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Part 1.—How the Engine Works

No driver can look after his tractor properly unless he knows something of the way it works. The modern tractor is a sturdy machine designed to stand continuous hard work, but it contains a certain amount of complicated mechanism. All drivers, therefore, should know enough of the working principles of a tractor to be able to undertake the “maintenance” of the one they use.

If through neglect or ignorance a tractor does not get proper maintenance—
1. It will never be capable of undertaking its full duty.
2. Repair bills will be heavy.
3. It will break down, generally at busy times.
4. Its working life will be considerably shortened.
5. Fuel will be wasted.

In the long run the only complete guide to the maintenance of a tractor is the instruction book issued by the makers. The instruction book is the most valuable part of the tool-kit supplied with a new tractor.

The internal combustion engine

The kind of engine used in a tractor is called an internal combustion engine because it converts the heat energy of fuel into mechanical work by burning the fuel inside the engine itself.

A steam engine, for example, is not an internal combustion engine because the engine part of it—cylinder, piston and so on—is quite distinct and separate from the fire-box in which the fuel is actually burnt. The fuel burnt in an I.C. engine can be any one of the following: Coal or producer gas, petrol or kerosene vapour, or diesel oil in the form of a finely-atomised spray.

The letterpress and illustrations in this series of articles are from a handbook prepared by the National Institute of Agricultural Engineering (England) and are reproduced by courtesy of the Institute and the British Ministry for Agriculture and Fisheries.
The general principle of all I.C. engines is the same and depends on the fact that air combined in the right proportion with any one of these fuels will form an explosive mixture. The various types of engine differ from one another only according to the fuel used, the exact arrangements for introducing and exploding it, and the number of cylinders. For tractors the most common and important type is the four-stroke engine starting on petrol and running on a special kind of kerosene known as vapourising oil.

Fig. 1 shows a diagram of a four-stroke I.C. engine cut across the middle, and viewed from the end. All the most important parts are labelled, and will be referred to throughout this book by these names.

**THE SINGLE CYLINDER FOUR-STROKE ENGINE**

The cycle of operations is shown in Fig. 2.

1. **Induction Stroke.**
   (a) The inlet valve opens.
   (b) The piston moves down the cylinder.
   (c) Fuel and air mixture is sucked into the cylinder.
   (d) When the piston reaches the bottom, the cylinder is full of explosive mixture and the inlet valve closes.

2. **Compression Stroke.**
   (a) Both valves are closed.
   (b) The piston rises.
   (c) The mixture in the cylinder is compressed into a much smaller space.
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3. Firing Stroke.
   (a) At the end of the compression stroke both valves are still closed.
   (b) As the piston reaches the top of this stroke a spark at the sparking plug ignites the compressed mixture.
   (c) The force of the explosion of that mixture drives the piston down the cylinder.

4. Exhaust Stroke.
   (a) The exhaust valve opens as the piston reaches the bottom of the firing stroke.
   (b) The piston moves up the cylinder again.
   (c) The burnt gases are driven out past the exhaust valve.
   (d) The exhaust valve closes.
Then once more the inlet valve opens—fresh mixture is drawn into the cylinder and the whole cycle starts over again.

An engine of this kind is called a four-stroke engine because, as indicated above there are four strokes of the piston for each explosion. The explosion stroke is the only working stroke, i.e., the only one in which the piston drives the crankshaft. During the remaining three strokes of the cycle the crankshaft continues to turn round because of the momentum of the flywheel.

**THE FOUR-CYLINDER ENGINE**

Smother running and a more uniform output of power will obviously result from using several cylinders with the corresponding pistons all coupled to the same crankshaft as indicated in Fig. 3.

The vast majority of tractor engines have four cylinders working on the above principle, i.e., they have what are called four-cylinder four-stroke engines. In such an engine one cylinder fires for each stroke: that is, two cylinders fire during each complete revolution of the crankshaft and flywheel. The order of firing in a four-cylinder four-stroke engine is either 1-3-4-2 or 1-2-4-3 depending on the make of the tractor. The more common is 1-2-4-3: but the firing order will usually be found marked somewhere on the engine. A four-cylinder engine runs smoothly and gives a fairly uniform output of power because, whatever the position of the crankshaft, one or other of the pistons is actually on the firing or "working" stroke.

**PETROL STARTING FOR TRACTORS RUNNING ON VAPOURISING OIL**

Most tractors in this country use vapourising oil (kerosene) as fuel because it is relatively cheap. But a tractor cannot be started from cold on vapourising oil because this fuel will not turn into vapour until it has been warmed up. For this reason all vapourising oil tractors are started on petrol and should be run on petrol until their engines are hot enough to vapourise the normal fuel properly.

**OTHER KINDS OF TRACTOR ENGINE**

In America petrol is cheaper than it is here so it is more often used as a tractor fuel. A petrol-air mixture can be more highly compressed than a vapourising oil-air mixture without giving trouble on the
firing stroke: or, as we generally say, an engine running on petrol can have a higher compression ratio than an engine running on vapourising oil. With a higher compression ratio more power can be obtained from the same size of engine, and so, if it has been specially designed for the purpose, a petrol engine will generally be more powerful than a vapourising oil engine of the same size.

**THE DIESEL ENGINE**

In some parts of the world vapourising oil is either expensive or difficult to obtain, and the only cheap fuel is diesel oil. In those places tractors with diesel engines are popular; some tracklaying tractors of this type are also to be found in this country. The diesel engine works on the same principle as the vapourising oil engine, but there is no sparking plug and
fuel is not introduced until the end of the compression stroke (see Fig. 4). The cycle is as follows:

1. **Induction Stroke.**—The inlet valve opens—the piston goes down, drawing in pure air—the inlet valve closes.

2. **Compression Stroke.**—Both valves are closed—the piston comes up and compresses the air in the cylinder. The engine has a high compression ratio and on this stroke the air is compressed so much that it get hot—as it does in a bicycle pump when a tyre is being inflated.

3. **Firing Stroke.**—As the piston reaches the top of the compression stroke a spray of diesel fuel is shot into the cylinder through a nozzle called an injector. The heat of the compressed air is sufficient to ignite the fuel, causing an explosion which drives the piston down.

4. **Exhaust Stroke.**—The exhaust valve opens and as the piston comes up the burnt gases are driven out of the cylinder. The exhaust valve then closes and the cycle starts again by drawing in fresh air.

Most four-stroke diesel engines can be started from cold but their high compression ratio makes them difficult to turn by hand, and they often have auxiliary starting devices. Thus some diesel-engined tractors have a small petrol engine for starting them, while others are arranged so that they can start on petrol, and operate as ordinary petrol engines until they warm up.

**TRACTOR COMPONENTS**

This section aims at showing how the principles of the internal combustion engine are put to practical use in a tractor.

**THE TRACTOR ENGINE**

The piston must make a gas-tight joint with the inside wall of the cylinder and yet be free to move up and down. This gas-tight fit is obtained by three or more cast-iron rings (piston rings) which are let into grooves around the piston. The rings tend to spring outwards and so project slightly from the piston and press against the cylinder wall.

The connecting rod is connected to the piston by the gudgeon pin, which passes through the little-end bearing in the connecting rod and is supported at each end in the wall of the piston. The end of the connecting rod attached to the crankshaft is called the big-end bearing and is in two parts bolted together round the crankshaft.

The crankshaft, like the pedal and crank of a bicycle, turns the up-and-down motion of the piston into rotary motion, which can be used to drive the tractor wheels. The crankshaft itself is carried in bearings known as main bearings—in a four-cylinder engine there can be two, three or five main bearings, three being most common.

The valves are generally of the poppet or mushroom type consisting of a mushroom-shaped head on a central stem. They move up and down in "sleeves" called valve guides and are held in the closed position by valve springs. There are two common arrangements—side valves and overhead valves as shown in Fig. 6. Practically all tractors, except the Fordson, have overhead valve engines. In tractors, overhead valves are operated by push rods from a camshaft at the side of the engine.

**The Camshaft.**—The valves are opened and closed at the correct times by means...
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of cams, which are merely projections from
the camshaft. The setting of the camshaft
is of great importance in the
running of the engine. On
this will depend the valve
timing, that is, the exact
moments at which the valves
open and close.

The Carburettor.—As the
piston descends, a stream of
air is drawn over a small hole
called the jet from which it
picks up some fuel and carries
it on into the cylinder. The
jet is fed from the fuel tank
through a fuel chamber con­
taining a float. If more fuel
enters the float chamber than
the engine needs, the float
will rise until the valve at the
top closes the pipe from the
tank. When the engine needs
more fuel, the float will fall
and allow more to enter the
float chamber. The quantity
of fuel reaching the jet is
controlled by the setting of a
needle valve (see Fig. 8).

The Vapouriser. — When
petrol is used, the fuel picked
ourises, i.e., turns into gas.
up from the jet rapidly vap-
Such a mixture of air and
petrol vapour explodes easily.
Vapourising oil does not turn
into gas unless it is heated. It
leaves the jet as a very fine
spray made up of small drops
of fuel, which must then be
heated in a vapouriser to
turn them into gas.

The vapouriser is a narrow
box, one side of which is heat­
ed by the hot gases leaving
the engine on each exhaust
stroke. When the engine has
been running for a short
time on petrol the vapouriser
becomes hot. If the engine is
then turned on to vapourising
oil, the spray of fuel from the
jet will be heated and turned
into a gas, which forms with
air an easily exploded mix-
ture (see Fig. 8).
The Throttle is shown in Figs. 7 and 8. It is a flat disc of metal which can be set so that it partially blocks the induction pipe, i.e., the pipe along which the fuel-air mixture flows to the engine. The speed and power of the engine are controlled by the amount of mixture that the throttle allows to enter the cylinders. In Fig. 7 the throttle is open, in Fig. 8 it is closed.

The Choke.—The engine requires a “rich mixture” for starting, i.e., more petrol vapour in the mixture than is needed for normal running. For this reason another disc, similar to the throttle, is placed in the air intake so that the air has to flow past it before reaching the jet. Normally this disc—called the choke—is wide open, but for starting it is partially closed to restrict the flow of air and make the mixture rich in petrol. It is shown in the two diagrams—in the top one it is open for normal running and in the bottom one it is partially closed for starting, i.e., the engine is “choked.”

The Governor is an automatic device which keeps the engine running at the same speed whether the load is heavy or light. The governor control allows the driver to alter the speed at which the governor keeps the engine running. If the load on a tractor increases so that the engine speed tends to fall, the governor opens the throttle and gives the engine more fuel. When the load decreases so that the engine tends to speed up, the governor closes the throttle and cuts down the fuel supply.

The Magneto produces the spark at the sparking plug which fires the mixture in the cylinders. It is a small dynamo and induction (or “shocking”) coil combined. When the end cover is taken off, the inside will look something like the diagram in Fig. 9. This shows the moment at which a spark is produced at the sparking plug in No. 1 cylinder. A spark is produced whenever the points of the contact breaker open, which occurs each time the end of the rocker arm passes the cams on the stationary cam ring. The spark appears at No. 1 plug because the rotor arm of the distributor is passing the end of No. 1 plug-lead. In the magneto shown, this rotor arm is geared to revolve at half the speed of the contact breaker, so that when the points next open the rotor arm of the distributor will be opposite No. 2 plug-lead. The magneto must be “timed” so that the points open, i.e., the spark occurs, in the right cylinder and at the right time in relation to the position of the piston at the end of each compression stroke.

A Sparking Plug is the means whereby the mixture is ignited in the cylinder by a spark appearing at the gap between its points. Sparking plugs must be kept clean and in good order or the spark they give will be weak. In that case the mixture will not be ignited properly: starting will be difficult and power will be lost.

It is most important, therefore, that plugs should be taken out periodically and cleaned thoroughly.

Not all sparking plugs are alike, and, whenever possible, the particular type of plug recommended by the makers of a tractor should be fitted.

The Impulse Starter is a device which makes tractors easier to start. When turned slowly a magneto gives a weak spark that makes starting difficult, so while the engine is being turned slowly some means has to be found to increase the magneto
FIG. 9 THE MAGNETO
speed. When the engine is turned the impulse starter prevents the magneto from turning with it until the piston reaches the top of the compression stroke. At this moment the magneto is released, and is driven round at high speed by a spring so that it delivers a "fat" spark. The spark thus produced by hand-turning is as good as the spark delivered in normal running at normal engine speed. The impulse starter engages automatically when the engine stops and can be heard to "click" as the engine is turned over by hand. As soon as the engine starts it disengages itself automatically. Any modern tractor can therefore be started simply by pulling up the starting handle.

The Lubrication System can be one of the following:

1. **Splash.**—The big-ends dip into trays carrying oil in the sump, and so cover the inside of the engine with oil.

2. **Pressure Feed.**—Oil drawn from the sump through a screen is pumped through pipes to every part of the engine (see Fig. 10).

3. **Force Feed and Splash** is a combination of the above. Usually the big-ends, little-ends and piston are lubricated by splash and the rest of the engine by a pump feed.

Few tractors nowadays have splash lubrication systems. Most of them are wholly or partly pressure fed and a gauge is fitted to show that oil is circulating. This should be watched during work and the engine stopped at once if no pressure is showing on the dial. In addition, an oil filter may be fitted to keep the oil free from contamination. This filter should be cleaned or replaced periodically as the makers advise in the instruction book.

The diagram (Fig. 10) shows a typical pressure-fed lubrication system. After
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being pumped through a filter the oil is carried by pipes to the various bearings, reaching the big-ends through oil-ways drilled in the crankshaft. In the drip feed to the overhead valve gear, the oil finds its way down the push rods and tappets to lubricate the cams before returning to the

HOT WATER
AIR

COOL WATER

FIG. 11 RADIATOR SECTION

COOLING FINS

sump. Lubrication of the cylinder walls and little-ends is effected by splash from the crankshaft and by oil-mist.

The Cooling System.—An internal combustion engine, with its large number of explosions per minute in each cylinder, needs some cooling device to prevent damage by excessive heat. Water is used, and the usual method of cooling is by the thermosyphon system. In this system the water circulates because hot water is lighter than cold. Hot water from the parts of the engine nearest to the cylinders rises and passes through a pipe to the top of the radiator. The radiator is a series of tubes with fins, through which air is drawn by the fan. As the water is cooled in the radiator it becomes heavier, falls to the bottom and passes to the lower part of the cylinder jacket, to replace the warm water leaving at the top. It is usual on tractors to have a pump or impeller at some point in the circuit to assist the circulation and improve the efficiency of the cooling.

In practice, tractors running on vapourising oil tend to keep cool, especially on light loads. In a cool engine the fuel is not completely vapourised, with the result that maximum power is not developed and unburnt fuel passes the pistons to the lubricating oil in the sump with harmful effect. There are three main methods of controlling the engine temperature:

1. Radiator blinds.
2. Radiator shutters.
3. A thermostat controlling the pump circulation.

1 and 2 are most satisfactory when used in conjunction with a thermometer, which can be read from the

FIG. 12

THE COOLING SYSTEM
driver's seat. The thermometer is best fitted near the top of the radiator, where the water should be kept just under boiling point. Radiator blinds can be raised to keep the engine warm for starting or during cold weather and periods of light loading, and lowered for warmer weather or heavy loads.
Radiator shutters are opened and closed by a hand lever from the operator's seat.

Some tractors use a valve called a thermostat which is fitted between the top of the cylinder and the radiator. When the water round the cylinders is hot enough, this valve opens and allows the water to flow to the radiator for cooling.

THE TRANSMISSION SYSTEM

The transmission system of a tractor is divided into three parts:

1. The Clutch may be one of two types:
   (a) Single plate.
   (b) Multiple plate.

   The single plate clutch is the more common in modern tractors. It consists of one plate held tightly between two surfaces by powerful springs. One of these surfaces is usually on the engine flywheel, the other is attached to the shaft which drives the gearbox and back axle. Pressing on the clutch pedal, parts these two surfaces so that the plate is free, and the gearbox is no longer driven by the engine. Releasing the pedal allows the clutch springs to clamp the plate together, and the engine drives the gearbox. Single plate clutches are fitted in a separate compartment in the transmission system where no oil can reach them and are known as dry clutches. The multiple plate clutch consists of a number of plates, half which are driven by the engine and half fixed to the shaft driving the gearbox. These plates are arranged alternately—one engine driven, then one that drives the gearbox and so on. When the clutch pedal is depressed the plates are allowed to spread, so that they do not touch and drive each other. In the same way when the pedal is released the clutch springs clamp the plates together, and the engine drives the gearbox. Multiple plate clutches are usually fitted in a part of the transmission to which the engine oil can penetrate and thus, running in oil, are known as wet clutches.

2. The Gearbox gives a choice of tractor speeds so that the power of the engine may be used to the best advantage, and the speed chosen for each farming operation. The gearbox is designed to allow gear changes only when the tractor is stationary, and the gears should not be changed while the tractor is moving.

3. The Back Axle is the final drive from the gearbox to the rear wheels. It consists of two half shafts and a differential gear which enables the driving wheels to turn at different speeds when going round corners.

(To be continued)

BEEHIVE REGISTRATION

The Director of Agriculture (Mr. G. K. Baron Hay) wishes to remind all beekeepers that under the Bees Act, 1930-1950, any person keeping bees must be registered for the current year, the period of registration ending on December 31, annually.

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