn choke shaft bearing.

and bearing or hole in intake manifold (Fig. 116) have been known to let in enough dirt to cut out the piston rings and cylinder sleeves in two or three days.

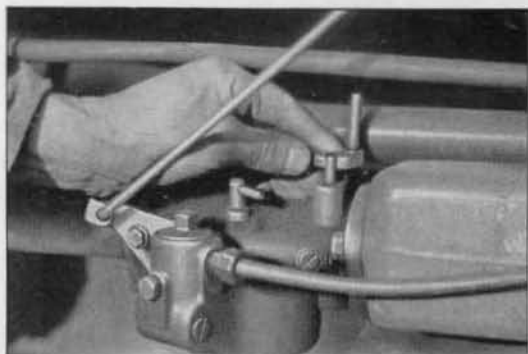


FIG. 112—A worn and enlarged throttle shaft bearing can also admit dirt laden air into the engine.

### WORN THROTTLE SHAFT

A worn throttle shaft bearing is another place where dirt may enter the air intake system (Fig. 112) and find its way into the engine. Although the throttle shaft is usually provided with a large bearing, it wears eventually and needs to be repaired or replaced. Tractor operators should inspect all such wearing parts frequently and make certain that they are tight and that all other connections are also air-tight.



FIG. 113—To make sure that there are no leaks into the air cleaner, check the condition of the gasket occasionally.

### LOOSENEED GASKETS AND CONNECTIONS

A gasket is generally used where the top of the air cleaner bolts onto the tractor (Fig. 113). In field service, these bolts often become loosened permitting air to be drawn past the gasket. In time, the gasket may dry out and also it may be "drawn in." Therefore, the gasket should be inspected to make sure that no leaks are present.

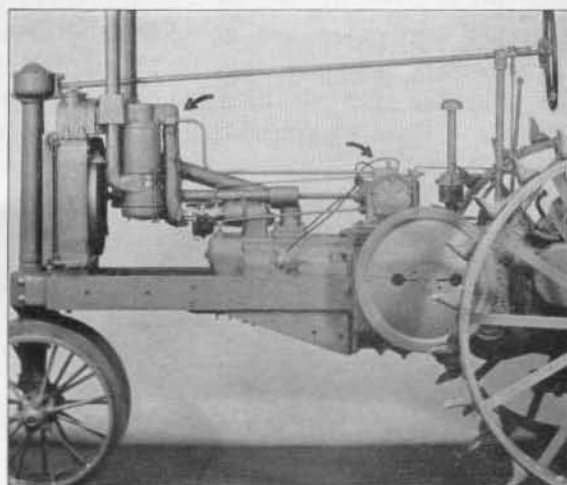


FIG. 114—Crankcase ventilator pipe connection (at arrows) must be kept tight to prevent entrance of dirty air into the engine.

On some tractors the crankcase ventilator is connected with the air cleaner (Fig. 114). These connections should be inspected to see that they



FIG. 115—Examine hose connections between the air cleaner and carburetor for cracks and breaks that can admit dirty air.

are tight, and to make sure that the pipe to the air cleaner has not pulled loose.

All connections between the air cleaner and engine must be in good shape and kept tight. A leaky hose connection is also a common source for dirt entry (Fig. 115). On some tractors a felt pad is used in the bottom of the carburetor so that, if the carburetor floods, the fuel will leak out of the air intake passageway. The felt must be set in tightly so that dirty air will not be drawn in at this point. All manifold gaskets should be tight and manifolds should be inspected to see that they are not warped. When replacing manifolds, care must be taken to see that all carbonaceous material and dirt are removed so that proper fit against the engine head is assured.

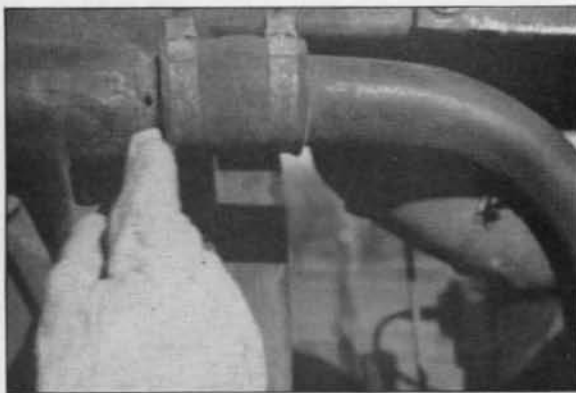


FIG. 116—An air leak into the air intake system caused by corrosion of pipe at the hose connection. Finger points to hole.

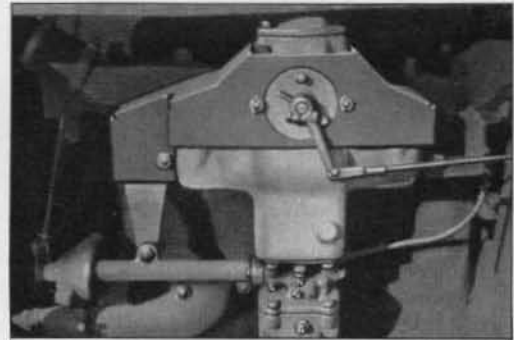


FIG. 117—Metal shield over the intake manifold to prevent cooling from fan blast and wind. When burning *gasoline exclusively*, this shield may be removed to advantage.

## MANIFOLD TEMPERATURE CONTROL

The position of the heat regulator can be identified if necessary by the sound of the exhaust. The exhaust has a muffled sound when the regulator is in the "hot," or proper, position for a heavier type of fuel. It has a much louder "cut-out" sound when the regulator is in the "cold" position for gasoline.

A metal shield over the intake manifold (Fig. 117) is often used to prevent the fan blast and strong cross-winds from striking and cooling the intake manifold. In warm weather when using gasoline only, it is a good practice to remove this metal shield; otherwise the extra heat applied may cause valve trouble.

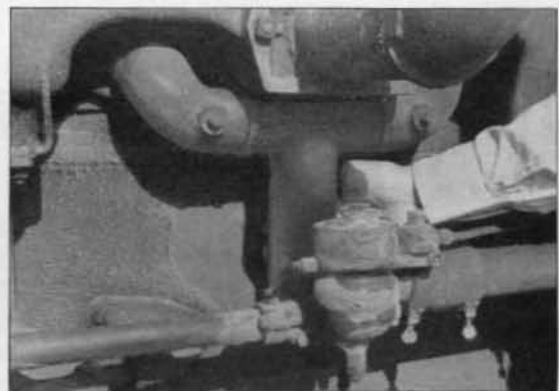


FIG. 118—On this two fuel tractor, the heat box surrounding the intake manifold has been cut off to adapt the engine to regular use of gasoline. The practice is not a good one because the manifold is of the low velocity type, needing some heat for proper operation even with gasoline.





FIG. 119—A 2-fuel tractor with adjustable manifold heat control.  
Courtesy, J. I. Case Company.

Some operators when using only gasoline, have attempted to improve on the manifolding of their two-fuel tractors by cutting off the heat box which surrounds the intake manifold (Fig. 118). This usually brings bad results because, where a low velocity manifold is used, some heat is necessary to aid in vaporizing a fuel even as volatile as gasoline. If all the heat is removed, the incoming fuel charge will cool and condense on the wall of the manifold when the tractor is idling. This results in faulty idling and may cause smoking.

Some gasoline engines are designed to operate without an application of heat on the intake manifold, but in these engines the design is such that a high velocity is imparted to the intake gases. Compare Figs. 119 and 120.

### PROPER ENGINE SPEED

As has already been suggested, there is a definite relationship between engine speed and the maximum torque or pull that the engine will develop. In heavy-duty engines, this speed usually varies from about 700 to 1200 r.p.m. In general, tractor engines are governed at a speed slightly above that which will develop maximum torque. Thus, when a heavy pull is encountered that would tend to slow down the engine, greater power will be available to carry the increased load. Therefore, the governed speed of the engine should not be too low when the engine is doing heavy work; otherwise, the engine will

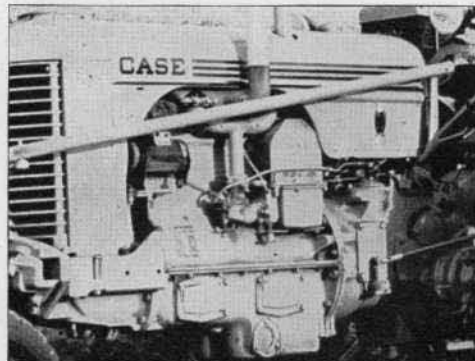


FIG. 120—A gasoline burning tractor with manifold designed to operate without heat application.  
Courtesy, J. I. Case Company.

lack the ability to "hang on." Tests have shown, however, that for lighter loads better economy can be obtained by shifting to a higher gear and operating the engine at lower speed.

### PROPER BELT SPEED

Proper engine speed is particularly important when doing heavy belt work. The most common belt speed for farm tractors is approximately 2,650 feet per minute. There are some tractors, however, which, because of their construction, have a belt speed that is higher than this (see page 32). In such a case, unless a larger pulley is used on the driven machine, it will run at a much higher speed than normal, and more horsepower will be required to pull the load. Proper belt pulley size should be used to keep the belt speed close to that for which the engine was designed to give its best performance.

### SPARK PLUGS

As is true of the entire ignition system, the spark plugs, too, must be kept clean and in proper adjustment. An accurate adjustment of the gap width in all cases is highly important. The engine builder specifies the correct setting, and this should be checked with the type of gauge recommended by the plug manufacturer either to take into account the cupped-out section of the electrode points caused by spark erosion (Fig. 122) or to promote dressing the scaled, oxidized, corroded area before the gap is set (Fig. 123).

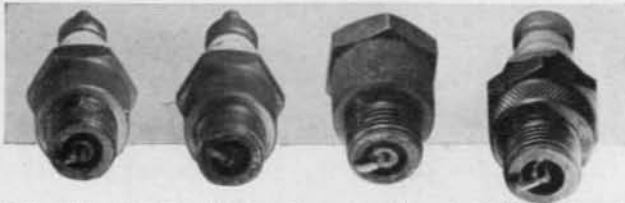


FIG. 121—Various kinds of spark plug deposits and evidences of faulty operation.  
Courtesy, Champion Spark Plug Company.

The latter reasoning holds that the physical gap is not the true gap unless the gap-growth material is removed down to clean, virgin metal, permitting better ignition while reducing electrode tip hot-spot hazard and wire burning tendencies.

The correct gap width for a particular engine is largely determined by the compression pressure existing within the cylinder. The higher the compression pressure, the more difficult it is for the current to jump the gap, and the closer the points must be set.

Gap setting is a very important factor in spark plug service. Somewhat like the engines, fuels and spark plug heat range, spark plug gaps will also fall into three general classifications: (1) the close gap for very high compression, very high speed engines; (2) the average gap for average compression, average speed engines; and (3) the wide gap for low compression, low speed engines. While a wider gap than that generally recommended may be used to improve idling, such a practice will require more frequent regapping to

keep the points from becoming so wide as to cause missing on heavy loads.

When adjusting the spark plug gaps, always make the adjustment on the side electrode and never on the center electrode, as the latter procedure may easily result in a broken or cracked porcelain.

Rapid burning of the electrodes or blistering and cracking of the tip of the insulator indicates a hot running plug and the need of a cooler plug than that recommended for normal service. In tractor engines, cracking of the plug skirt is often caused by using low octane fuels, such as kerosene and water-white distillates. If this is found to be the trouble, the only practical remedy is to use higher octane power fuels.

If plugs are fouling due to black carbon deposits on the insulator skirt, the engine should be checked for an over-rich mixture, high carburetor float level and cold operation. If these points are found to be normal, a hotter type plug will improve engine operation. If the plugs are oily and remain wet after being out of the engine for a few minutes, the fouling is usually due to oil pumping. To correct this trouble, it is usually necessary to install new pistons, rings, and sleeve assemblies or replace the block assembly.

Even in normal operation, the spark plug insulator in time becomes coated or encrusted with an oxide deposit, formed from residuals in the combustion gases. This oxide coating is a con-

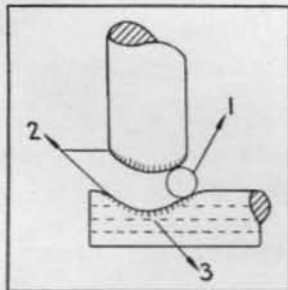


FIG. 122—In checking spark plug gap, a round wire gauge fits the depression of the corroded area and therefore measures the physical gap (1) more accurately than a flat gauge. However, the actual gap (2) from virgin metal to virgin metal, is wider than the physical gap, and the restricted area (3) retards heat flow and is likely to cause a hot spot at the exposed tip of the electrode.

Courtesy, Champion Spark Plug Company.

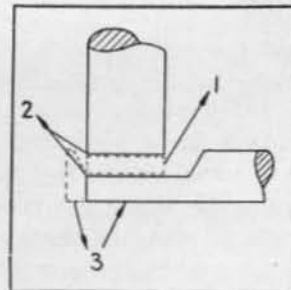


FIG. 123—In checking spark plug gap, a flat gauge, because it does not fit the depression of the corroded area, is likely to induce the checker to dress the gap surfaces, thus making them flat as well as clean. Then the physical gap (1) and the actual gap (2) from virgin metal to virgin metal are identical, and hot spot hazard at the electrode tip (3) is removed.

Courtesy, Champion Spark Plug Company.

ductor of electricity, especially when hot, and may cause missing. The deposit is usually brown in color, but sometimes yellow or white, and should be removed, taking care not to injure the insulator. One-piece plugs should be cleaned in a sand blasting machine, but two-piece plugs generally have a glazed finish and should, therefore, be taken apart to do a good job of cleaning without damage to the finish.

## TIMING

### SPARK

Tests show that in a typical tractor engine from four to six-thousandths (.004 - .006) of a second are required for a properly proportioned fuel charge to burn. Even in this short time an engine running 1200 r.p.m. would turn 28 to 36

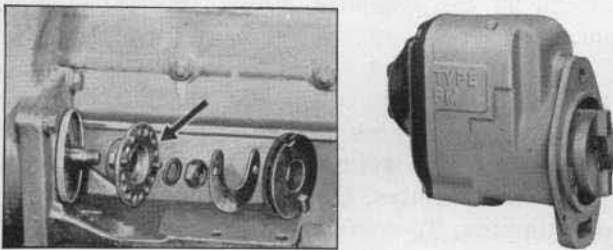


FIG. 124—(Left) Magneto drive coupling showing holes which permit timing adjustment. (Right) Magneto showing elongated mounting hole at bottom of flange (there is a corresponding one at top of base) to permit timing adjustment.

degrees of crankshaft travel while the fuel charge is burning—one reason why spark advance is usually necessary for proper engine performance. The exact advance needed is determined by combustion chamber design, compression ratio, fuel characteristics, etc., as well as by the speed and load of operation.

Tractor engines have a timing mark located either on the flywheel or the fan pulley. To properly time the engine locate the timing mark and turn the engine so that the marks are correctly aligned. Number one piston should be just completing the compression stroke when the marks match. This can be determined by loosening No. 1 spark plug and listening for the compression leak while the engine is being turned over by hand. The unmounted magneto is then turned with a

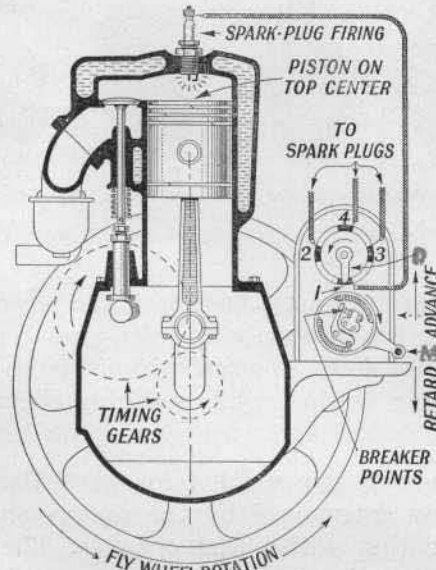


FIG. 125—Ignition timing details. D—distributor arm; M—breaker case arm.

wrench until a spark is generated at the No. 1 terminal, the magneto mounted in position, and the remaining spark wires connected to the proper plugs in accordance with the firing order of the engine. If it is impossible to locate the timing marks, adjust the magneto so that the impulse clicks for No. 1 cylinder just as the exhaust valve closes on No. 4 or 6 cylinder, giving a timing that is very nearly correct (See Fig. 127.)

The final adjustment of spark timing is controlled by slight changes in the setting of the magneto drive coupling or by slightly rotating

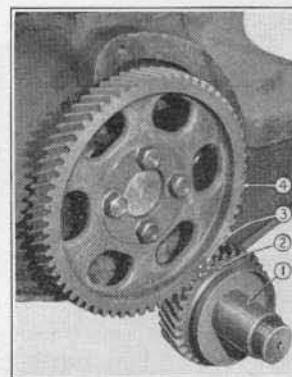


FIG. 126—Marked teeth on timing gears:  
1. Crankshaft.  
2. Crankshaft gear.  
3. Marked teeth.  
4. Camshaft gear.

Courtesy, The Massey-Harris Company.



the magneto on its mounting flange. (Fig. 124.)

Early ignition is desired in order to secure the greatest expansive force of the burning fuel charge. However, under some conditions, to prevent what is commonly called a "spark knock," it may be necessary to actually retard the spark. Care must be taken not to retard the spark too much or the engine will overheat.

### MAGNETO CARE

Keeping the magneto clean and the points properly adjusted are two items essential to proper functioning of this unit. Magneto points wear in service and should be replaced when badly burned and pitted or, should be regapped, usually after 200 to 300 hours of operation, if they cannot be replaced, using a special file or hone.

### VALVES

Timing of the valves is set properly by the engine manufacturer, but it may be necessary to

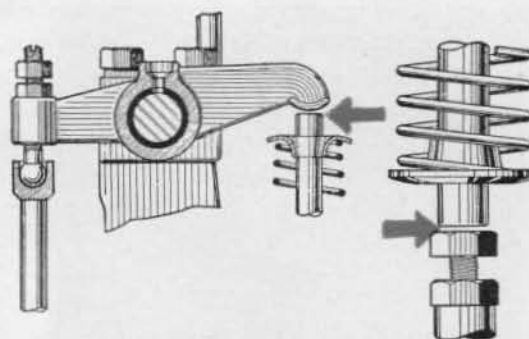


FIG. 128—(Left) Valve tappet clearance on an engine with overhead valves, (right) on an engine with L-head valve arrangement.

understand what is involved if the engine is taken down for repairs. Manufacturers usually mark, either on the flywheel or on the camshaft gears, the correct positions for timing. These marks should be located before taking an engine down and, if they cannot be found, suitable marks should be made. In reassembling the engine, all that is necessary to restore correct timing is to match the markings. (Fig. 126).

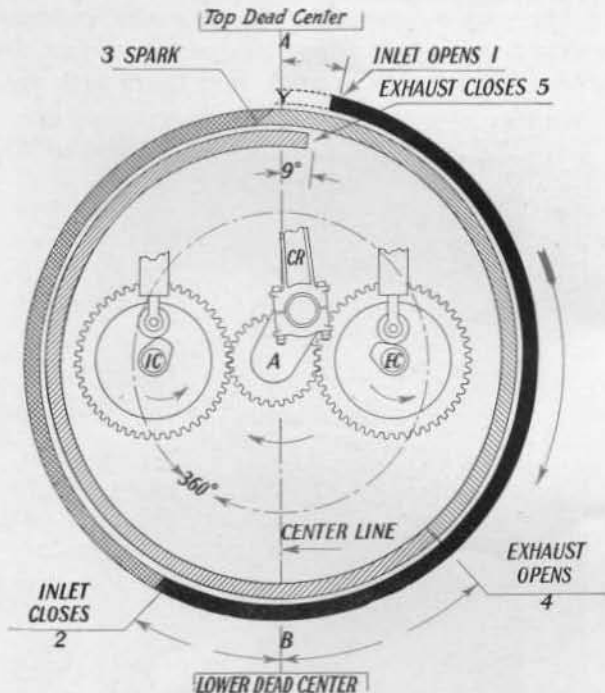


FIG. 127—A typical timing diagram of a vertical tractor engine designed to operate at about 800 r.p.m. The diagram starts at Y. Inside the diagram is a sketch of the intake and exhaust cams and gears. "A" is the crankshaft, "IC" is the intake valve cam, "EC" is the exhaust valve cam, and "CR" is the connecting rod.

### COMPRESSION AND VALVE CONDITION

Faulty operation of the engine is often the result of improper valve clearance. A certain amount of clearance between the valve stem and push rod tappet is necessary so that, when the engine becomes warm and the valve stem slightly lengthens from normal expansion, the valve will not ride the tappet and stay open (Fig. 128). Insufficient clearance of exhaust valves is a common cause of valve burning.

Whenever the valves are ground, the combustion chamber should be cleaned, and all gaskets inspected to make sure that they are in good condition. When tightening the head stud nuts, start on the center nuts and tighten each a little at a time. Check the valve tappets to make sure each has ample clearance, run the engine until warm, draw down the cylinder head and then make the final tappet adjustment.

The proper amount of valve clearance varies with different types of engines and can be deter-

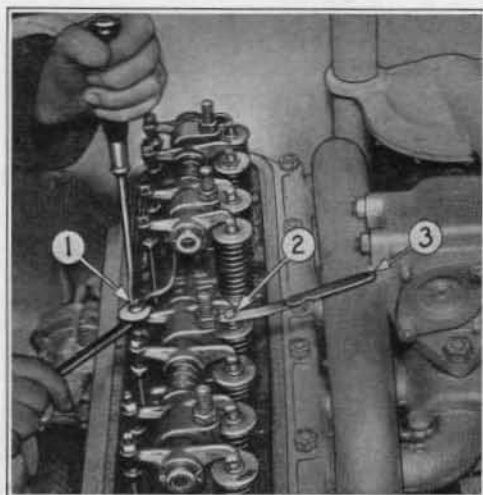


FIG. 129—Adjusting the valve tappets on an overhead valve engine. (1) Wrench for lock nut and screw driver for adjusting screw. (2) Tappet clearance. (3) Thickness gauge. Courtesy, Caterpillar Tractor Company.

mined from markings on the cover plates or by consulting the manufacturer's instruction book. The new type stainless steel valves should have more clearance than the older type valves. It is important that the tappet clearance be measured when the valve is completely closed and usually while the engine is at operating temperature.

If only the valve tappets are being adjusted and some of the valves seem to have excessive clearance, make sure that they are not sticking open before the clearance is taken up. Also see that the piston in the cylinder being checked is in the firing position in order that both valves will be fully closed. This position can easily be determined by removing the spark plug wire on number one, the front cylinder, and holding it about a quarter of an inch from the engine block. Slowly turn the engine until the piston comes up on compression and a spark jumps the gap. When the spark is noted, stop turning the engine immediately and adjust the tappets on number one cylinder. To adjust tappets on the other cylinders, give the crank a half turn if it is a four-cylinder tractor (a third of a turn on a six-cylinder tractor), and adjust the pair of tappets on the cylinder then in firing position. The order of tightening is determined by the firing order of the engine. All Case, International, Minneapolis-

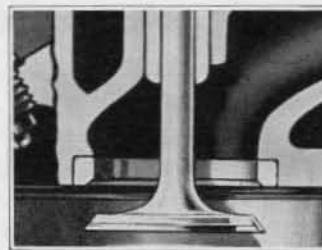


FIG. 130—Special heat-resisting inserted valve seats are used on some tractor engines. Courtesy, Tractor Div., Allis-Chalmers Mfg. Co.

Moline and Massey-Harris four-cylinder tractors have a firing order of 1-3-4-2; all Oliver and Allis-Chalmers tractors, except the Model "A," fire 1-2-4-3; and all six-cylinder farm tractors fire 1-5-3-6-2-4.

Valves should usually be reconditioned after every 700 to 1000 hours of operation, or whenever it is noticed that the compression is weakened. A leaky valve can usually be determined by cranking the engine slowly and listening for the sound of blow-by (hissing) in the exhaust or intake manifold. The best course to follow in having the valves ground is to take the cylinder head to a competent shop or a tractor service department and have the work done there with spe-

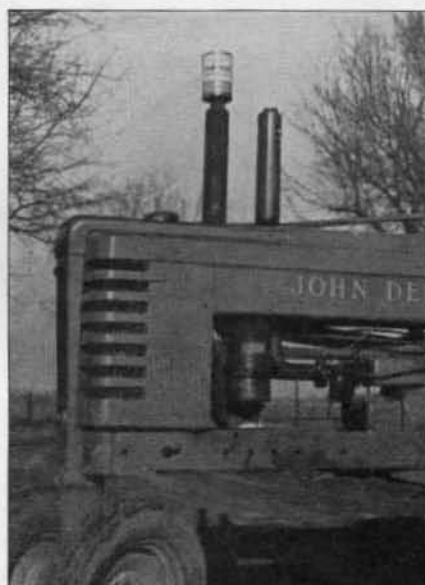


FIG. 131—A can placed over the exhaust stack during storage of the tractor keeps rain and snow from reaching the valves.

cial grinding equipment. It pays to do this because correctly seated valves will last much longer than valves that are incorrectly seated.

To guard against rusting of valves, keep them well lubricated and during periods of tractor idleness also keep the exhaust stack covered with a can (Fig. 131) to keep out rain and snow. This is especially important where tractors are left in the open.

Ample valve lubrication is most necessary in eliminating valve troubles. On tractors depending on hand lubrication of the valves, the valves should be lubricated from an oil can at least once a day and before draining the oil in the crankcase, it is a good idea to flush the valves with kerosene. On most of the later model tractors, the oil for lubricating the valves is carried to the rocker arm shaft through a small pipe. Make sure that this pipe is open. To check its condition, have the engine running, remove the valve cover, and see if oil is flowing around each of the rocker arms.

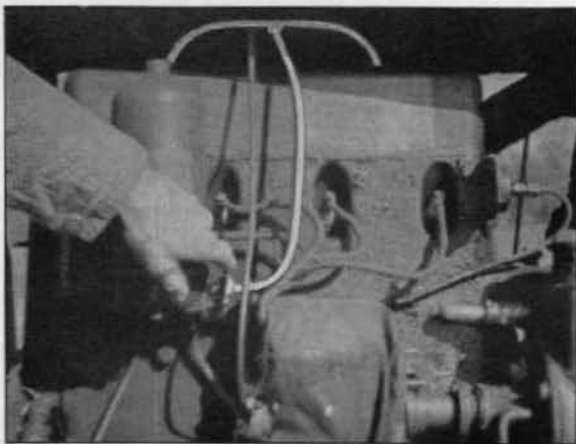


FIG. 132—A separate oil line and petcock attached to the existing oiling system makes it easy to oil the valves from time to time. Finger points to petcock in line.

On some tractors, a separate oil line and petcock (Fig. 132) can be attached to the existing oiling system to be used just for lubricating the valves from time to time. To lubricate the valves, it is only necessary to open the petcocks for 5 or 10 seconds while the engine is running.

## COMPRESSION AND PISTON RING AND CYLINDER BORE CONDITION

Good compression is obtained, assuming that the valves are properly seated, when the fit of the piston and rings in the cylinder is maintained within proper limits. Ordinary wear within the cylinder first shows up on the piston rings, preventing them from contacting the cylinder wall snugly all the way around or with sufficient tension to be most effective. Most of the wear takes place on the thrust sides of the cylinder bore so that an elliptical form of piston and rings really is required for perfect fit. In the early stages, loss of compression from this source can be corrected by pulling the pistons and installing new rings. It is generally recommended that, when installing new rings, the glazed surface of the cylinders be honed lightly to aid more rapid seating of the rings. The piston rings should be checked and fitted for correct gap or end clearance before installing. S. A. E. standards for piston ring gap clearance specify a minimum of .007" in rings below 4", a minimum of .010" in rings from 4" to 4 15/16", a minimum of .015" from 5" to 5 15/16" and a minimum of .020" from 6" to 7 15/16" diameter. Rings should never be installed with gap clearances below these minimum figures. In advanced stages of cylinder wear, because of the "out of round" or elliptical wearing that takes place, the cylinder should be rebored or new cylinder sleeves installed together with new pistons and rings.



FIG. 133—Replaceable cylinder sleeve being installed in a tractor engine.

Courtesy, International Harvester Company.



## CYLINDER SLEEVES

The tractor manufacturer's instructions for installing new sleeves should be specifically followed. The use of replaceable cylinder sleeves, while not general, is a practice employed in a good many tractors today (Fig. 133). Make sure that the block is clean before forcing in new sleeves, and that the rubber seal, used to prevent water leakage, is installed properly.



FIG. 134—(Left) Stuck piston rings from excessive deposits packing in the ring grooves. (Right) The rings on this piston have remained entirely free.

## RING STICKING

Good compression is only maintained, of course, when the piston rings are completely unrestricted and free to move in their grooves. This is particularly important because the cylinder bore wear from top to bottom takes on a slight taper, more wear occurring at the top than at the bottom. Stuck rings will, under such a condition, improperly contact the cylinder wall in the top region.

Ring sticking is due to packing, in the grooves behind and around the rings, of carbonaceous and gummy materials that bake into a solid mass under the high temperatures of piston operation. Abnormal operating conditions or operating an engine too long without changing oil can cause these ring sticking difficulties, but, in any case, troubles of this kind are minimized by using only properly refined fuels of correct volatility for the type of tractor and operating conditions, and by using only good quality lubricating oil in the crankcase. Detergent type lubricating oils are especially designed to minimize ring sticking.

## ENGINE LUBRICATION

It is well recognized that a long and useful life for a tractor engine is determined more by the kind of lubrication it receives than by any other single factor. Many times, however, it is not realized to what extent good lubrication controls general operating efficiency. A well lubricated engine not only continues to serve without excessive maintenance and repair expense, but more than earns its keep by continuing to develop full power at a substantial saving in operating costs, resulting from a more economical use of fuels and lubricants. This long-range view of total operating costs places additional emphasis on the importance of lubrication.

## OIL FUNCTION

The crankcase oil has five main functions to perform:

1. Reduce wear to the lowest possible minimum.
2. Minimize friction.
3. Absorb shocks and cushion loads.
4. Seal power between piston rings and cylinder wall.
5. Supplement engine cooling.

Keeping the vital working parts clean and unrestricted is another function that detergent type motor oils are especially designed to perform. Since this function is of a special nature, it is not listed among the main functions that a motor oil is expected to perform.

## OIL PROPERTIES

*Wear* is reduced by an unfailing film of lubrication that prevents metal-to-metal contact on rubbing surfaces and flushes away any abrasive materials.

*Friction* is reduced by the same film of lubrication, but it is also necessary to consider the friction imposed by the lubricant itself. For example, a heavy-bodied oil imposes a greater fric-

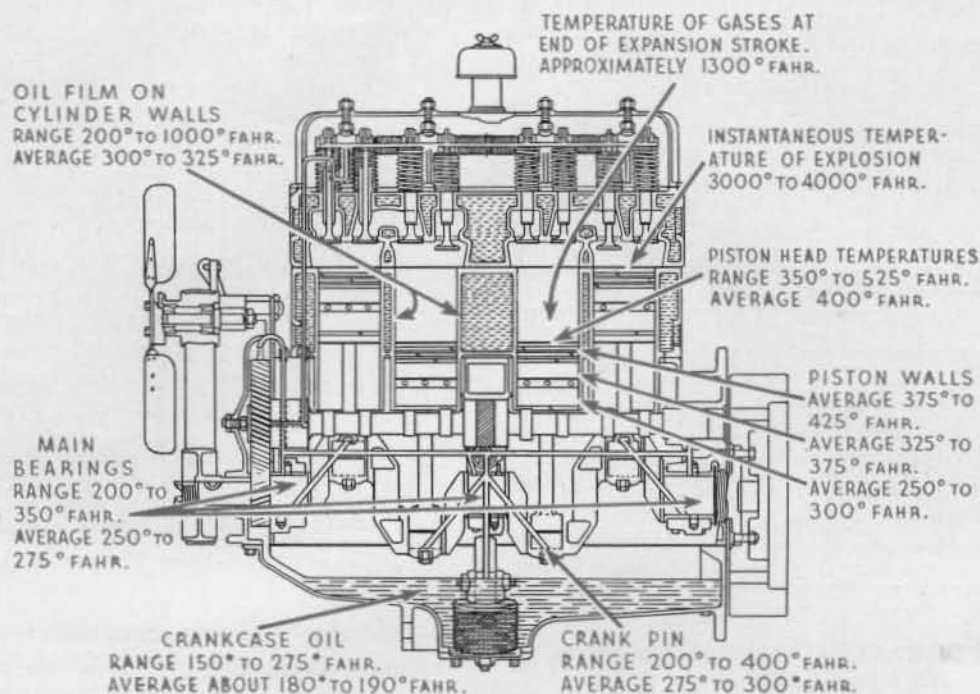


FIG. 135—Operating temperatures of a typical tractor engine in reasonably hard service, but not overloaded, running 1200 to 1300 r.p.m. at 75% of rated drawbar horsepower and at an average plowing speed of 3 miles per hour.

tional drag upon parts in motion than a light-bodied oil. The general rule, therefore, is to use an oil of as light a body as will maintain an un-failing film of lubrication on the frictional surfaces under the prevailing conditions of operation. The body of any oil is a measure of its viscosity or fluidity. In the viscosity test, the fluidity of the oil is determined by recording the length of time, at a given temperature, for 60 m.l. of oil to flow through a small hole in an instrument known as a viscosimeter (Fig. 137). The S. A. E. (Society of Automotive Engineers) crankcase oil classification (Table II) is used to determine the S. A. E. Viscosity Number grade of a motor oil.

It is important to remember that oil must actually reach the frictional surfaces at all times. Light-bodied oils circulate more easily and penetrate snug clearances more effectively than heavy-bodied oils. This is another reason why such oils are favored where it is possible to use them satisfactorily.

The pour point of an oil, while it is not a measure of viscosity, is of special interest for cold weather operation as it indicates the ability of an oil to flow to the pump. A low pour point, however, does not necessarily assure easy starting. Oils which will give easy cranking for easy starting, must have a low viscosity at low temperatures. Although good low-temperature characteristics are sometimes found in SAE 10 and SAE 20 oils, they are usually present in oils indicated as 10W and 20W. The "W" indicates that the viscosity does not exceed certain established maximum limits at a temperature of 0° F. Oils listed as 10W and 20W may, however, also meet the S. A. E. requirements for 10 and 20 oils.

The *absorbing of shocks* and the *cushioning of loads* is seldom the major consideration in well-fitted modern engines or in other engines in good mechanical condition. When piston fit and bearing clearance becomes so enlarged that mechanical knocking or pounding results, a heavier-bodied oil will help cushion these hammer-like

TABLE II  
CRANKCASE OIL CLASSIFICATION

S.A.E. Recommended Practice

The S.A.E. viscosity numbers constitute a classification of crankcase lubricating oils in terms of viscosity only. Other factors of oil quality or character are not considered.

S.A.E. Viscosity Number	Viscosity Range, Saybolt Univ., Sec.			
	At 130° F.		At 210° F.	
	Min.	Max.	Min.	Max.
10	90	Less than 120	----	-----
20	120	Less than 185	----	-----
30	185	Less than 255	----	-----
40	255	-----	----	Less than 80
50	----	-----	----	Less than 105
60	----	-----	105	Less than 125
70	----	-----	125	Less than 150

AUTOMOTIVE MANUFACTURER'S VISCOSITY CLASSIFICATION\*

Viscosity Number	Viscosity Range at 0° F., Saybolt Univ., Sec.	
	Min.	Max.
10W	5,000	10,000
20W	10,000	40,000

\*Based on original A.S.T.M. Viscosity Temperature Chart (D 341-32T)

blows and tend to quiet the engine, but the real remedy is to correct the mechanical condition.

The same situation is true with respect to *sealing power between the piston rings and cylinder wall*. When wear enlarges the clearances to the point where a heavier-bodied oil seems to be needed to maintain the seal, the really best remedy is to hone the cylinder so as to remove the glazed surface and put in new rings or, if necessary, replace cylinder sleeves and install new pistons and rings. The use of heavier oils in an attempt to correct poor piston seal is not favored because such oils do not provide the free circulation and penetration needed for the proper lubrication of other engine parts and, for that matter, the upper rings and top regions of the cylinders themselves.

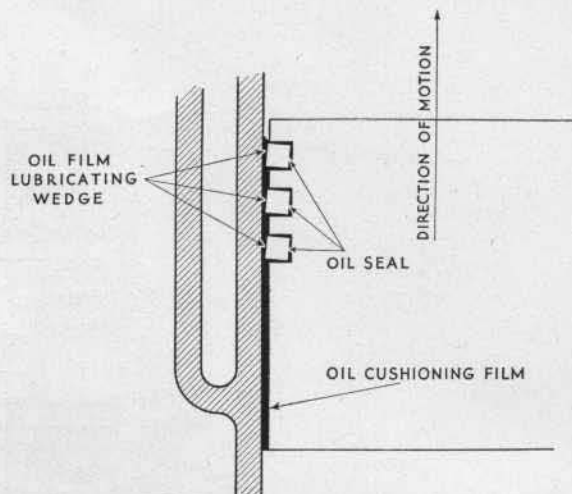


FIG. 136—Illustrating how an oil seal is formed between and around the rings and the cylinder wall. The wedge action is shown greatly exaggerated.

It is also generally true that free action of the rings in their grooves, which is highly essential to good piston seal (Fig. 136), is more readily maintained with light oils than with heavy oils although other properties of the oil besides viscosity sometimes have an important influence. An example of such a property is the one called "detergency." Its principal function is to keep vital engine parts clean and unrestricted.

The function of the lubricating oil in the crankcase, to *supplement engine cooling*, is, ob-

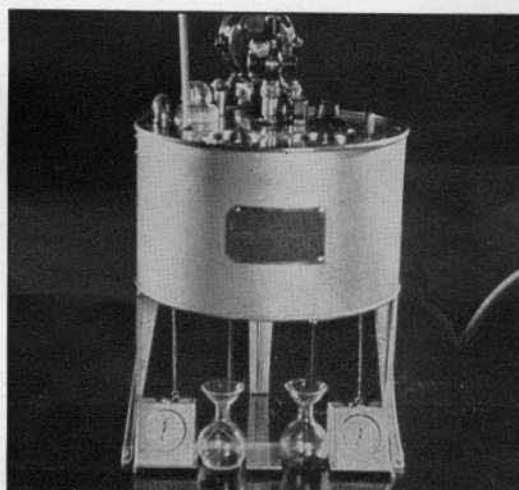


FIG. 137—An instrument, called a "viscosimeter," is used for determining the viscosity or body of an oil. This one is determining the viscosity of two oils at once.



viously, achieved principally by keeping down frictional heat. However, since the oil is circulated or splashed freely over all surfaces within the engine, it also serves as a cooling medium in the customary sense, although oil is far less effective as a coolant in this respect than other liquids which, of course, cannot be used because they are not good lubricants. It can be observed in this connection that, since the crankcase oil does help to dissipate some of the engine heat, keeping the oil level up at all times is an aid to preventing unduly high crankcase oil temperatures.

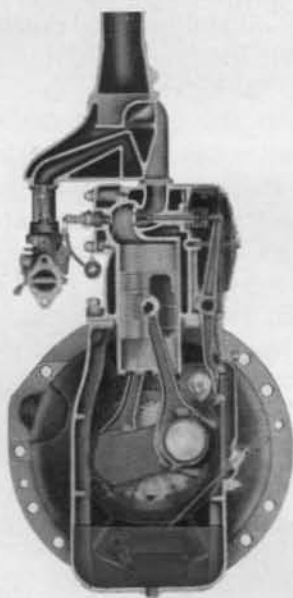


FIG. 138—Combined pressure circulation and splash lubrication system on an engine of unique design. Note valve, rocker arm, and camshaft arrangement.

Courtesy, Minneapolis-Moline Power Implement Co.

#### ADVERSE AND VARIABLE CONDITIONS OF SERVICE

The engine oil, which must perform all of the functions just explained, is carried in the engine crankcase and is used over and over again for relatively long periods with occasional additions, as needed, to keep up the level. Such an oil is, therefore, subjected to very hard service and it must be capable of performing its functions under extremely adverse and variable conditions (Fig. 135).

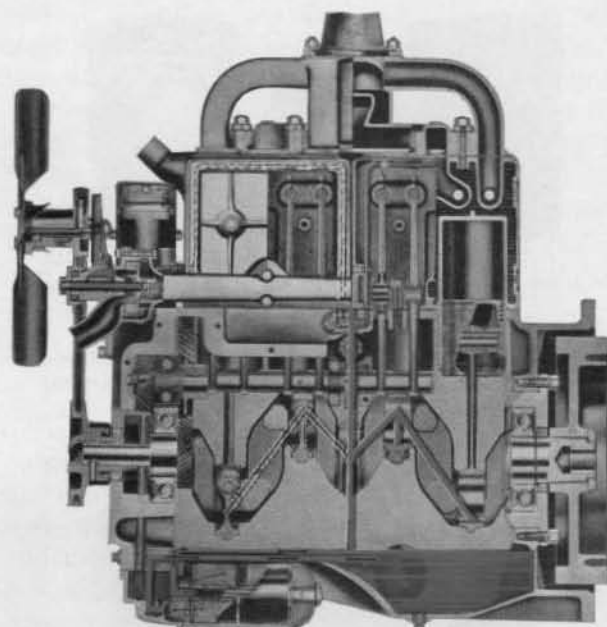


FIG. 139—Side view of same engine shown in Fig. 138 showing further details of lubricating system. Note, at lower left, combination oil pump and oil filter assembly.

Courtesy, Minneapolis-Moline Power Implement Co.

Temperature conditions, for example, vary from the one extreme of cold starting to the other extreme of hot, heavy-duty operation. Regardless of these extremes, the oil must flow un-faillingly to all frictional surfaces, and the lubricating film on these surfaces must be adequate to protect. The effect of temperature on the body of the oil must be considered in this respect. In addition, if very low temperatures are likely to be encountered, an oil must be selected that will not congeal because of inadequate pour point and fail to flow to the oil pump inlet. Also to be considered with all of these factors, is the matter of dilution of the crankcase oil with portions of unburned fuel. Even small amounts of dilution reduce the viscosity of the crankcase oil decidedly; hence, when operating conditions, or the kind of fuels used, tend to increase dilution, somewhat heavier-bodied oils are selected to compensate for the anticipated thinning effect.

Since tractor engines are constant speed heavy-duty engines, an oil one or two grades

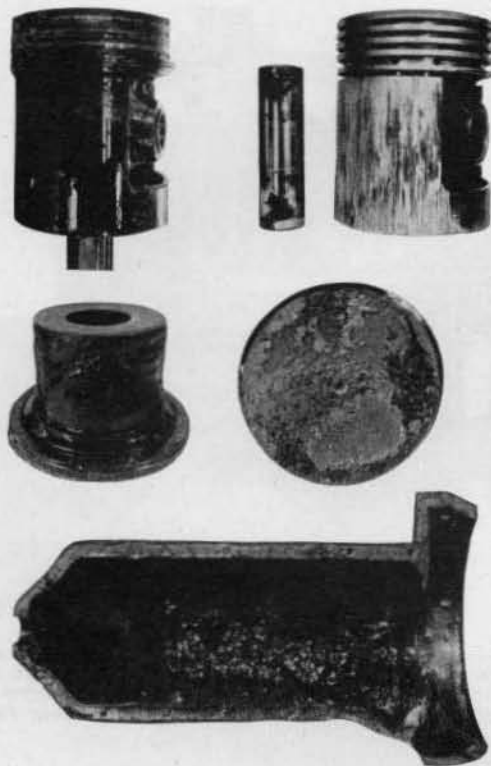


FIG. 140—Damaged or fouled parts resulting from faulty lubrication. (Upper left) Stuck piston rings and varnish coated piston. (Upper right) Scored wrist pin and piston. (Left center) Sludge clogged oil pump screen. (Right center) Carbon encrusted piston head. (Bottom) Sludge coated crankcase.

heavier than that commonly recommended for automobile engines is generally recommended for tractor use. It is always advisable, of course, to use the S. A. E. viscosity number oil recommended in the tractor manufacturer's instruction book or in the lubrication recommendation charts published by reputable oil companies.

Another adverse condition is occasioned by the oil staying on the cylinder wall above the piston, where it is repeatedly subjected to the flame of combustion in the momentary exposure occurring on each power stroke. Some of the oil is also exposed to the extremely high temperatures prevailing around the upper rings of the piston and on other parts of the piston which necessarily operate very hot. Excessive carbon deposits may interfere with free action of the rings in their grooves and, besides, in the combustion space,

may aggravate fuel knocking by their insulating effect. Moreover, carbon particles collecting in the oil may restrict oil passages and interfere with oil circulation. Therefore, an oil with minimum carbon-forming tendencies should be used.

Still another adverse condition is the continued punishment which the oil receives in the crankcase. This condition makes it necessary for the oil to have good resistance to deterioration (Fig. 140). Difficulties that can be traced to oil deterioration are caused by products of partial oxidation which form in some oils more rapidly than in others. In excessive amounts, they increase the viscosity of the oil and have a tendency to collect dirt, metal particles from wear, and water into sludges which, in extreme cases, may clog oil passages, restrict the action of valves and rings, and coat exposed metal surfaces with a semi-solid deposit. When sludging occurs, obviously, engine performance and economy of operation are likely to suffer, and the danger of serious lubrication failures always threatens. Good resistance to deterioration is, for these reasons, regarded as necessary for the very maximum of efficient operation and lubrication protection. Even with the best of oils, the chance of a certain amount of oil deterioration is so great that the oil must be



FIG. 141—Cleaning a metal element type of oil filter by removing and placing it in a can of kerosene or tractor fuel, followed by scrubbing with a stiff brush until clean. Varnish-like deposits may require boiling in a strong solution of lye water, making sure afterwards to remove all loosened material which might later block an oil passage.

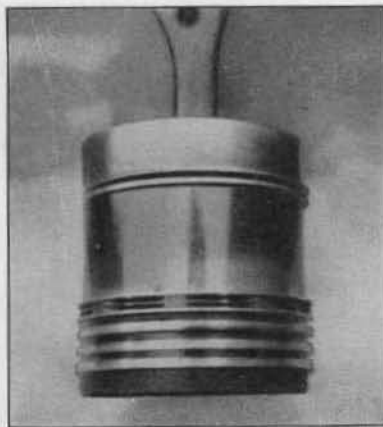


FIG. 142—A clean piston, with rings free, resulting from the use of a good quality oil, changed at regular intervals.

changed regularly to assure maximum protection. The crankcase should always be drained immediately after engine operation and while hot so that the contaminants will not settle to the bottom of the pan or cling to the sides, but will drain out with the oil.

#### DRAINING THE CRANKCASE

Engine tests show that maximum engine life can be obtained only when the crankcase oil is changed and the filter serviced regularly (Fig. 141). Moreover, even if the oil looks clean, there is a tendency for wear to take place and varnish to form on pistons and bearings and valves when



FIG. 144—The appearance and feel of oil taken from one of the upper test cocks can be misleading because water and sediment settle to the bottom of the oil pan.

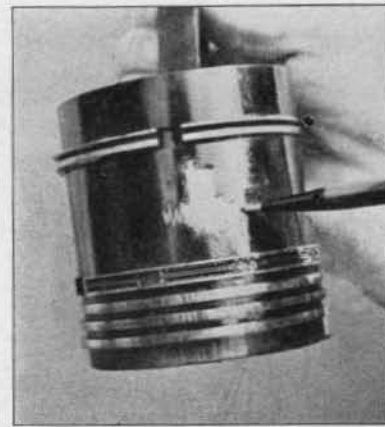


FIG. 143—A varnish-coated piston, with stuck rings, resulting from the use of an inferior quality oil, or one of good quality, but not changed at frequent enough intervals.

the oil is run too long between changes (Figs. 142 and 143). It is definitely true, therefore, that engines should be drained promptly at the recommended time. As already pointed out, this draining should be done when the oil is hot, for then the oil will be stirred up and more of the contaminants will drain out. When possible, it is a good idea to wash out the crankcase with kerosene or flush with a special petroleum flushing oil having good cleansing characteristics.

One of the principal reasons why the crankcase on some engines becomes so dirty is that the tractor is often allowed to stand for weeks or months with dirty, used oil in it. The dirt settles out and packs into the bottom of the pan. If, after the tractor has been standing idle for sometime, the top cock on the oil pan is opened and a little oil is allowed to run out on one's finger, it will be noted that the oil often looks clean (Fig. 144). However, this test is very misleading for most of the dirt and water have settled to the bottom of the pan. If the bottom drain plug is removed, plenty of dirt will usually be found and also some water. When deposits collect in the bottom of the pan of an engine, they harden and later break loose. When this happens, pieces of deposits are often drawn onto the oil inlet screen, shutting off the oil flow and causing bearings to burn out. On many tractors, a removable oil pump screen is used. It is recommended that this be cleaned regularly.



## WATER SLUDGING IN COLD-WEATHER OPERATION

A common cold-weather operating problem is that of water sludge. To guard against this, always warm up the engine to proper operating temperature before putting it under load (Fig. 145) and maintain this temperature thereafter.



FIG. 145—Watch the oil pressure and water temperature gauges and do not put the engine under load until the proper operating conditions are attained.  
Courtesy, John Deere Tractor Company.

Naturally, during winter operation, draining should be more frequent and the filters should be serviced more often. If frequent draining, as well as the cleaning of the filter, is neglected, the filter soon plugs up. Then the oil pump screen begins to act as a filter and when this happens, the oil flow to the pump is shut off and the bearings soon burn out.

As earlier stated, every time a gallon of fuel is burned, about a gallon of water is formed. This water normally passes out with the exhaust gases in the vapor state, but when the engine is cold the exhaust gases coming into contact with the cold metal of the engine will condense (Fig. 146) and the water will find its way into the crankcase (Fig. 147). Tractors have a greater exposed surface on the inside of the crankcase than most other automotive equipment and are, therefore, more susceptible to water condensation unless special precautions are taken to keep them warm. If it is noted that the used oil has a milky color this is a good indication that it contains a small amount of water. A simple test for water is to place some oil in a tin lid and heat it with a



FIG. 146—The cold metal of this shovel causes condensation of water-vapor from the exhaust gases on the contacting surface. This is an easy way to demonstrate that the exhaust gases are moisture laden.

match. This will drive off the moisture and restore the oil to a good color.

In winter some tractor manufacturers recommend loosening the drain plug and draining the water from the bottom of the crankcase after the tractor has stood for about an hour. Another place in which water is often found is in the oil fill pipe. The reason why water forms in this area is that the air blast from the fan or a side wind striking the fill pipe or governor housing, cools it, thus causing it to act as a condenser for some of the moisture carried in the blow-by gases in the crankcase.

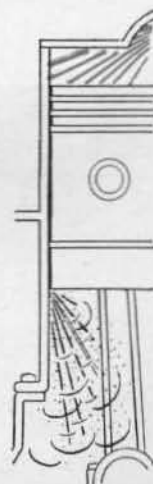


FIG. 147—Illustrating blow-by of combustion gases past piston and rings into the crankcase. This condition may result from excessive wear and enlarging of clearances or from sticking of rings in their grooves.



FIG. 148—An example of water accumulation in crankcase oil. The drainings in the small pail are mostly water which came out of the drain first.

### OIL DISCOLORATION

In use, motor oil may soon become discolored by fuel soot, moisture, lead ash from fuel combustion, and other such contaminants which gain access to the engine crankcase. Certain very excellent oils get dark more quickly than others because they have the ability to purge the engine and hold the loosened material in suspension. Since this is the situation, the color of a used oil can in no way indicate how well the engine is being lubricated. In fact, a dark colored oil most probably would be keeping an engine cleaner than an oil which maintains its original color. Similarly, it is often found that piston rings may become filled with deposits as shown in Fig. 149, while the oil in the crankcase still maintains its original color. Yet, under the same conditions exactly—but with a different oil—piston rings may stay clean although the oil has become dark.



FIG. 149—The top rings of this piston are badly stuck in their grooves, and the oil ring filled up with deposits.

This is proof that it is the final condition of the engine, not the color of the used oil, that tells the story.

During the past few years, the general use of leaded gasoline has introduced another type of oil discoloration which sometimes appears as a gray cast in the oil. Finely divided, gray lead salts (combustion products) find their way into the crankcase, discoloring the lubricating oil. There is, however, no indication that this type of oil discoloration does any harm to the engine when a normal drain practice is followed.

### BEARING CLEARANCES

Bearing clearances are important in controlling the amount of oil which reaches the pistons and cylinder walls in engines with a pressure circulation system. If the connecting rod bearings become worn in service, more clearance will result and more oil will be thrown out of the rod bearings, thus over-lubricating the cylinder walls and imposing an extra burden on the oil control piston rings. The use of a heavier oil than that usually recommended in an effort to correct oil consumption is not always advisable because, if only part of the bearings have enlarged clearance, the bearings that still have normal clearance will not throw off the required quantity of a too heavy oil, and starvation or under-lubrication of that cylinder and piston may result. The additional friction drag of heavier oils than recommended also reduces the efficiency of the engine.

Frequently excessive oil consumption can be remedied by adjusting or installing new bearings. On many of the older model tractors, heavy adjustable bearings are used. Most of these bearings have been poured or cast into the rod and cap. A number of shims are used on each side of the cap and these can be removed for tightening the bearing (Fig. 150). Whenever a bearing of this type is tightened, an equal number of shims should be removed from each side. A common practice is to first remove enough shims to produce a slight drag when the engine is turned by

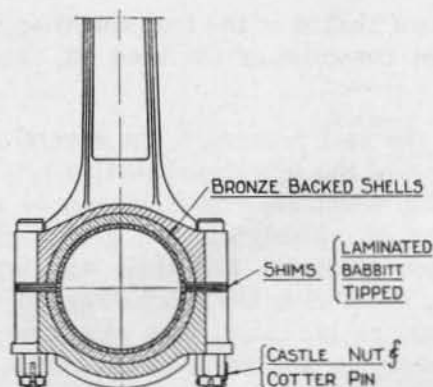


FIG. 150—An adjustable, shimmed connecting rod bearing. Courtesy, J. I. Case Company.

hand; after that, put back a thin shim on each side to provide clearance for an oil film. This clearance should be approximately .001 of an inch for each inch of crankshaft diameter. Tightening a bearing too much is a common reason for a bearing running hot and shortly afterwards "cracking out" (Fig. 151). Another common cause of bear-



FIG. 151—A "cracked out" bearing. Courtesy, Federal-Mogul Corporation.

ing failure on tractor engines is lack of oil in the region affected. In a circulating-splash type lubricating system, for example, it is not uncommon for a particle of dirt or carbon to become lodged in the small discharge hole leading to the dip trough. This shuts off the oil flow to the bearing and soon it is likely to burn out (Fig. 152).



FIG. 152—A "wiped out" bearing from overheating because of blocked oil flow. Courtesy, Federal-Mogul Corporation.

Bearing failure from oil line stoppage is more likely to be noticed after putting in new oil if a tractor engine is being operated with the oil level above the full mark. With such a high level, the rods beat through the surface of the oil and the bearings receive ample lubrication even though an oil hole has become plugged. Now, when the engine is drained and new oil put in, the level being normal will be lower, and under these conditions the rod bearing will not receive sufficient oil through the blocked oil hole to prevent failure.

Whenever bearing failure is suspected of having resulted from oil stoppage the oil line should be removed and cleaned before a new bearing is installed. It is customary to enlarge the 3/32 inch discharge holes in the line (Fig. 153) by drill-

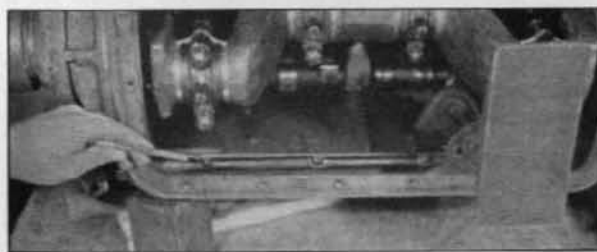


FIG. 153—Enlarging the 3/32" discharge holes leading from the oil line to the dip troughs by drilling them 1/8" size may overcome a tendency to bearing failures due to clogging. Pencil points to one of the discharge holes.

ing to an 1/8 inch size. When this is done, all burrs must, of course, be removed to eliminate the possibility of catching more carbon particles and causing the build-up of a mass of collected material which, when it breaks loose, may again clog the discharge hole.

On most of the later model tractors, removable, steel-backed, babbitt bearings are used. These bearings have no provision for adjustment and no attempt should be made to tighten them. Whenever they become loose or fail, a new bearing should be installed. When installing this type of bearing, care must be exercised to keep it clean and fit it properly into the cap. If a particle of dirt becomes lodged on the cap or in the back of the bearing, it will hold the bearing away from the cap, interfering with heat transfer and causing a hot spot to develop at this point, and even-



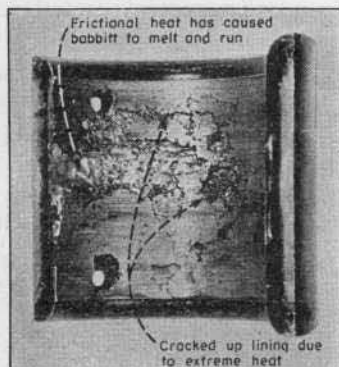


FIG. 154—Bearing which has failed because impurities and oil deterioration products have blocked the free flow of oil.  
Courtesy, Federal-Mogul Corporation.

tually the bearing may “crack out” (Fig. 154). The cap must be within .002 of an inch of being perfectly round and the bearing must fit into it tightly. A removable bearing may seem to be a little large for the cap, but it is made this way so that it will have what is called “crush” (Fig. 155), which will enable it to fit the cap tightly.

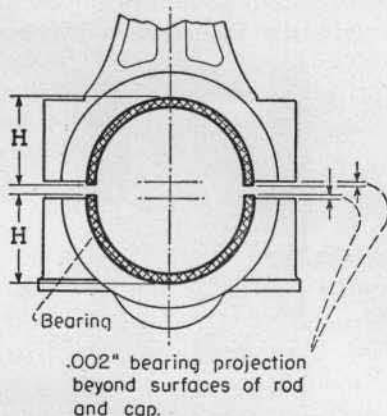


FIG. 155—To obtain perfect contact between the bearing back and its seat, the interchangeable bearing halves are made with a somewhat greater height (H) than the height of the half bore in the rod. These projecting bearing faces are squeezed in or “crush-fitted” to obtain a firm seat that will insure proper heat conductivity.  
Courtesy, Federal-Mogul Corporation.

The fitting of removable bearings is a precision job and is best done by a competent mechanic. By no means should the bearing or cap be filed. A bearing which upon inspection is found to be bright and shiny on the back, has most probably moved in the cap. Such looseness is attended by poor dissipation of heat and can reduce the life of a bearing. Short bearing life may also be

caused by: (1) dirty oil, (2) running an engine with a severe spark knock or fuel knock, (3) worn and out-of-round crankpins, (4) bowed crankshaft, (5) warped crankcase, (6) out-of-round bearing caps, (7) bearings out of line, (8) slightly bent connecting rod, (9) lack of oil, etc.

## OIL PRESSURE

The pressure circulation system makes use of an extra large oil pump which pumps an excess amount of oil over that actually required. To maintain constant pressure in the system, a bypass valve is used which is regulated by spring tension. The operator should realize that the pressure shown on the gauge of a system like this does not necessarily indicate how much, if any, oil is being circulated, but only indicates how much pressure is being applied to the oil line. For example, when the tractor is first started, the engine is cold and the oil is heavier than it will be after it has warmed up. The oil pressure gauge will naturally show a high reading at first and then decrease as the engine and the oil warm up. This is simply due to the natural decrease in oil viscosity that results from increases in temperature. It should be noted, however, that more oil is actually being circulated to the bearings and other lubricated surfaces after the gauge pressure drops than formerly. A very low pressure reading may result, however, from a plugged or blocked-off oil intake, a faulty pump, loose bearings, or the oil relief valve sticking open (Fig. 156).

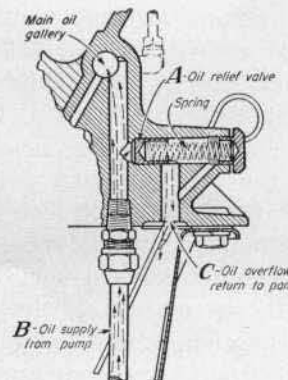


FIG. 156—Oil relief valve in a pressure circulation lubricating system.  
Courtesy, Federal-Mogul Corporation.

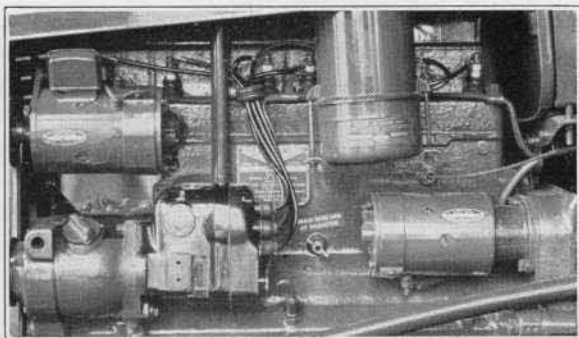


FIG. 157—The electrical equipment on this tractor includes a magneto at lower left, generator at upper left (for lights and starter and storage battery), and electric starter at lower right.

Courtesy, Oliver Farm Equipment Sales Company.

### MAGNETO LUBRICATION

The magneto has some of the most finely finished and closely fitted bearings in the tractor and it has a number of small parts that must be free to move quickly and precisely at rather high speeds. Little trouble usually occurs if the magneto is given proper care and is lubricated correctly.

Some magnetos are lubricated at the factory and sealed, with no provision for subsequent lubrication. They are fitted with sealed bearings and, if trouble develops, the magneto must be returned to the builder for repairs.

All other magnetos require occasional attention and lubrication. In general, ordinary grades of engine oils are not suitable for magneto lubrication because they are much too heavy. A very light, highly refined lubricating oil (such as a household or cream separator oil) should be used, *but used sparingly*, and the manufacturer's instructions should be followed and special care taken not to over-lubricate. Usually these instructions specify that a few drops of light oil be applied to the two armature bearings and to the distributor bearing, which also lubricates the distributor gears. It is usually recommended that the circuit breaker receive a very careful application of a little petrolatum. If the impulse coupling becomes sluggish, it is usually recommended that it be flushed with kerosene and refilled with light oil or, in very cold weather, refilled with kerosene. On magnetos with a removable distrib-

utor it is generally recommended that the distributor be removed every so often, and wiped out with a cloth dampened with kerosene, and afterward wiped dry. The distributor should then be wiped with a cloth slightly dampened with a little of the same oil that is used for magneto lubrication.

### WATER PUMP AND FAN LUBRICATION

On most tractors, if a water pump or impeller is employed, it is operated on the same shaft with the fan. The water pump or impeller bearing and the fan hub bearing require periodic application of a suitable lubricant. Generally, the manufacturer's instructions call for the use of grease at these points of the same type specified for chassis lubrication, but caution against the application of too much grease at one time. If a hand operated pressure gun is used, not more than two pumps of the gun should be given once a day. Excess grease simply goes into the cooling system to very seriously interfere with cooling effi-

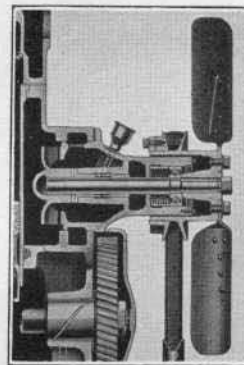


FIG. 158—Water pump lubricated with a screw down grease cup.

Courtesy, J. I. Case Company.

ciency on all the surfaces it coats. If a screw-down grease cup is provided on the water pump or impeller, a special water pump grease can be used that is more resistant to water than other types of greases. In no case, for either the water pump bearing or fan hub bearing (the latter usually being a ball bearing) should grease be applied until it oozes out the sides. This indicates an excess of lubricant which should definitely be avoided.

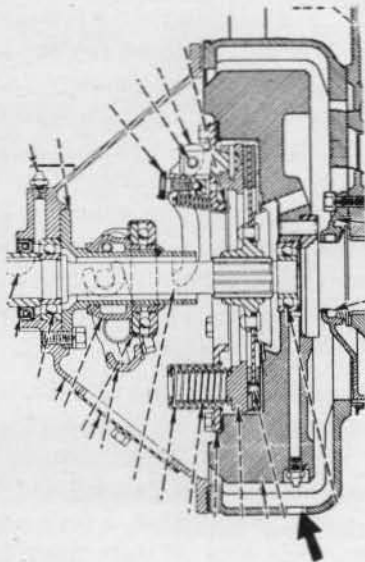


FIG. 159—The fitting for lubrication of the clutch pilot bearing on some tractors is reached through a hole in the bottom of the clutch housing (see Fig. 160).  
Courtesy, International Harvester Company.

### LUBRICATING CLUTCH PILOT BEARING

Although complete instructions for the lubrication of the clutch pilot bearing are given in the tractor's instruction book, many operators fail to find the fitting on some tractors (Fig. 160). This fitting is located on the flywheel (Fig. 159). Before the grease gun can be applied, it is necessary to turn the crank so that the fitting on the



FIG. 160—Lubrication of clutch pilot bearing by a pressure grease gun fitting which is serviced by lining up the fitting with a hole at the bottom of clutch housing (see Fig. 159). A mark on the fan belt pulley is provided to show when the fitting is in this position.

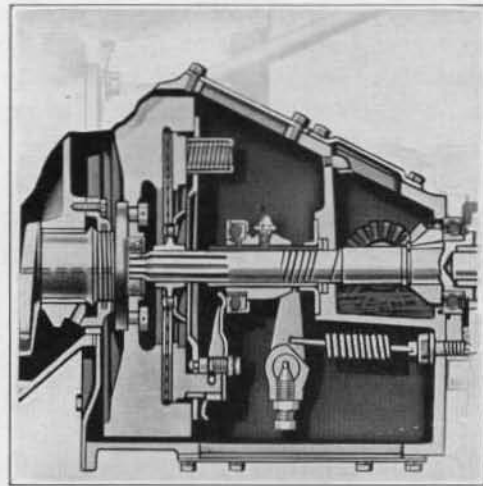


FIG. 161—Showing, from left to right, (1) lubrication of clutch pilot bearing by a wick extending through crankshaft from crankcase oil reservoir, (2) lubrication of clutch throw-out bearing by a pressure grease gun fitting, (3) lubrication of belt pulley drive from separate oil reservoir ahead of main transmission.

Courtesy, Tractor Division, Allis-Chalmers Mfg. Co.

flywheel will align with the hole in the bottom of the housing. When doing this, first be sure the ignition is off, then crank the engine slowly, while someone watches through the hole for the fitting to come into alignment. One man can align the grease fitting by using the mark on the pulley which drives the fan. The third or single notch in the pulley should then be aligned with the pointer to bring the fitting into proper position for greasing. Very little pressure gun grease is needed in this fitting—only two strokes of the gun every sixty hours. On another make

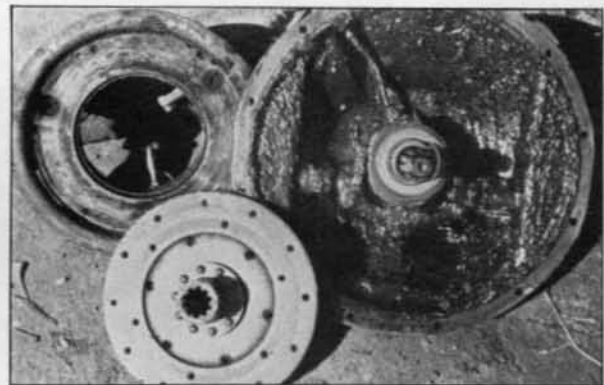


FIG. 162—Guard against over-lubrication of clutch parts. Here excess grease has caused slipping and scoring of the clutch plate, and surplus grease has coated the inside of the housing.



of tractor it is first necessary to remove the small cover at the bottom of the clutch housing to lubricate the bearing. The clutch release bearing should be given a couple of shots of pressure gun grease every twenty hours.

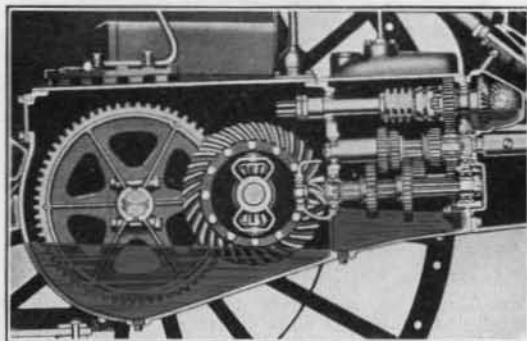


FIG. 163—Three separate compartments carry the lubricant for this tractor transmission. The belt pulley drive is at the upper right.

Courtesy, Oliver Farm Equipment Sales Company.

### CARE OF TRANSMISSION DIFFERENTIAL AND FINAL DRIVES

One of the most important and hardest-worked parts in all farm equipment is the tractor transmission unit. It is a part that thrives on simple care, struggles along temporarily without it, but all too often gives out prematurely because of neglect.

When the operating conditions of the farm tractor are compared with that of the automobile, the wonder is how transmission gears and bearings of tractors stand up as long as they do. On a car, the gears transmit power mainly for propelling the vehicle over a smooth, hard-surfaced highway. Most of the time, too, the car is run in high or direct drive, so that only the gears in the differential are carrying the power load, which is only a fraction of the total engine power. But a transmission unit on a farm tractor (Fig. 163) must transmit full engine power almost continuously, day after day, as the tractor moves across a soft-surfaced field, sometimes in a cloud of dust, while pulling a two-bottom plow, a disc, a lister, or some other piece of farm equipment that imposes a continuous heavy load.

Experience with automotive equipment has proved that it is advisable to replace gear lubricants at least twice a year, usually summer and winter. Tractor transmissions should also be drained and serviced seasonally or at least once a year. But even though manufacturers recommend a regular transmission drain practice, operators too often neglect these units, with the result that unnecessary wearing and grinding of gears and bearings is taking place, due to the presence of contaminated lubricants.

Tractor transmission units are made of heavy duty alloy steel gears and chains (Fig. 63), assembled on steel shafts which turn in large ball or roller bearings, but the one thing which keeps these steel parts protected is a tough-bodied film of lubricant. This film of lubricant is supplied to many of the antifriction bearings and smaller gears by the large gears, which rotate in a supply of the lubricant, since most of them are located above the level of the lubricant (Fig. 163). The heavy lubricant clings to the turning gears and is carried or splashed to all working parts. To give long life and hold the gears in rigid alignment, the bearings must be kept in adjustment and must receive an ample supply of good clean lubricant. Failure on the part of the operator to maintain proper transmission lubricant level at all times, and to drain and refill regularly with fresh lubricant is the principal cause of excessive wearing of these costly transmission units. Gear replacement is always very costly, for even



FIG. 164—Foreign material which has collected in a neglected transmission gear case.

though only one gear breaks or wears out and needs to be replaced, it is advisable to replace the mating gear also or to turn it around, if possible, so that the other side of the gear teeth may be used.

### WHY CLEAN LUBRICANT IS NEEDED

In service, transmission lubricants are likely to become contaminated with fine dust, rust (Fig. 165), moisture from condensation, and fine metal particles. The latter come from the inside of the transmission case, as a result of normal wear and from chipping of the gears when they clash during shifting. The contamination of the lubricant, in combination with stirring by the gears and alternate heating and cooling, causes the lubricant to thicken gradually in service.

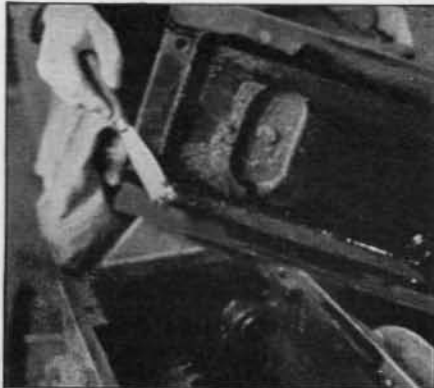


FIG. 165—Evidences of rusting tell of moisture that has collected inside of a transmission case. This moisture can cause corrosion of finely finished parts and is especially damaging to ball and roller bearings.

### DRAINING AND FLUSHING REMOVES CONTAMINANTS

The heavy body of the transmission lubricant causes most of the foreign material which finds its way into the transmission case to be held in suspension and circulated with the lubricant. If a fine metal particle is thus carried to an antifric-tion bearing, it is likely to cause a small rupture or pit on the ball or roller, and soon the bearing will destroy itself due to roughness. A bearing failure allows the gears to get out of alignment and hence they, too, are soon likely to fail.

The only sure way to eliminate the possibility of such trouble is to drain every gear case periodically and flush it each time with kerosene or furnace oil, always remembering to drain the lubricant while warm.

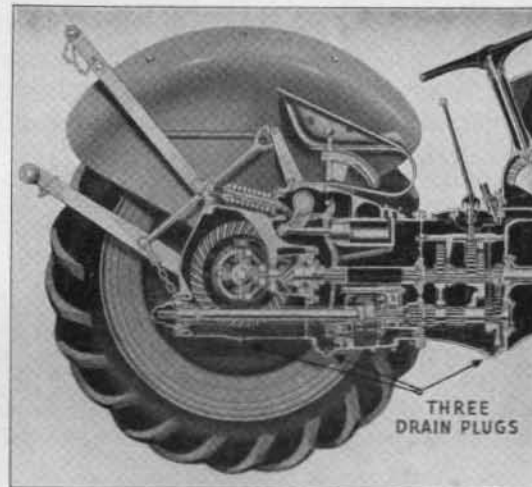


FIG. 166—A transmission and hydraulic unit having several compartments. To drain this transmission requires the removal of three drain plugs.  
Courtesy, Harry Ferguson, Inc.

When flushing, fill the cases to the proper level with kerosene or furnace oil and then drive the tractor around for a few minutes without load before draining. This gives the inside of each case a good washing or flushing action.



FIG. 167—To protect the tire when draining final drives, use a piece of sheet metal like that shown.

Care should always be taken to make sure that all the fuel and dirt are drained from the transmission case. On some tractors, the transmission has more than one compartment (Fig. 166) and will have more than one drain plug. It is, therefore, always advisable to refer to the instruction book when draining to make sure that all the drain plugs are located and removed for complete draining. To protect the tires when draining the final drives, use an old piece of sheet metal to carry the drainings into the pail (Fig. 167).

**TABLE III  
TRANSMISSION AND AXLE LUBRICANT  
CLASSIFICATION**

*S.A.E. Recommended Practice*

The S.A.E. viscosity numbers for transmission and rear axle lubricants constitute a classification in terms of viscosity and of consistency at low temperatures only. Other factors of quality or character are not considered.

S.A.E. Viscosity Number	Viscosity Range Saybolt Universal	Consistency Must Not Channel in Service at Specified Degrees F.
80	100,000 sec. at 0° F., max.*	Minus 20
90	800 to 1,500 sec. at 100° F.	Zero
140	120 to 200 sec. at 210° F.	Plus 35
250	200 sec. at 210° F., min.**	

\*No minimum specified since this grade is special for use at very low temperatures at which S.A.E. No. 90 would be too heavy. Oil companies are responsible for maintaining proper minimum viscosity of such lubricants to provide satisfactory lubrication.

\*\*No maximum specified since this grade is special for use at high temperatures at which S.A.E. No. 140 would be too light. Oil companies are responsible for maintaining proper maximum viscosity of such lubricants to provide satisfactory shifting of gears without channeling at the lowest temperature for which the lubricant is recommended.

General note: A lubricant made by adding soap (such as a grease) or other thickening ingredients to oil are classified by the viscosity of the oil before the addition.

After draining and flushing transmission cases, refill them with new lubricant of the recommended grade (usually specified by S. A. E. Viscosity Number as described in Table III). For summer use in most tractors, S. A. E. No. 140



FIG. 168—Occasional belt work in the winter is sufficient reason for using a light winter grade of lubricant in the transmission even though the tractor is not used much otherwise.

gear lubricant is recommended. However, for some of the older tractors where a worm drive is used, a lubricant such as Standard Gear Lubricant No. 250 should be used. *Caution:* Never use an E. P. lubricant on worm gears.

### **LIGHTER LUBRICANTS SHOULD BE USED IN COLD WEATHER**

Cold weather operation requires a lubricant light enough to flow freely at prevailing temperatures. If the heavy summer lubricant is used in winter, it will channel and will not be carried up to the bearings. Even though the tractor is used only a little for belt work (Fig. 168), a light lubricant should be used, for on many tractors the belt pulley gears and bearings are lubricated from the transmission, and a lubricant light enough to flow is definitely needed. For winter service, S. A. E. 90 gear lubricants are generally used. However, for limited winter service on tractors which have large capacity, low speed transmissions, the summer grade of lubricant can be lowered in viscosity by diluting it with 10% to 15% of kerosene. Some manufacturers recommend diluting the transmission lubricant with a light, 10W grade motor oil but when this is done, about 65% of it is required to give the necessary low temperature characteristics. In either case, whether a light lubricant or a diluted summer lubricant is used, the transmission should always be drained the following spring



before the beginning of the heavy work season. Spring is the logical time for servicing all transmission units—especially those containing last year's worn contaminated lubricant.

#### POSITION OF TRACTOR AFFECTS BELT PULLEY LUBRICATION

It is not uncommon to see a tractor inclined at a sharp angle doing belt work. When it is considered that on many tractors the lubricant for the pulley and power take-off is carried in a front compartment, it can easily be seen that, if a tractor is operated in such a position for a continued length of time, all of the oil will flow back into the main transmission case and leave the pulley gears and bearings without lubrication. Wear can quickly occur under such conditions.



FIG. 169—A tractor should not be towed at high speed behind a car. Transmission parts are subject to damage when this is done, and the practice is unsafe for the operator.

#### PRECAUTION ON TOWING TRACTOR

A practice that is very likely to be damaging to transmission units is the pulling of a tractor behind a truck or car (Fig. 169) at excessive speed. If a tractor is pulled, the actual road speed of the tractor should not be exceeded by more than five miles per hour. Pulling a tractor at higher speeds causes the gears and bearings to rotate terrifically fast and if continued for any length of time, will cause overheating of the transmission lubricant and may cause premature failure of parts. At high speeds, there is also danger of the operator being bumped off the tractor or of a brake heating and locking and causing the tractor to be ditched.

#### GREASE LUBRICATION

Greases differ from oils in that they consist of an oil and a thickening agent, usually a special type of soap. The soap gives the mixture a consistency ranging from very soft, almost fluid at one extreme, to very stiff or hard at the other extreme. When greases are skillfully made of the finest quality ingredients, they are particularly well suited for certain of the incidental lubrication needs of tractors. They can also be used effectively for the lubrication of such parts as clutch throw-out bearings, water pumps, and so on. In general, greases are used on relatively inaccessible bearings or where single applications must provide lubrication for a relatively long time while also serving the function of helping to keep contamination out of the bearings. Finally, greases are preferred by some operators principally for convenience in handling.

#### TYPES OF GREASES

Two very common types of greases are known to the trade as "cup greases" and "pressure gun greases." A cup grease is somewhat stiffer than a pressure gun grease, but so prepared that it will feed properly from a vertical, or nearly vertical, screw-down cup from the normal heat of bearing operation even if the cup is not screwed down from time to time. Performance like this accounts for the empty grease cup that is sometimes discovered even when the cup has not been screwed down. The softer pressure gun grease is so designed that it can be applied by a pressure gun. However, since it is forced to the bearing, it can be made of a heavier oil that will last longer in the bearing than the relatively light oil of a cup grease. Utilizing these principles and others, a variety of particular types of greases has been developed for particular purposes, and in general these purposes are indicated by the trade names carried by the products. Knowing these differences, it is important to remember how necessary it is to use the right type of grease



FIG. 170—Photomicrographs showing similarity between dust (lower left) and two grades of grinding compound.

in the right place in accordance with the published, authentic recommendations.

### CLEANLINESS MOST IMPORTANT

Apart from the necessity of using the right kind and grade, it is important to know that only good, *clean* grease should be used. In all stages of its storage and handling by the user, care must be exercised to keep the grease clean because, from its nature, it readily picks up every sort of dust and dirt. Much of this dust and dirt is abrasive and therefore would be destructive to many types of bearings. For these reasons, always be sure to wipe off the cup or fitting and surroundings before applying the grease; otherwise dirt will carry into the bearing with the grease. The precautions just given are very important, yet many times they are overlooked by tractor operators. The observation of these precautions has a great deal to do with the obtaining of good performance, long life of vital parts, and low operating costs which are the ultimate goals of all tractor lubrication practices.

### GREASE APPLICATIONS

There are a number of points about the chassis of most tractors that need individual lubrication with grease. These include such items as front and rear wheel hub bearings, steering gear and linkage, front wheel knuckle bearings, and on

some crawler types of tractors, the track-wheel hubs and track rollers.

The front wheel hub bearings are usually of the tapered roller type protected against the entry of dirt and other contamination by the working out of some of the lubricants. *Daily* attention and servicing with a pressure grease gun is usually recommended (Fig. 171). At least



FIG. 171—Front wheel hub bearings should be lubricated with pressure gun grease at least once a day when the tractor is in regular operation.

once a year, and more often if the tractor is being operated in very dusty surroundings, the front wheel bearing should be removed (Fig. 172) and bearings and hub washed clean in kerosene. All of the old lubricant should be removed from the hub cavity and enclosure before repacking with fresh lubricant. If the inner felt dust seal is removed, it should be replaced with a new one, as poorly fitting and faulty dust seals often cause excessive wheel bearing wear.

If the front wheels are hand packed and have no lubricating fittings, each bearing should be packed with wheel bearing grease. It is advisable to install a new grease seal at the same time. Do not fill the hub with grease. To adjust wheel bearings, tighten the adjusting nut until the wheel begins to drag when turned, then loosen the nut one-sixth to one-third turn. The wheel should rotate freely but should not have end play.

Rear wheel hub bearings are usually lubricated with the final drive transmission lubricant. In some instances, however, independent lubrication is provided by a screw-down grease cup or pressure fitting. This is intended to serve a double function; keep the oil from leaking out in the summer by forming a seal of grease, and lubricate the bearing positively in the winter when the transmission lubricant is likely to be too thick to carry to the wheel hub bearing.

The steering mechanism and linkage on wheel-type tractors also requires individual lubrication. It is recommended that once every five to ten hours the lubrication of these parts be checked and lubricant applied to the draglink steering shaft bearings, etc., until lubricant starts out of the bearing ends. The bearings of the front wheel knuckles should be checked at this time and lubricated in the same way.



FIG. 172—It is necessary to remove the wheel to inspect and service the front wheel hub bearing and seal.

The idler and driving wheels of crawler-type tractors may be considered as corresponding to the wheels of conventional type tractors, but lubrication of the wheel hubs may or may not be handled individually. The only general recommendation that can be made is to follow the manufacturer's instructions. The track rollers

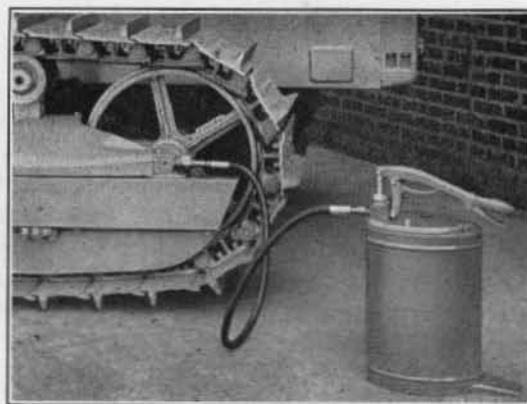


FIG. 173—Lubricating oil type track rollers with a volume pump.  
Courtesy, Caterpillar Tractor Company.

may be equipped with individual fittings and lubricated by means of a low-pressure gun, sometimes called a volume compressor (Fig. 173), or may be lubricated with a special gun for dispensing motor oil (Fig. 174), or may have lubricant piped to them from a central supply.



FIG. 174—Special oil dispensing pump for applying motor oil to oil-type track rollers.  
Courtesy, Tractor Division, Allis-Chalmers Mfg. Co.



## ENGINE COOLING

## TEMPERATURE CONTROL

Operators of tractor engines should know that efficient engine operating temperatures must be maintained to obtain long life, maximum economy, and full power (Fig. 176). They should know that an engine must always be warmed up before it is put under load, and that proper operating temperatures must be maintained thereafter (165-185° F. for gasoline, 190-200° F. for heavier fuels). But even when they know this, many operators fail to use the radiator curtain or shutters when starting the engine, and also fail to regulate these controls after the warm-up period to maintain proper temperatures during operation.

Tractors are designed with a large cooling capacity so as to prevent overheating in hot weather when pulling a heavy load. Thus, for light load and cold weather operation, it becomes necessary to cover part of the radiator to increase the operating temperature. It is the temperature of the water flowing from the bottom of the radiator to the engine, its coolest part (Fig. 175), that affects engine operation. This should be kept as high as possible without boiling

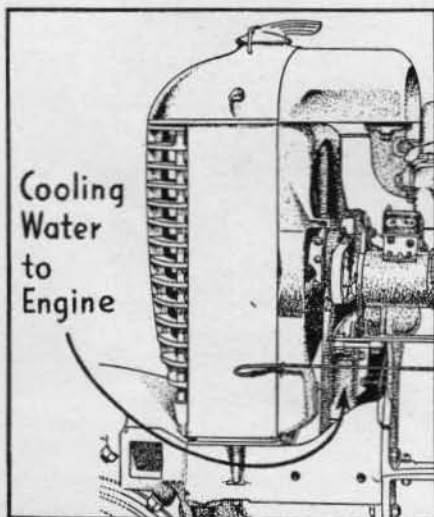


FIG. 175—Keeping up the temperature of the return flow of cooling water from the radiator to the engine is important to good engine operation. Regulate this temperature by judicious use of the radiator curtain or shutters.

Courtesy, J. I. Case Company.

## 60 HOUR GASOLINE ENGINE TEST

## OPERATING TEMPERATURE:



## CYLINDER WEAR:



## FUEL CONSUMPTION:



## POWER:

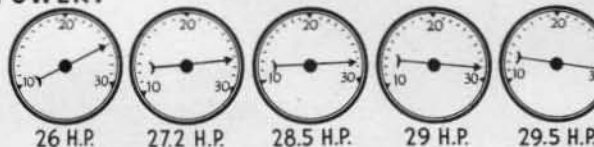


FIG. 176—An engine run at the proper high operating temperature wears less rapidly, uses less fuel, and develops more power as shown by comparing the vertical columns of the above test data.

the water away in the top of the radiator. In other words, the temperature drop through the radiator should be maintained at a minimum.

## COLD ENGINES WEAR RAPIDLY

Much of the excessive wear found in a cold-running engine comes from corrosion, coupled with the rubbing action of the piston rings over a corroded surface. When the piston travels downward, carbon dioxide and moisture from combustion collect on the exposed cylinder wall and form a thin film of oxide. This film is scraped off by the rings on the up-stroke of the piston. A continuous repetition of this process causes a high rate of wear. Not only does the water mix with the carbon dioxide to form a corrosive acid, but it also tends to remove the lubricant from the cylinder wall, exposing the metal surface.

The cylinder wall of an engine at full load is about 72° F. above the temperature of the cooling water, and at one-quarter load, 52° F. above the cooling water temperature. Thus, it is quite evident that an engine running at light load will be more subject to corrosion unless the temperature of the cooling water is increased.

The above conditions explain why an engine should always be run without load after starting in cold weather until full operating temperatures are reached. They also explain why frequent cold starts and stops before the engine has warmed up have ruined many an engine.

To shorten the length of time for warm-up and assist in temperature control, a thermostat is often used in the cooling system of tractors equipped with a water pump.



FIG. 177—A thermostat valve in the cooling system which has stuck open.

### THERMOSTAT MAINTENANCE

Thermostats removed from tractors during warm weather operation should by all means be replaced before operating in cool weather. Failure to use thermostats and keep them in good working condition causes many engines to run cold and give trouble. If it is noted that a tractor engine equipped with a thermostat warms up slowly, the thermostat should be checked to make sure that it is not stuck open (Fig.177). Any thermostat found to be stuck open should be replaced. The bellows-type thermostat contains a liquid which is placed in the bellows under vacuum. If the

bellows material cracks, it will leak and the thermostat will stay open.

When replacing thermostats, always be sure to obtain one which has the same temperature range as the one formerly used.

### OVERHEATING

During the extremely hot summer months, some operators have difficulty with their tractors overheating. Although tractors which use the thermo-siphon system of cooling will operate with a little steam coming out of the radiator during hot weather this should not be confused with overheating. However, if the tractor knocks considerably and the cooling water rapidly boils away, that is a sign of overheating and steps should be taken to remedy it.

### CAUSES OF OVERHEATING

Some of the more common causes of overheating are as follows:

1. Pulling too heavy a load.
2. Using a fuel too low in antiknock rating.
3. Operating with a loose or badly worn fan belt (Fig. 178).



FIG. 178—The fan belt tension is usually adjusted to provide about one inch of slack.  
Courtesy, Caterpillar Tractor Company.

4. Operating with a faulty water pump.
5. Operating with faulty timing or a weak magneto.
6. Operating with improper carburetor adjustment (usually too lean).

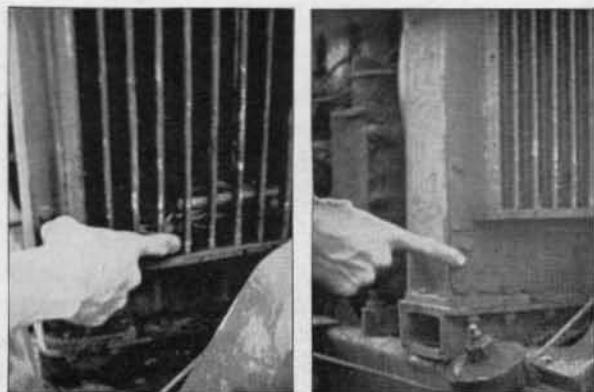


FIG. 179—(Left) Radiator fins plugged with leaves and shucks. (Right) In extremely hot weather this baffle plate may need to be removed to prevent engine overheating.

7. Operating with plugged radiator fins (Fig. 179 left).
8. Operating with lower part of radiator covered by a baffle which may need to be removed in hot weather (Fig. 179 right).
9. Operating with collapsed or deteriorated hose connections.
10. Operating with a badly limed cooling system (Fig. 180).

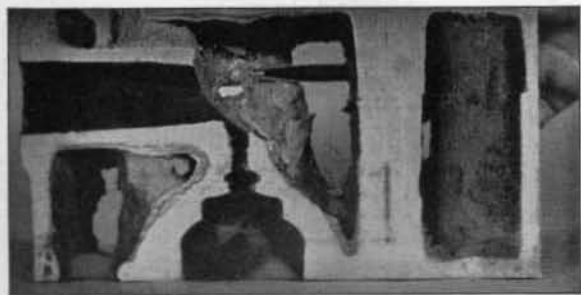


FIG. 180—Cross section through cylinder block showing how cooling system deposits have caused overheating sufficiently to burn a hole in wall where pencil points.

If overheating cannot be corrected by the more obvious remedies, it is quite possible that a badly limed cooling system (point 10, above) is responsible for the trouble. Lime and other such salt deposits from hard water act as heat insulators, preventing the cooling system from dis-

sipating the engine heat. Since these deposits come from the water, the more water required to keep the cooling system filled, the more rapidly such deposits accumulate. If they become very heavy, the engine may overheat sufficiently to knock, burn and stick valves, and even in an extreme case burn a hole in the cylinder head, as shown in Fig. 180.

### HOW TO REMOVE ENGINE COOLING SYSTEM DEPOSITS

In most cases cooling system deposits can be removed by using a solution of washing soda or lye. About 3 pounds of ordinary washing soda to 7 gallons of clean soft water is the proportion usually recommended. This solution should be placed in the radiator and the engine operated with the filler cap left off until the water becomes hot. Then the cooling system should be drained and flushed with clean water.

To clean cooling systems that are more badly limed, it is necessary to use a stronger solution or special solutions that are capable of dissolving the heavier lime deposits. Certain commercial cleaners may be used as recommended by their manufacturers or a solution of formaldehyde and muriatic (commercial hydrochloric) acid may be found satisfactory if used as recommended below:

TABLE IV  
COOLING SYSTEM CLEANING SOLUTIONS

The following recommended mixtures for different capacity cooling systems are based on a mixture of approximately 1 part of formaldehyde, 5 parts muriatic acid, and 42 parts water, as published by Kansas State College in a bulletin on engine overheating:

Approx. Capacity of Cooling System (gallons)	Water	Muriatic Acid	Formaldehyde
6	20½ Qts.	5 pts.	1 pt.
8	28 "	6 "	1¼ pts.
10	36 "	8 "	1½ "
12	43 "	10 "	2 "
15	54 "	12 "	2¼ "
20	72 "	16 "	3 "



It is recommended that this solution be allowed to remain in the tractor for two or three hours at operating temperatures, then drained. To neutralize the acid, the cooling system must then be flushed with clean soft water to which a can of lye has been added. After running the engine for a few minutes, the lye water should be drained and the cooling system again flushed with soft water to remove all traces of the lye water.

The formaldehyde is used as an inhibitor to prevent the acid from attacking the metal parts; hence it is not advisable to use muriatic acid alone. Both of these liquids are poisonous and must therefore be stored away from children and animals.



FIG. 181—Rain water, or a soft water, is free from scale-forming tendencies and should be used in the radiator.  
Courtesy, J. I. Case Company.

### WATER FOR COOLING SYSTEM

Lime deposits in cooling systems can be minimized by the exclusive use of soft water. To prevent the possibility of rust with soft water in the cooling system, some operators use one of the commercial rust inhibitors which are sold for this purpose. If a soluble oil is used in a tractor engine cooling system to protect against rust, it must be used sparingly—not more than one ounce to a gallon of water—so as not to cause excessive deterioration of the rubber hose connections or the rubber rings used to seal cylinder liners.

### ALLOW ENGINES TO COOL BEFORE STOPPING

Before stopping a hot engine, it should always be allowed to idle for a few minutes to give the pistons a chance to cool, otherwise the engine keeps on running, and the hot pistons, after stopping, may "stew" and "coke" the oil on their frictional surfaces. A newly rebuilt engine is likely to seize if the ignition is turned off without first

allowing the engine to cool for a few minutes since, in such an engine, the piston clearance is not large and is "taken up" by expansion of the overheated parts.

### WINTER PROTECTION OF COOLING SYSTEM

Tractors used in freezing weather should either be drained each time after work, or employ an antifreeze solution in the cooling system. It is generally recommended that an antifreeze solution with a higher boiling point than alcohol be used, especially in tractors employing high temperature thermostats or the thermo-siphon system since in such engines an alcohol antifreeze would soon boil away.

When draining any cooling system, always make sure that *all* the drains are opened. Many tractors have a drain at the bottom of the radiator and also a drain on the engine block (Fig. 182). It is necessary to *open both of these drains* to remove all the water.

If the outside temperature is below freezing, it is a good idea to start a tractor that has been drained before filling the radiator. First, turn the fan by hand to make sure the water pump is not frozen. Have the water handy and put it in immediately after the engine is started. This procedure avoids the possibility of a "freeze-up" if the engine fails to start. At temperatures above freezing it is, of course, advisable to fill the radiator before starting the engine.



FIG. 182—Left hand points to radiator drain. Right hand points to drain plug on engine block. Do not fail to drain the block when draining the radiator if laying up the tractor in freezing weather.

## STORING THE TRACTOR FOR WINTER USE

In preparing a farm tractor for winter storage, a regular procedure should be followed. First, the tractor should be cleaned, inspected and serviced just as though one were getting it ready for a big day's work.

Next, the crankcase should be drained, the oil filter cleaned or replaced, and the crankcase refilled with new oil. The motor should then be operated long enough to circulate the new oil to all the working parts, thus providing a protective oil film during the storage period.

The tractor should now be driven into a dry shed and the wheels run up on some old boards, if necessary, to keep them off the ground.

The air cleaner should be serviced and the tractor should be well greased.

Drain the radiator and flush it with a radiator cleaner. After using the radiator cleaner, the radiator should be flushed with clean water, drained dry, and the drain plugs left out.

If the tractor is equipped with pneumatic tires, the wheels should be jacked up.

The spark plugs should be removed and about two tablespoons of heavy motor oil placed in each cylinder.

Then the engine should be turned over several revolutions by hand so as to coat the cylinder walls with an oil film.

If the tractor is equipped with a storage battery, the battery should be removed, brought to a fully charged condition, and stored inside in a cool place. Once a month it is advisable to check the condition of the battery.

The exhaust pipe should be closed with a piece of rag or a cover of some sort.

The fuel should be drained from the fuel tanks and carburetor, and all drain cocks left open. It is very important that no gasoline be allowed to remain as it will gradually evaporate, and it also constitutes a fire hazard. Moreover, evaporation of gasoline may leave a gummy deposit on the inside of the fuel tank or carburetor which may cause difficulty when an attempt is made to operate the tractor again next spring. This condition can also result in valve sticking. If the small passages, jet openings and valves of the carburetor become wholly or partially inoperative from deposits of this kind, they can be loosened and cleaned with a mixture of one part alcohol and one part benzol, or with acetone, which will completely dissolve the deposits.

## CONCLUSION

Whatever the type of tractor, whatever the operating needs and conditions—the Stanolind Oil & Gas Company is qualified by experience with farm needs to supply the right fuels and lubricants.

Whether the tractor operator's choice or the engine's needs call for one kind of fuel or another—Stanolind is able to supply the proper fuel, and the tractor operator can use that fuel with the assurance that it has been specifically built to meet the latest requirements for the type of fuel selected.

Stanolind's lubrication recommendations, also, are authentic and trustworthy. They are published in detailed form for all individual makes and models of tractors. Good lubricants of every type needed for dependably safe operation and low maintenance are offered on the basis of superior performance and lower operating costs.

The general suitabilities of Stanolind's leading brands of recommended fuels and lubricants are very briefly described in the following supplement.