GASOLINE TRACTORS

HAYWARD

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A PRACTICAL PRESENTATION OF TRACTOR PROBLEMS AND THEIR SOLUTION

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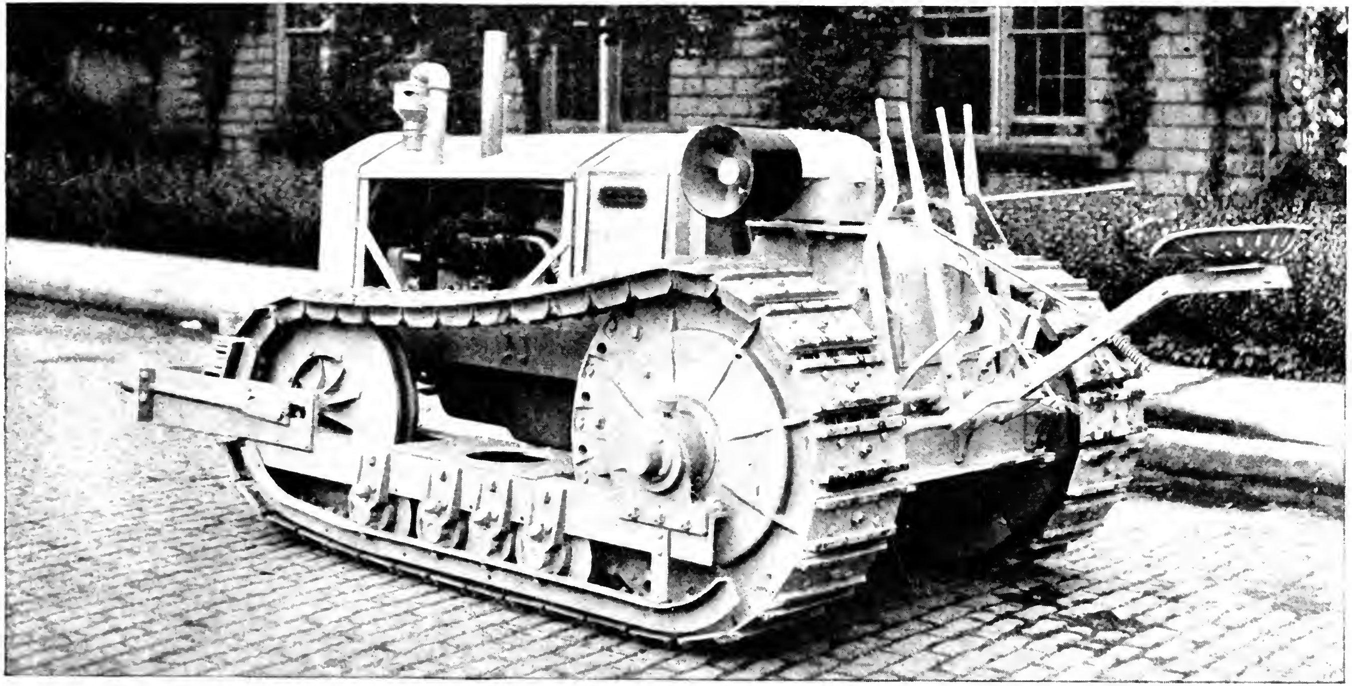
INTRODUCTION

THE huge slow-moving steam tractor has been known in farmland for many years. It was used by big ranchers to plow their broad acres and to harvest their grain. Individual owners also made their tractors sources of revenue by going around among smaller farmers to thresh their oats and wheat, the same tractor doing duty for all of the farmers of a certain district.

¶ Within the last few years, however, the development of the gasoline motor and the dearth of available farm labor has called for the design of small gasoline tractors sufficiently inexpensive to make their acquisition a possibility for the average farmer, and sufficiently flexible as to power to make them economical for all sorts of operations about the farm, from plowing to running a corn sheller or a feed grinder. These small tractors, while not having the flexibility of control of the automobile, are easily manipulated and have been found adaptable to so many farm processes that they have been received by the farmer with open arms.

¶ Of course, the farmer for years has been so thoroughly acquainted with the automobile that he recognizes the gasoline tractor as a friend but nevertheless he has found the mechanisms, the action, and the management of his new assistant sufficiently full of mystery to make him wish for a manual at his elbow to help solve his difficulties. His need is particularly great when the machine stops on its job or when some part has to be replaced. This situation, coupled with the fact that the farmer must usually be his own repairman, has created a real need for an authoritative book on the subject—a book which will tell the owner of a tractor just what he ought to know, will guide him in his selection of a machine, and will tell him what to do when the ignition fails to work, when the carburetor is out of adjustment, etc. The author of this work has had a great deal of experience in the gas engine field and has made special study of the subject. It is the hope of the publishers that this little volume will successfully fill the place for which it was designed.



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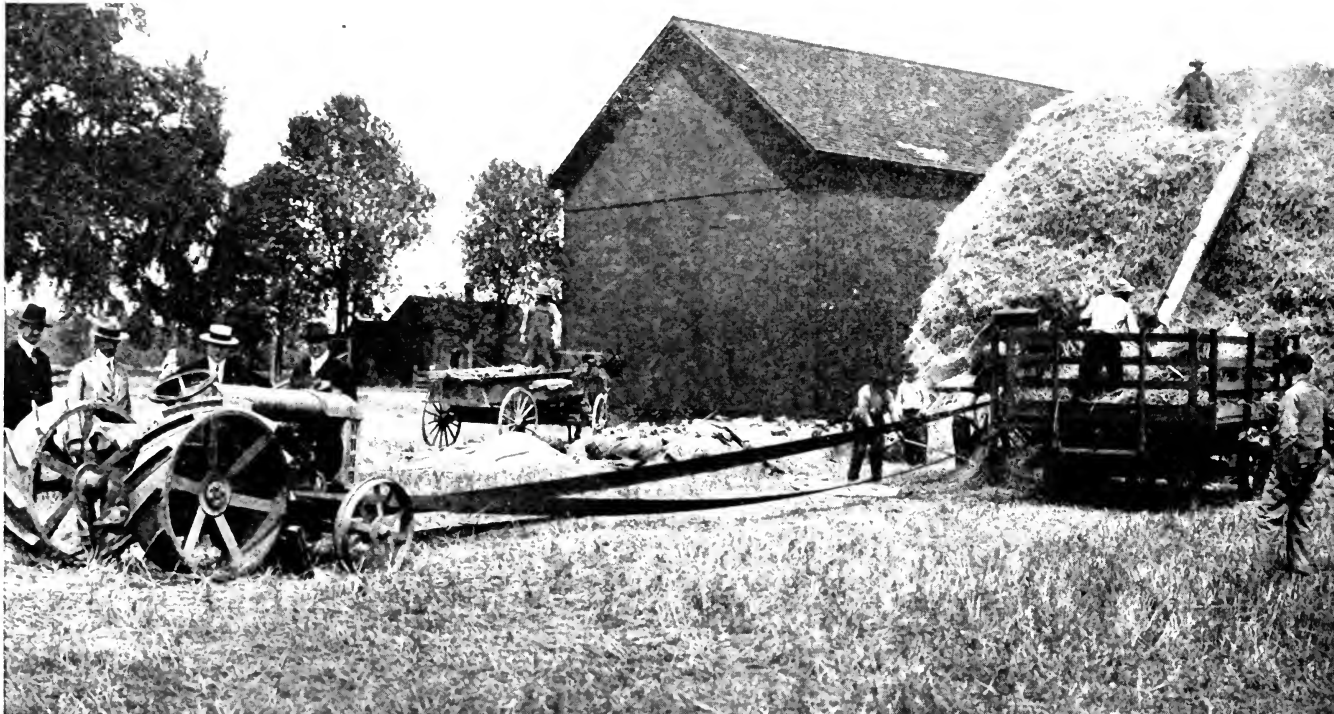


FORDSON TRACTOR BEING USED FOR BELT WORK
Courtesy of Henry Ford and Son, Inc., Dearborn, Michigan

GASOLINE TRACTORS

PART I

INTRODUCTION

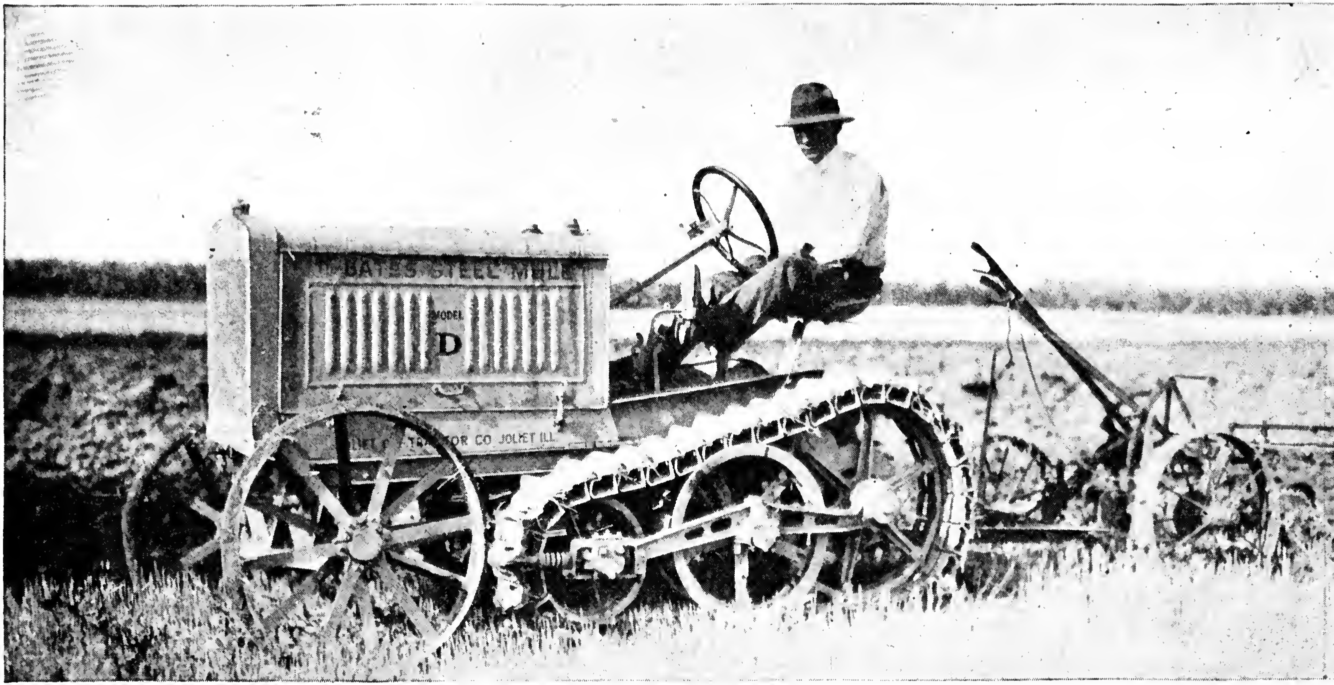
Relation of Tractor to Automobile. At first sight it appears to be rather a fortunate coincidence that the man to whom the tractor will prove of the greatest benefit is he who has found most advantage in the automobile—the progressive American farmer. The automobile has proved a veritable godsend to the farmer, and there is no question but that he has thoroughly mastered it. He appreciates that it is a piece of machinery and as such can only be kept in satisfactory operating condition by proper attention; and further, that even despite attention it is subject to breakdown at times. Having acquired this knowledge of an automobile by experience, the prospective purchaser of a tractor naturally feels perfectly competent to judge the merits and demerits of the various types offered and to give the one he buys whatever attention it may need to keep it operating satisfactorily. This is a mistake and has proved a more or less costly one to many farmers who have proceeded on such an assumption. The tractor is driven by a gasoline or kerosene engine, it has a gear set, clutch, and final drive—all counterparts of the automobile—but it is not an automobile any more than an aeroplane or a motorboat is, and the attention that will suffice to keep an automobile going will fall far short of what a tractor requires. Unlike an automobile, the tractor is always operating at full, or almost full, load. Moreover it operates for ten, twelve, or even eighteen hours a day under this load. Its requirements are those of the mogul freight engine rather than those of the high-speed passenger locomotive.

Need of Judgment in Selection of Tractor. Not every one can hope to operate a tractor satisfactorily, but the experience of those who have acquired the many thousand machines turned out in the last few years shows that, given proper judgment in the selection of a tractor for the work it is to perform and the right kind of attention to its needs, it will do all or more than is claimed for it. Buying a tractor may be likened in some respects to building a house. Many people never succeed in building just the house they want until they have made two or three attempts. This is equally true of tractor purchases; many farmers do not succeed the first time in buying the tractor they should have, but in the end the value of the experience gained usually offsets its cost.

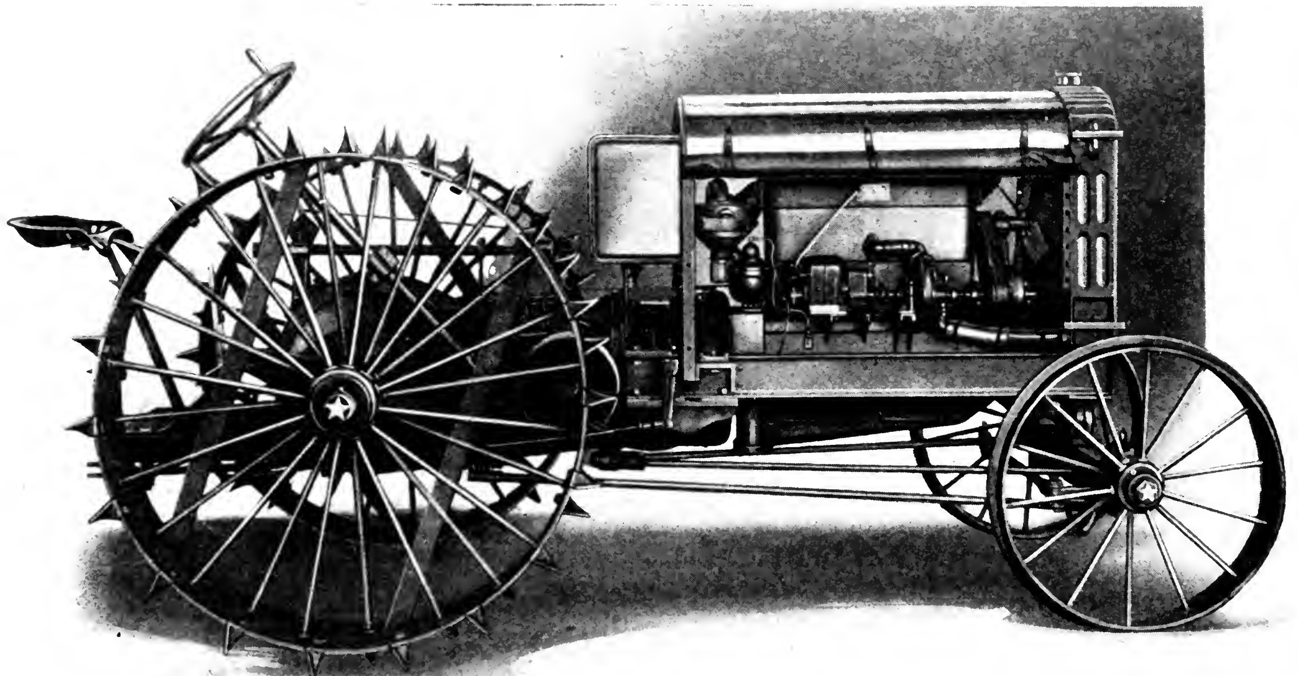
CLASSES OF TRACTORS

Development of Tractor Industry. According to a recent issue of a directory of the industry one hundred and thirty-five different American manufacturers are building over two hundred models of tractors. This statement holds good only for the time at which it is written since both the number of manufacturers in the field and the number of models the old and the new entrants are turning out are constantly on the increase. The use of tractors on large farms dates back almost half a century, but up to less than ten years ago they were all of the steam-driven type. Their first cost as well as the expense of maintenance made them practical only on very large farms where skilled labor is constantly employed. This bit of history is mentioned merely to emphasize the infancy of the industry as it now exists, a factor that makes it exceedingly difficult to classify the product of all the manufacturers in the field and even harder for the prospective purchaser to make his selection of a machine. The business of building gasoline- and oil-driven tractors only dates back to about 1910, and for the first five years of its existence its progress was not very rapid. Consequently it is only during the last four years or so that most of the many manufacturers mentioned have entered the field in response to the great demand for tractors on the part of the farmers, caused by the acute shortage of farm labor and the corresponding increase in wages.

Lack of Standardization. When an industry comes into existence almost overnight, as in the present instance, every manufacturer proceeds along individual lines in the design of his machine with the result that the divergence in types is almost as noteworthy as the number competing. The tractor industry now finds itself in about the same position as did the automobile industry



COMBINATION TRACK AND WHEEL TYPE TRACTOR
Courtesy of Bates Machine and Tractor Company, Joliet, Illinois



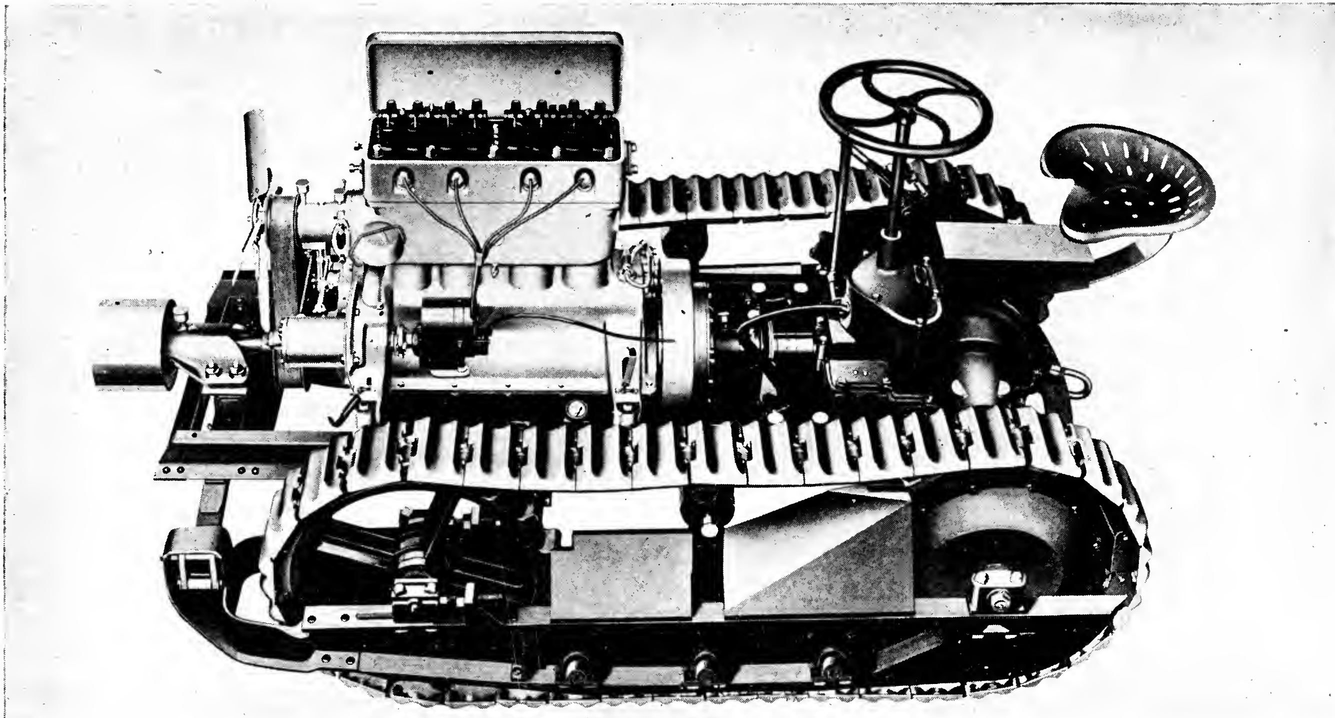
BETHLEHEM FOUR-WHEEL TRACTOR DESIGN, SHOWING SIMILARITY TO AUTOMOBILE PRACTICE fifteen years earlier in that the machines differ widely in design and construction, horsepower ratings bear little relation to the dimensions or speed of the motor, and weights for the same horsepower are often far apart. There is accordingly an entire lack of standardization where any of the essentials are concerned though efforts to remedy this situation by the Society of Automotive Engineers are already well under way. It is scarcely to be expected, however, that the recommendations adopted can come into general use for two or three years at least. Meanwhile, many thousands of tractors are being turned out annually, and the prospective purchaser must make his selection of a machine from those offered, since conditions make it impossible to wait for the perfected tractor to be produced several years from now.

Types of Tractors. Regarded from the mechanical standpoint, the large number of machines now being built may be classified in groups according to some feature of design, such as the type of motor employed, the method of transmitting the power, the manner of securing traction, and the number of wheels, where the latter are used. For example, when classified according to type of motor, there would be a group consisting of those tractors using a slow-speed two-cylinder engine adapted from stationary-engine practice, and a second group of those employing a high-speed four- or six-cylinder motor designed along lines that have been made familiar on the automobile. When classified according to transmission of power, the tractors using a drive through a clutch, which are in the majority, would fall in one group and those employing a friction type of drive in another. On the basis of the method of obtaining traction we would have a group consisting of tractors employing wheels, also in the majority, and a group composed of the so-called *caterpillar*, or tracklaying, type and its numerous modifications. A subdivision of the class using wheels can be made to cover three- and four-wheel types since many machines differ chiefly in this respect. As a matter of fact, subdivisions of practically every one of these classes are possible. For instance, in some three-wheel machines there are two driving wheels, while in others but one is employed. These numerous differences are cited merely to point out the great range of variation that exists.

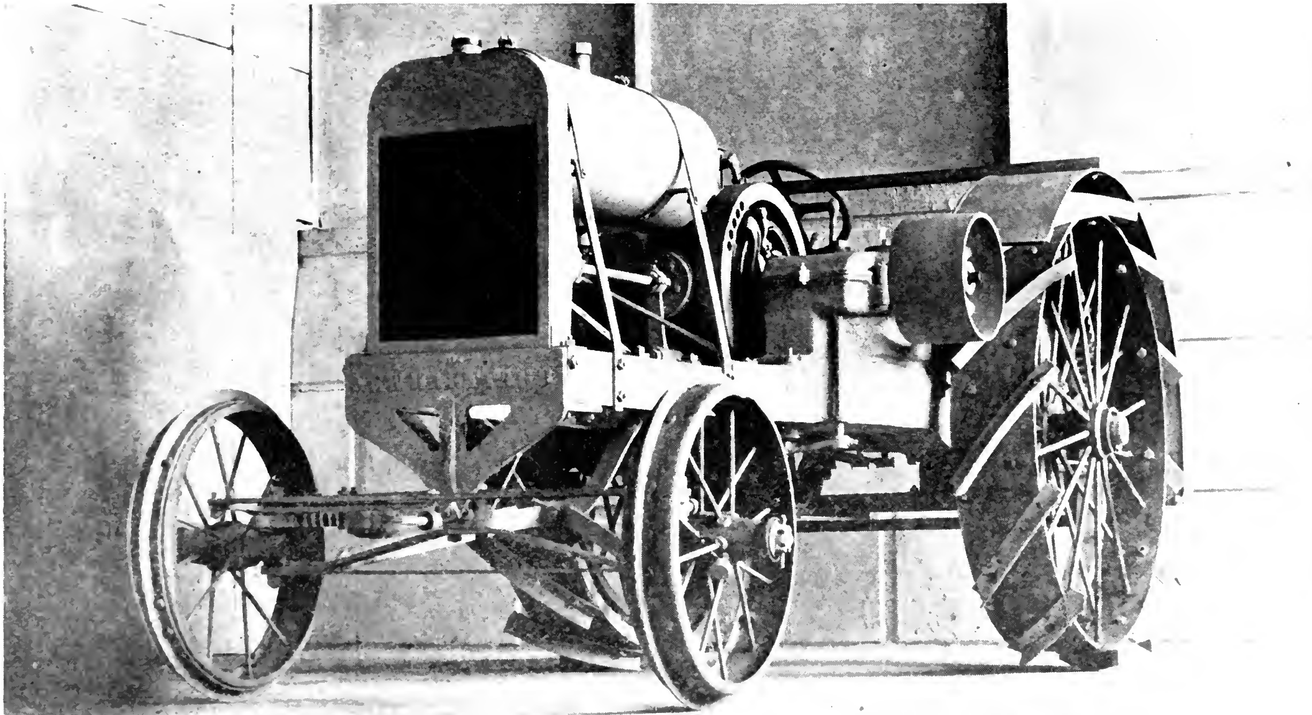
SELECTING TRACTOR

Work Done on Demonstration No Criterion. Involving, as it does, an investment larger than that of almost any other single farm machine, the selection of a tractor should be made the subject of as much study and investigation as the prospective buyer can possibly give. One of the commonest fallacies in tractor buying is to judge the merits of the machine by the class of *work* it does, the term "work" in this connection being applied almost entirely to plowing since the latter represents the heaviest service to which the tractor is put. It should be borne in mind that the tractor is nothing more than the motive power, and neither its reliability nor its value as a farm machine can be judged from the character of the plowing it does on a demonstration. Good or poor plowing depends entirely upon the plow itself and the methods used in its handling, so that a poor tractor properly hitched to the right type of plow and in the hands of a skilled operator will do better work than the best tractor that can be built will turn out when handled improperly. The method of hitching the plows to the tractor governs not only the quality of work turned out but likewise the amount of power consumed in doing it, granting that the right type of plow is being used for the soil under consideration. It would be just as sensible to judge the value of a team of horses by the character of the furrows they turned in plowing.

Financial Return. It has become customary to criticize American farming methods as compared with European solely upon the difference in production per acre, the fact that the application of intensive cultivation by hand labor to very small areas is accountable for the disparity being lost sight of entirely. American agricultural methods produce more per acre for each man employed than is grown anywhere else in the world, and this is due solely to the application of farm machinery to production on a larger scale than has ever been attempted abroad. This has a direct bearing on the purchase of a tractor, since the capital required for the latter must be invested for one of two reasons: either the tractor will enable its owner to cultivate the same number of acres more economically, or it will place him in a position to cultivate a greater number of acres with the same number of "hands."



CLEVELAND TRACK LAYING TYPE TRACTOR
Courtesy of Cleveland Tractor Company, Cleveland. Ohio



HART-PARR FOUR-WHEEL TYPE TRACTOR
Courtesy of Hart-Parr Company Charles City, Iowa

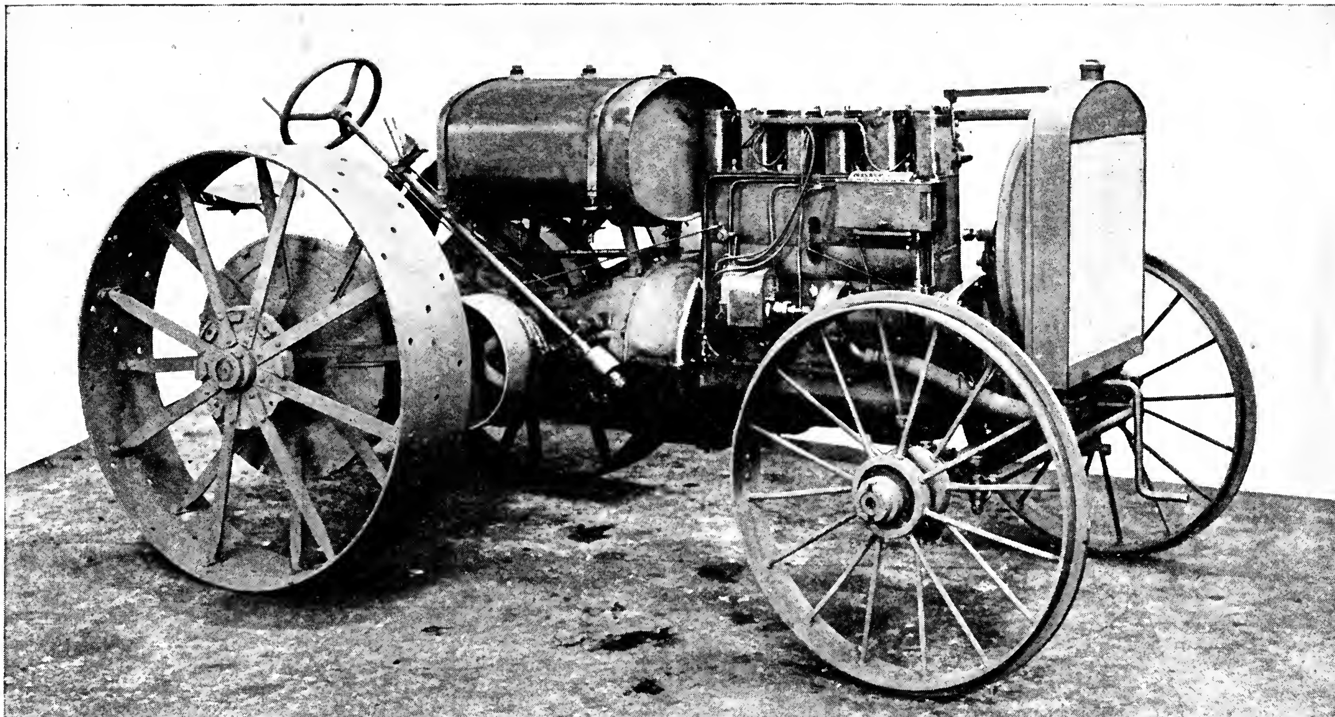
The impression has been more or less general that the first of these two reasons, "It will do the work cheaper," is the chief one for purchasing a tractor. Investigations carried out by the Department of Agriculture, however, have shown that this reason is not valid. Taking into account the capital outlay required, the cost of operation, and the depreciation, and considering the average life of a tractor as seven or eight years, it has been found that plowing cannot be done any more cheaply with a tractor than with horses, but that the use of the tractor does enable the farmer to cultivate a substantially increased number of acres with the same number of men. Out of the large number of farms investigated, a majority of the owners found it necessary to increase their acreage after purchasing a tractor in order to use their machines most efficiently. In other words, the same crops could not be raised any more cheaply with the tractor than without it, but much larger crops could be raised by increasing the acreage under cultivation. This naturally applies more particularly to small farms, by which is meant those of 150 acres or less, taking the country as a whole, since what is considered a small farm in the Middle West would be thought quite the contrary in New England.

Size of Farm. It goes without saying that a tractor will not prove a profitable investment on farms of such a size that all the land available for cultivation may be as easily worked by horses in the time allowed, which classification would cover all farms having 100 acres or less of cultivable land since only a portion of the total acreage is open to cultivation on any farm. Many farmers consider the purchase of a tractor on the assumption that its excess capacity can be taken care of by doing "custom work," or plowing for neighbors. In a number of cases of this kind that were investigated the charge made for this work was not sufficient to leave a profit after deducting the cost of operation and the interest on the investment, so that the farmer would have been better off without undertaking this extra work. As a means of paying for the tractor when the owner's farm is not sufficiently large to absorb its full capacity, this practice did not show a profit that would warrant the investment in a tractor, since, as before stated, the charges were too low to cover the cost of operation, while increasing the rates to a point that would leave a profit would result in a falling off in the demand as the renter could do the same work for considerably less with horses.

Judging from the results of the investigations in question, it will not pay the owner of a 150-acre farm of which not more than 100 are cultivable to invest in a tractor unless he can add from 20 to 50 acres to that under cultivation. This, of course, is a general statement that may be subject to modification in numerous instances where specially favorable conditions make the use of a machine advantageous. But this statement as well as the preceding matter is intended chiefly to emphasize to the prospective purchaser of a tractor the fact that it is unwise to make the investment required in anticipation of doing the same amount of work much more economically than it can be performed with horses.

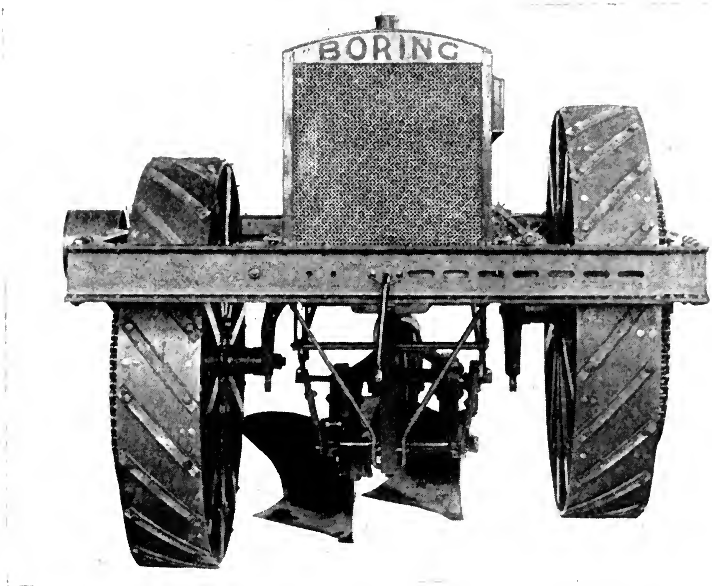
Size of Tractor. First cost is naturally the chief item considered in the purchase of a tractor, and in this connection true economy is to be found in the selection of a machine that is not only of good quality, properly designed and well built for the work it is to do, but that likewise has ample capacity to handle it without overloading. It will prove as expensive in the long run to pay for a good small machine that must be overloaded to do the work required as to buy a cheap machine of any size. In either case the repair bills and the time lost through delays at the height of the season are apt to make the buyer regret his choice, if, in fact, he is not led to condemn tractors altogether. In this connection, however, the skill and experience of the operator are factors which have a very important bearing on the successful use of the machine and largely govern the amount of time that it is out of service due to breakdowns. This is dwelt upon at greater length in later paragraphs.

Tests have demonstrated that at the maximum speed of plowing recommended for all tractors, that is, $2\frac{1}{3}$ to $2\frac{1}{2}$ miles per hour, a two-gang plow will not cover much more ground in a day of ten hours when drawn by a machine than when pulled by horses. In other words, the advantage of the tractor-drawn two-gang plow over horse work is so small that it usually does not pay to buy a machine whose *maximum capacity* is two plows. Whether it be a tractor or any other type of machine, it is not good practice to depend upon running it at its maximum capacity continuously.



ALLIS-CHALMERS FOUR-WHEEL TYPE TRACTOR

Courtesy of Allis-Chalmers Manufacturing Company, Milwaukee, Wisconsin



BORING THREE-WHEEL TRACTOR WITH FORWARD DRIVE AND UNDERSLUNG PLOWS

HEAVY THREE-WHEEL TYPE OF TRACTOR

The machine will not do as good work and it will be much more subject to frequent breakdown than where it has power in reserve to meet emergencies that will seriously overload a machine that is already working at its full output.

The number of plows that any given machine is capable of pulling depends upon so many other factors besides its power rating that it is often misleading to term a tractor a two-, three-, or four-plow machine, as the case may be. The depth of the furrow, the character and condition of the soil, and the method of hitching all influence this to such an extent that a machine capable of pulling three plows under favorable conditions might make a very poor job with two where the soil conditions were not so good or the plows were not properly hitched.

Margin of Safety Needed. It should be borne in mind that any machine will give the most satisfactory service and have the longest useful life when operated continuously at not more than 75 per cent of its rated capacity. Expense incident to delays as well as the cost of repairs will accordingly be minimized when a machine larger than is actually required is selected and is operated at less than its full capacity. Experienced tractor operators have proved this in many instances by investing in four-plow machines and pulling but three plows. It does not pay to load a machine to its limit since it cannot carry such a load continuously and give satisfactory service, so that in selecting a tractor the chief points to bear in mind are not to buy a lightly or cheaply built machine; and not to select a machine so small that it can only do the work required by working continuously at full load.

Power for Belt Work. While plowing constitutes more than one-half the work for which the tractor is required, it would pay few farmers to invest in a machine for that purpose alone. All tractors are designed to be used as stationary power plants as well, and one-third or more of the service demanded of them consists of driving other machines, such as threshers or ensilage cutters, or, as it is usually termed, belt work. Unless a machine has ample power for this, it will not be found satisfactory since there is usually a tendency under such conditions to load it to the stalling point and when a cutter has been "choked down," much valuable time is lost in getting it under way again.

A tractor that is not powerful enough to do all the work required of it is not likely to prove a satisfactory investment, though an error may also be made by going to the other extreme and selecting a machine of such a size that it is too expensive to operate on many of the jobs that a tractor of the proper size would perform economically.

Factors Governing Capacity. Why a machine that will pull three plows very satisfactorily under some conditions will with difficulty do good work with only two bottoms in other locations will be readily apparent from a consideration of the difference in drawbar pull required for plowing different soils. The average resistance of soils is given approximately in Table I.

While the figures in Table I have been drawn from experience, the draft of a tractor plow can only be approximated, since the condition of the plow itself and the method of hitching are of the greatest importance. The figures given are based upon the supposition that the plow is clean, sharp, and properly hitched so as to cut easily. When a plow is dull or does not scour well, the power required to draw it will be substantially increased. This is equally true when a plow is not leveled or is out of line in any way.

The draft likewise increases in proportion to the grade and the figures given are based upon plowing on level ground. For each 1 per cent rise in grade, that is, for each foot of vertical lift in each 100 feet of horizontal travel, 1 per cent of the combined weight of the tractor and the plows must be added to the draft. For example, assume a tractor weighing 5000 pounds and hauling four plows each weighing 250 pounds, making the total 6000 pounds: the maximum draft of the four plows in corn stubble, plowing 6 inches deep, would be 3200 pounds, to which it would be necessary to add 60 pounds for each 1 per cent increase in grade. Even on rolling prairie land, which is ordinarily thought of as being level, the dips and hollows often represent 10 per cent grades for short distances, and in this case they would necessitate adding 600 pounds to the draft required.

When planning to buy a tractor to do certain work, keep the figures given in the table in mind; consider the character of the soil, the grades, the depth of the furrow, and the horsepower rating of the machine desired—and it is always well to discount that

TABLE I

Average Resistance of Soils

Soil	Pounds per Square Inch	6 Inches Deep	8 Inches Deep
Sandy loam	4–6	600– 800	750– 950
Corn stubble	6	700– 800	900–1000
Wheat stubble	8	800– 900	1000–1100
Light clay	12	800–1200	1000–1400
Medium clay	14	900–1400	1200–1500
Heavy clay in good plowing condition	16	1600–2000	1800–2100
Sod or heavy clay, medium moisture	18	2500–3000	2700–3100
Gumbo—dry, hard	36	2600–3200	2800–3300

horsepower rating somewhat. It will also pay to keep these figures in mind when the over-enthusiastic salesman begins to make claims.

ANALYSIS OF TRACTOR MECHANISMS

TRACTOR MOTORS

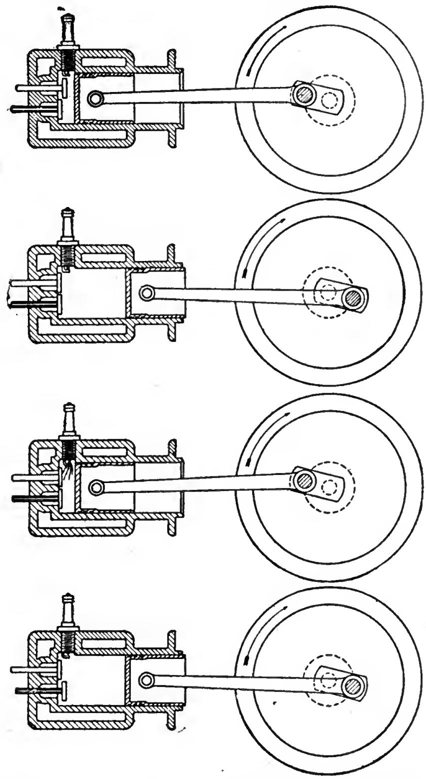
Steam Tractors vs. Internal-Combustion Tractors. Although tractors have been used in this country for almost half a century, they were all steam driven until less than ten years ago, so that the present widespread and rapidly increasing adoption of the tractor is due to the remarkable development of the internal-combustion motor, which, in turn, is largely the result of the great strides the automobile industry has made since 1900. The present work is accordingly confined to tractors with such motors since, although steam tractors will continue to be used on some of the very large farms on which they have been employed so long, they are not available to the average purchaser of a tractor and, at best, it will be only a matter of a comparatively few years before they will have been displaced by the internal-combustion type in most parts of the country.

Superiority of Four-Cycle Motor. The experience of the automobile manufacturer as well as that of the stationary oil-engine builder has demonstrated that of the several types of internal-combustion motors that may be used that based upon the so-called four-cycle method of operation combines the fewest drawbacks with the greatest number of advantages and is accordingly the most practical for general use. The two-cycle motor has never proved successful owing to its inefficiency where fuel consumption is concerned, while other types involve the use of excessive weights for the power generated.

Motor Parts. Assuming the motor to have but one cylinder, a four-cycle motor consists of a cylinder, inlet valve and exhaust valve, piston, piston rings, piston pin, connecting rod, crankshaft and bearings, flywheel, camshaft, valve springs and crankcase. Its accessories are a carburetor (or fuel-mixing device), magneto or other method of generating electric current, spark plug for igniting the fuel, lubricating system, cooling system, and the necessary piping for supplying lubricating oil and for conducting the cooling water between the cylinder jackets and the radiator, the fuel mixture from the carburetor to the combustion chamber of the cylinder, and the exhaust gases away from the latter after they have been burned. A circulating pump may or may not form a part of the cooling system according to the method of circulation employed. These auxiliaries, plus a fan to assist in the cooling of the water or oil in the radiator of the cooling system, complete the motor and the addition of any number of cylinders only involves the duplication of those parts directly attached to or working in the cylinder, such as valves, pistons, and connecting rods with, of course, the provision of an additional crankthrow on the crankshaft for each additional cylinder.

Four-Cycle Principle. *Intake Stroke.* The operation of the motor is based upon a cycle, or recurrence of operations, consisting of four distinct parts. Starting with the piston at the upper dead center, the first of these operations is the *intake,* or *suction, stroke.* The inlet valve has been opened through the revolution of the camshaft bringing the cam in contact with the valve tappet and raising the valve off its seat, Fig. 1. The piston is a gas-tight fit in the cylinder, being sealed by the piston rings, which press out against the cylinder walls, and by the presence of a film of lubricating oil between the piston and the cylinder. The downward travel of the piston accordingly creates a partial vacuum (negative pressure, or less than atmospheric) in the cylinder, and the atmospheric pressure (14.7 pounds at sea level), acting upon the liquid fuel in the carburetor, forces the liquid up through the spray nozzle of the carburetor and also draws a predetermined volume of air up through this spray, thus forming a fuel mixture which is forced into the cylinder. The action of the piston on this first part of the cycle is exactly the same as that of a pump in drawing water out of a well. The water is forced up into the pump, following the plunger owing to the decreased pressure in the pump barrel caused by the stroke of the plunger and to the outside pressure of the air on the surface of the water.

Compression Stroke. When the piston reaches the limit of its travel, or lower dead center, the inlet valve closes and the piston in rising then compresses the fuel mixture against the head of the cylinder, the valves also being gas tight. This is the second part of the cycle, or the *compression stroke,* and gives to the fuel mixture what is known as the *initial compression.* This stroke has an important bearing on the power output of the motor since it renders the combustion of the fuel more rapid and complete and also increases the pressure developed when the charge is fired. The initial compression used in the average gasoline motor ranges from 50 to 80 pounds per square inch, and the higher it is, the more power the motor develops, other factors such as cylinder dimensions and number of cylinders being the same. In the case of gasoline, however, this initial pressure is limited to 90 pounds per square inch since the heat generated by compression above that point would cause the ignition of the mixture. In kerosene, alcohol, or low-grade fuel engines, it may



Figs. 1–4. Strokes of Four-Part Cycle: 1. Intake; 2. Compression; 3. Power; 4. Exhaust

be much higher, but in this case a compression release must be fitted to the engine in order that it may be turned over by hand for starting.

Power Stroke. The third part of the cycle begins with the firing of the charge by the passage of a spark at the plug, and the piston then starts downward on the *power stroke.* Just before the piston reaches the lower dead center on this stroke, the exhaust valve is lifted by the camshaft and the remaining pressure in the cylinder, which cannot be utilized for driving the piston, is allowed to escape. A very large part of the heat value of the fuel is wasted in this manner through the exhaust, but the drop from the very high pressure at the moment of ignition is so rapid that no advantage is to be gained from lengthening the stroke beyond a certain point in an attempt to utilize a greater percentage of the pressure.

Exhaust Stroke. The following upward movement of the piston is termed the *exhaust stroke* and serves to clear the cylinder of the remaining burned gases in preparation for the succeeding suction stroke, which recommences the cycle. Although it is one of the three idle strokes of the four-cycle method of operation, the exhaust stroke is quite as important as those which precede it since, unless the cylinder is swept clear of the burned gases of the previous explosion as completely as possible, a volume of dead gas is left to occupy space which should be filled with fresh fuel and the amount of power developed on succeeding strokes is reduced in proportion. This is one of the chief defects of the two-cycle method of operation, in which compression immediately follows the power stroke, there being no exhaust stroke or suction stroke. As a result, a considerable percentage of the cylinder space is always filled with burned gases and the time available for the power stroke is so short that part of the fresh gas escapes unburned. In the four-cycle method, upon the completion of the exhaust stroke, the exhaust valve closes and the inlet valve opens, beginning a new cycle. The relative positions of the piston and the valves during the compression, power, and exhaust strokes are shown in Figs. 2, 3, and 4.

Pressure and Temperature. While even the most skilled operator of a traction engine need not be conversant with the intricacies of its design nor with the scientific aspect of its operation, a knowledge of what goes on inside the cylinder will be found an aid to a clearer understanding of the engine itself and the principles on which it works. The internal-combustion motor is a heat engine pure and simple, and each part of its cycle is attended by an increase or decrease in pressure and temperature. One is a function of the other, a given degree of pressure resulting in an equivalent rise in temperature, and this fact is taken advantage of in determining the pressure and the temperature in the cylinder by means of an indicator, the use of which need not be described here since it is only used by designers in the shop.

Range of Pressure and Temperature. Some idea of the great range of pressure and temperature inside the cylinder during but two parts of the cycle, the compression and power strokes, may be gained by assuming that the motor is operating on a summer day with the surrounding temperature at 70° F. The temperature of the entering mixture will then be raised to approximately 100° F. or more through the use of hot air in forming the fuel mixture by taking the air supply from a "stove" attached to the exhaust manifold or by using exhaust gases direct from the engine and also through having a water jacket surrounding the intake manifold. Without these heating devices the mixture would be considerably cooler than the atmosphere since the conversion of the liquid fuel into a vapor is attended by the abstraction of heat from the air. Assuming that the engine has been running, the end of the previous exhaust stroke leaves the interior of the cylinder at a temperature of approximately 260° F. and the incoming mixture is further heated by contact with the cylinder walls and the piston head. At the moment of intake the pressure in the cylinder is slightly less than atmospheric. During the compression stroke this pressure is raised to 50–85 pounds, depending upon the amount of initial compression given, and the temperature rises to a point between 800° and 900° F. Upon the gases being ignited, their tremendous expansion in the confined space raises the pressure to 225–250 pounds per square inch with an increase in temperature ranging from 2500° to 4000° F., depending upon the character of the fuel used. This pressure decreases very rapidly as the piston moves outward on the power stroke, the so-called terminal pressure, that is, the pressure at the end of the stroke when the exhaust valve opens, reaching 40 to 50 pounds with a temperature of approximately 1000° F. The exhaust stroke lowers the pressure to approximately that of the surrounding atmosphere with a decrease in temperature that is governed to some extent by the length of time that the engine has been running.

Effect of High Temperature. The extreme range of temperatures inside the cylinder should impress upon the operator of a tractor engine the necessity for prompt attention if anything goes wrong. For example, in the presence of such great heat as is developed by the explosion it will be evident that failure of the lubrication or of the cooling system can cause serious damage in a very brief period. Pistons will score and scratch the cylinder walls, valves will warp, bearings will be burned out, and finally the pistons will bind hard and fast, all in the short space of a few minutes. In fact, five minutes will suffice to cause damage, the repairing of which will take a week and will represent a bill of three figures.

Grouping of Motor Parts. *Mechanical Group.* The parts necessary to a four-cycle motor, whether of one or several cylinders, have already been outlined. Upon studying these, it will be apparent that they may be divided into groups and that each group has as its object the carrying out of a certain function in the operation of the motor. The foundation of all the groups is naturally the chief mechanical group consisting of the cylinders, valves, pistons, connecting rods, crankshaft, camshaft, crankcase, and flywheel. The functions of this group are to provide a container in which the fuel may be compressed and ignited and moving parts against which the force of the explosion may act—first, to produce linear motion in the stroke of the piston and, second, to convert that motion into rotary motion at the crankshaft.

Auxiliary Groups. All the other groups really consist of auxiliaries, such as the carburetor, heating devices, and intake and exhaust manifolds, designed to mix the fuel with the proper proportion of air, warm it, conduct it to the cylinders, and lead it away from the latter after it has been burned. These parts constitute the second group, or fuel-supply system. The third group consists of the apparatus for igniting the fuel in the cylinders and is represented by the magneto (or other method of generating electric current), the spark plugs, the connecting cables, and any distributing or timing devices necessary when a battery instead of a magneto is employed. The fourth group is represented by the lubricating system, the function of which is to supply oil to all the moving parts; while the fifth group is the cooling system, consisting of the water jackets of the cylinders, the pump, the radiator, and the piping connections. On the traction engine there are further auxiliaries not necessary on an automobile engine, namely: the governor and the air cleaner. A large part of the work of the tractor consists in serving as a stationary power plant, and while doing belt work it is necessary that a steady engine speed be maintained under a wide range of load. Unless the engine were automatically governed under such conditions, it would stall when the load was increased and race when the load was relieved; and racing would be dangerous to the engine itself owing to the great stresses set up by the high speed. While not constituting a group in itself, the governor may be included in a further group consisting of the control system, in which the throttle and the spark levers represent the hand control, and the governor the automatic control of the engine.

Interrelation of Groups. It will be apparent upon a little study of these different groups, or systems, that all are equally essential to the operation of the motor and that precedence cannot be accorded to any one as compared with the others since the failure of any one would prevent the functioning of the rest. An understanding of the relations that these groups bear to one another will go a long way toward making clear the principles on which the engine operates and also the manner in which the different systems must work together in order that it may run satisfactorily. The interdependent functions of the groups are considered at some length in the following paragraphs.

Mechanical Group. Unless the pistons are free to move in the cylinders and the crankshaft and the connecting rods on their bearings, no movement can result. This free movement of the pistons and other working parts is entirely dependent upon the lubricating system maintaining a constant supply of oil on all contacting surfaces. But unless the cooling system continues to function properly, the fact that the lubricating system is working will not keep the motor running since the oil will be burned up on coming in contact with the cylinder walls owing to the high temperature inside the cylinder.

Fuel-Supply System. Air must be drawn through the carburetor and mixed with the spray of liquid fuel issuing from the carburetor nozzle, but this cannot be done unless the inlet valve of the cylinder opens just before or when the piston reaches upper dead center on the exhaust stroke, as otherwise there will be no difference in pressure between the inside and the outside of the carburetor and no suction will result. Nor will the admission of a charge to the cylinder be effective unless the inlet valve closes when the piston reaches or just after it passes lower dead center on the upward stroke as otherwise, instead of being compressed ready for firing, the fuel mixture would again be forced out of the cylinder.

Ignition System. Movement will naturally cease after the admission of a charge unless the electric spark takes place at the proper moment to fire that charge in order to produce the power, or third, stroke of the cycle. The entire failure of the spark will prevent further operation; its occurrence too early will stop the engine by driving the piston down in the reverse direction before it has completed its stroke on compression; and its occurrence too late will cause a substantial proportion of the power to be wasted although the motor will continue to operate. After the completion of the power stroke the mechanical system again enters since, unless the exhaust valve opens near the end of this stroke, the burned gases will remain in the cylinder and when the inlet valve opens, they will be blown back through the carburetor owing to the terminal pressure of 40 to 50 pounds per square inch remaining in the cylinder at the end of the power stroke just before the exhaust valve opens. Owing to the high temperature of these gases they may ignite the liquid fuel in the carburetor if blown back through it. This is known as a back fire, and while failure of the exhaust valve to operate is not as common a cause as either too lean or too rich a mixture, it is evident that back fire must invariably follow unless the exhaust valve does open.

Summary of Operation. Continued movement of the mechanical parts of the motor is dependent upon the working of the lubricating system. Lubrication fails unless the cooling system does its part to keep the temperature down to a point where the movement of the parts in contact is possible, as otherwise the oil is burned. Unless the inlet valve opens at the right time, the carburetor cannot supply a fuel mixture to the cylinder, while a failure of the electric spark to ignite this mixture at the proper moment renders the admission of the fuel supply useless. Failure of the exhaust valve to permit the escape of the burned gases from the cylinder stops further operation by preventing the admission of a fresh charge.

Value of Skilled Operator. It is necessary to take up each of these systems in detail and learn the principles upon which its operation is based in order to understand more clearly the manner in which they must co-operate to produce satisfactory running of the engine and also in order to recognize the symptoms at once when anything goes wrong and to know the remedy to apply to keep the engine going and avoid laying up the machine at the time when it is most needed. In the numerous investigations undertaken by the Department of Agriculture, some of which have been referred to, it was brought out in a most striking manner that in the majority of cases where repair bills were lowest and the most satisfactory service was obtained from the tractor, it was due in very large measure to the fact that a skilled operator was on the job.

It has not been a very uncommon thing in the past for manufacturers to advertise that their machines can be driven by a child. So can a big mogul freight locomotive be run by any boy with strength enough to pull the throttle, but no railroad company would entrust valuable machinery to the care of a boy even were the danger of collision entirely absent. A tractor cannot be run satisfactorily by a boy or a girl, nor can it be so run by a man unless he takes the trouble to acquaint himself with its principles of operation instead of trusting to luck and experience to acquire the necessary information haphazard. In other words, he must qualify as a skilled operative by familiarizing himself thoroughly with the sequence of operations responsible for the working of the motor and the principles upon which those operations are based.

VALVES AND VALVE TIMING

Placing of Valves. By referring to the description of the four-cycle method of operation, it will be seen that it is necessary to draw a fuel charge into the cylinder on one stroke, compress it on the second stroke, fire it on the third, and exhaust the burned gases on the fourth to complete the cycle. There must accordingly be valves to control the entrance and escape of the gases, and these valves must open and close at certain intervals with relation to the rest of the cycle. The placing of these valves depends upon the type of motor, of which there are three in general use, namely: the L-head motor, in which the valves are all on one side; the T-head motor, in which the inlet valves are placed on one side and the exhaust on the opposite side; and the valve-in-head type, in which the valves are located directly in the cylinder heads.

Valves in L-Head Motor. The L-head motor forming the power plant of the Fordson tractor is shown in Fig. 5 in phantom to bring out the details of the valves and valve-operating gear. In a motor of this type all the valves are placed on the same side of the motor so that in the line of eight valves an inlet and an exhaust alternate. The operation of the valves may be traced through their entire range of movement in this illustration by noting their positions in the different cylinders. Cylinder 2, for example, is on the first stroke of the cycle, the intake stroke. The inlet valve is accordingly open and the exhaust valve closed. Cylinder 1 is shown on the compression stroke, during which both valves remain closed. This is also true of the explosion stroke, as indicated by cylinder 3. On the fourth stroke of the cycle the exhaust valve opens to discharge the burned gases into the air, as shown by cylinder 4. (The cylinder numbers mentioned here refer to the cylinders counting from the forward end and not to the numerals shown on the illustration.)

Valve Details. The valves used on automobile and tractor motors are variously referred to as *mushroom* and *poppet* valves, the former name referring to their shape and the latter to their method of operation. The valve proper consists of a head and a stem, and as the valve is subjected to high temperatures, it is either made of cast iron welded to a steel stem or is a piece of nickel steel or other heat-resisting metal. Unless some expedient of this nature is employed, the valve heads are apt to warp under the terrific heat, this being particularly true of the exhaust valves. The stem passes down through a guide drilled and reamed in the cylinder casting itself, and below the point where it leaves this guide the stem is surrounded by a heavy helical spring. This spring is held against the guide at its upper end and against a washer at its lower end. A key passing through a slot in the valve stem itself holds this washer in place. The valve is accordingly held down on its seat by a strong spring, and it is the pull of this spring that returns it to its seat with a snap, or *pop*, after it has been opened. The inch or so of the valve stem extending below the spring washer contacts with the valve push rod when the latter is lifting the valve off its seat, but in order that the valve may come down squarely on its seat when closing, the valve stem and push rod should not be in contact normally. This distance, or clearance, that must exist between the valve stem and the valve push rod is not indicated in the illustration since, in this case, the valve push rod also acts to a certain extent as a lower guide, the valve stem entering its upper end for a short distance.

Camshaft and Timing Gear. At its lower end the valve push rod rides on a cam, and the position of this cam with relation to the camshaft determines the point at which the valve will open and close. There is, of course, a cam for each valve, and as their positions must remain absolutely fixed, they are usually drop-forged in one piece with the camshaft itself. While Fig. 5 shows all the details of the valves and valve gear of an L-head motor, it must be borne in mind that every manufacturer has his own designs and standards. For example, in most motors a cam follower is introduced between the valve push rod and the cam in order to minimize the friction. This usually takes the form of a fork which is in a guide of its own and has at its lower end a roller which rides on the face of the cam.

The inner end of the camshaft carries a gear known as the timing gear in that its position with relation to the smaller gear on the crankshaft, from which it is driven, determines the time at which all the valves open and close. In a T-head motor there are two camshafts and two timing gears, and there are also usually additional gears for driving the circulating pump and the magneto,

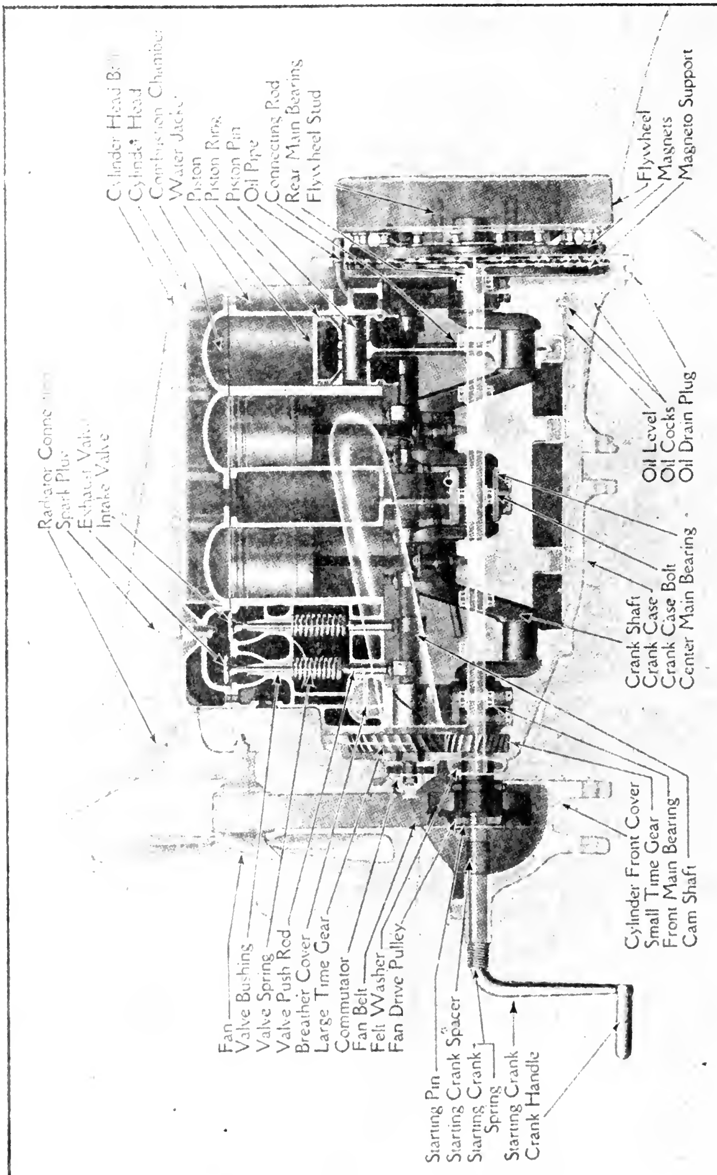


Fig. 5. Power Plant of Fordson Tractor
Courtesy of Henry Ford and Son, Inc., Dearborn, Michigan

which make the timing-gear end of the average motor look very complicated to the layman. In the motor shown in Fig. 5 there is but a single timing gear, and it also carries the ignition timing cam which determines the occurrence of the ignition spark in the different cylinders. This is marked *Comm. Roller* on the illustration. Just below the timing cam will also be noted zero marks on the time gears; these are check marks to enable the gears to be reassembled in the proper relation after a motor has been taken down for repairs. The gear on the crankshaft is but half the size of the camshaft gear since each cylinder has but one power stroke for every two revolutions. There are two power strokes per revolution in a four-cylinder motor, and the camshaft must accordingly be driven at half the speed of the crankshaft in such a motor.

Timing Valves. In a motor making 1000 r.p.m. (revolutions per minute), 2000 strokes or reciprocating movements of the pistons must take place in sixty seconds, so that the entire time consumed in making each stroke at this speed is three-hundredths second. A full realization of what an exceedingly short period this is in which to perform any mechanical operation should make it unnecessary to emphasize either the need for accurately timed valves to ensure an efficient running motor or the necessity of closely watching all parts of the valve gear to take up any lost motion caused by wear, since very little slack is required to cut down the effective opening of the valve. For example, assume the maximum lift of the valve from its seat to be $\frac{1}{4}$ inch plus the clearance of $\frac{1}{32}$ inch provided between the valve stem and the tappet to permit the valve to seat positively. Then if wear or lack of adjustment be permitted to increase this clearance to $\frac{1}{16}$ inch, the valve can only lift $\frac{7}{32}$ inch, so that the effective opening is reduced $12\frac{1}{2}$ per cent for every thirty-second of an inch lost motion between the valve tappet and the valve stem.

It is nothing unusual to see automobiles brought to the repair shop with so much clearance between their valve tappets and stems that the valves barely leave their seats when the cams come around. A tractor motor would not be of much service in this condition since it would not develop enough power to carry its load. If it were not for the fact that usually in driving an automobile only a very small fraction of its power is used it would be impossible to keep a motor running after it gets in such a condition. A knowledge of the principles of automobile operation will be an aid to the tractor operator but he will do well not to attempt to apply them literally to tractor handling since they fall far short of what is needed to keep a tractor running.

In designing a motor, both the contour, or outline, to be given the cams and their position on the camshaft are fixed, and the finished camshaft is a single piece of steel the cam faces of which have been ground to a high degree of precision. In timing a motor, it is accordingly only necessary to time the valves of one cylinder as the others must of necessity also be correct. This process is made very simple on the Fordson motor, since it is accomplished merely by the correct meshing of the timing gears. When the two zero marks on the driving and the driven gear coincide the camshaft is in the proper position to open the valves of all the cylinders in the correct order. This, of course, has nothing to do with the proper adjustment of the tappet clearance, which must be looked after at each valve.

Checking Valve Timing. A closer check is usually considered necessary than is afforded by the meshing of the timing gears just mentioned, and to provide this, the necessary data is marked on the flywheel of the motor while a reference point is also marked on the crankcase, Fig. 6. In the illustration, the line *U.D.C. 1 and 4* shown on the rim of the flywheel opposite the reference mrka on the crankcase indicates that that point represents upper dead center for the pistons of cylinders 1 and 4. The line *E.O. 2 and 3* indicates that when that line on the rim coincides with the reference mark, the exhaust valves of cylinders 2 and 3 open. Similarly, *E.C. 1 and 4* and *I.O. 1 and 4* represent, respectively, the exhaust closing and inlet opening points of cylinders 1 and 4, while *I.C. 2 and 3* gives the inlet closing point for cylinders 2 and 3. The rest of the points for the various cylinders are not shown.

Lead and Lag of Valve Movement. While the strong spring brings the valve down on its seat with a snap the moment the valve tappet rides off the cam, the valve cannot be opened in this manner. It must be lifted against the force of the spring, and as the time available for both its lifting and its closing again is so very short, it must begin to open somewhat before the moment when it is to be fully open. This *lead* is given to the inlet valves to a degree dependent upon the speed of the motor in order that a full charge of fuel mixture may be drawn into the cylinder on the intake stroke.

It is possible to start the opening of the inlet valve on the suction stroke before the exhaust valve has closed because of the fact that a gas, as well as a solid body, has *inertia*. Inertia is that property of all matter that tends to resist a change of state, whether that state be rest or movement. If a man runs full speed down a hallway and a door at the other end is suddenly closed, he crashes into the door because he cannot overcome his own inertia in time to stop. On the other hand, if, when standing quietly at the roadside, he attempts to board an automobile passing at twenty miles an hour simply by grasping the part nearest to him, the consequences are apt to be extremely unpleasant if his hold is good. If it is not good, he stays pretty much in the same place although his arm gets a severe wrench. In the same manner a gas possesses inertia, varying with its weight and velocity, or lack of it.

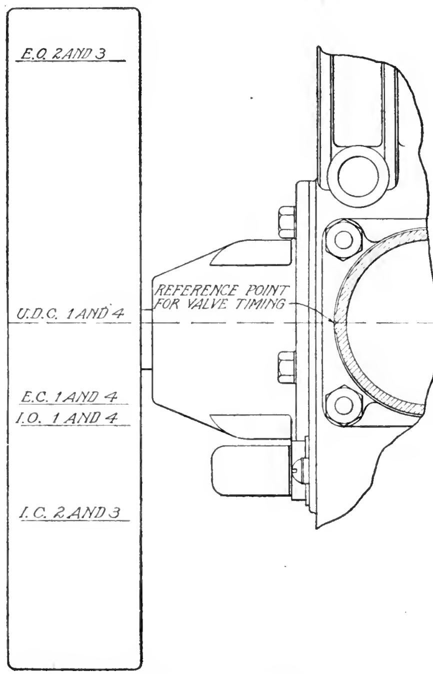


Fig. 6. Reference Marks for Valve Timing

When the gas is flowing out through the exhaust valve at a high rate of speed, since it has had almost the entire exhaust stroke in which to accelerate. the opening of the intake valve has no effect on its movement. Nor is there any risk of the incoming fresh charge passing through the cylinder and out the exhaust valve because its inertia makes it as hard to start as the high-speed exhaust is to stop and it cannot attain any speed until the piston is well down on the suction stroke. Then it in turn is hard to stop, so that it is possible to hold the inlet valve open after the piston has actually passed the lower dead center and started upward on the compression stroke. This delay is termed the *lag* given the valve closing, and in the case of the inlet valve it insures filling the cylinder with the fresh charge to the maximum extent as the fresh gas is rushing in at its highest speed just at that moment; and every fraction of a second, or of an inch on the stroke, that the valve can be kept open, the more efficient the motor will be.

Need of Closely Checking Valves. While not of the high-speed type as compared with automobile motors, which run up to 2000 r.p.m. or over, many tractor motors are high-speed types for the service they are designed to render since the tractor runs at a very considerable fraction of its load most of the time it is working while the automobile motor seldom carries over 20 per cent of its full load and then only for very brief periods. Many tractor motors are designed to deliver their rated output at 1000 r.p.m., and that is high speed for a motor which must carry 80 per cent of its maximum load for eight to ten hours a day. Wear of small parts such as valve tappets is apt to be rapid in such service, so that to keep such a motor up to a good degree of efficiency, the valve timing must be carefully checked and valve tappet clearances adjusted to $\frac{1}{32}$ inch at fairly frequent intervals. This is about the thickness of a visiting card. Some manufacturers supply a small metal gage for the purpose of testing this clearance, and it should be used often since under the continued vibration and jolting of a tractor adjustments are apt to shake loose.

Sixteen-Valve Engine. Particular attention has been called to the important influence that the rapid filling and emptying of the cylinders has on the efficiency of the motor, and mention has been made of the different expedients resorted to in order to increase this. The limit of efficiency in this respect is reached when single valves are used for the intake and the exhaust by placing both these valves directly in the cylinder head, so that neither the incoming nor the escaping gases have to go round any bends in entering or leaving the cylinder, while the combustion chamber of the latter is entirely free of pockets or dead spaces. To increase the efficiency still further, multiple valves are used, with the result that a larger effective area of opening is obtainable with a given cylinder head than could be secured by increasing the diameter of the single valves to the maximum permitted by that of the head. In other words, four valves are placed in the head with their centers located at the corners of a square, so that the greatest possible amount of space available in the circle represented by the combustion chamber is utilized for valve openings. Two of these valves are used for the intake, while the other two are employed for the exhaust.

Twin City Multiple-Valve Engine. In Fig. 7, which illustrates the Twin City tractor engine, the application of multiple valves to a valve-in-head type of motor is clearly shown. These valves have a clear diameter of 1½ inches and are operated by overhead rocker arms, each arm carrying two valves. The part sectional view at the left shows the intake side of the motor, while the end sectional view at the right illustrates the complete valve operating gear of both the intake and the exhaust valves.

Another unusual feature of this engine is the use of cylinder liners. The upper half of the crankcase and the cylinders themselves are cast in a single block. The liner is made with a flange which rests on a ground seat in the cylinder, so that when the liner is inserted, the upper face of the flange is flush with the upper surface of the cylinder casting and the cylinder head, when bolted on, holds it in place. This construction is clearly shown in the right-hand cylinder in the side elevation. These liners form the entire cylinder wall, so that the pistons do not come in contact with the cylinder castings at any point. The dimensions of this motor are 4¼ by 6 inches, and it is governed to run at 1000 r.p.m., at which speed it is rated at 20 hp.

FUEL SUPPLY SYSTEM

Operating Principle of Internal-Combustion Motor. The principle upon which the internal-combustion motor works is that of utilizing the great expansion of a volume of hydrocarbon vapor ignited when in intimate contact with a sufficient volume of oxygen to permit of extremely rapid combustion. In other words, an "explosion of gas," so to speak, is the driving force back of the piston. The various phases through which the gas passes in being drawn into the motor, compressed, fired, expanded, and exhausted have been referred to briefly in connection with the description of the four-cycle method of operation. Mention has also been made of the fact that the carburetor, while not strictly speaking a part of the motor proper, is a very important accessory. The purpose of the present section is to make clear how the fuel mixture of gas and air is obtained from the different liquid fuels employed.

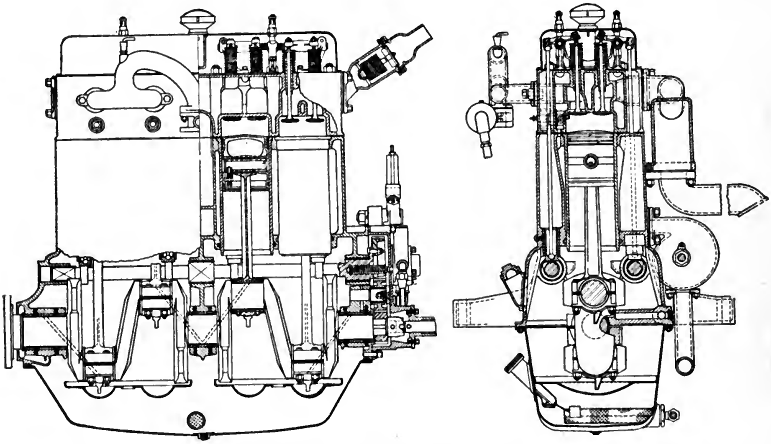


Fig. 7. Side and End Sectional Views of Twin City Sixteen-Valve Motor
Courtesy of Minneapolis Steel and Machinery Company, Minneapolis, Minnesota

Fuels Available. While there are a number of liquid hydrocarbons that may be employed as fuel in the motor, owing to their cost but very few of them are available for tractor operation. It is scarcely necessary to discuss what may be done with benzol, or alcohol, or any one of a number of other fuels since their present cost is prohibitive. The choice of a fuel is limited to petroleum and its derivatives, gasoline, kerosene, and distillate. Owing to the great demand for gasoline for other purposes its cost has reached a point where the difference between it and the cost of kerosene is more than sufficient to offset the disadvantages of the latter. Some farmers prefer to pay the higher price for gasoline because of the greater ease of operating the motor with this fuel, but they are greatly in the minority, and their plowing operations are generally on a comparatively small scale.

Petroleum as it comes from the ground is a heavy viscous liquid combining in one fluid practically the entire range of hydrocarbons (combinations of the gas hydrogen and carbon) all the way from that compound so light that it is evaporated by exposure to the atmosphere before the oil ever reaches the refinery to the heavy residue that is left after all the refining operations have been completed and that is suitable only for making arc-light carbons or for similar purposes. So far as their value as fuel for the internal-combustion motor is concerned, the only difference between any two of the hydrocarbons contained in petroleum lies in their evaporation points, that is, the temperatures at which the different liquids can be converted into vapor. The exceedingly volatile fraction that passes off into the air as an invisible vapor practically as soon as the oil is exposed to the atmosphere would make an ideal fuel; it would hardly be necessary to have a carburetor in its present form in order to handle such a fuel. But this highly volatile fraction forms such a very small percentage of the oil that running a motor on it would be equivalent to using perfumery essence at a dollar an ounce for the same purpose.

Products of Distillation. Up to within a few years ago the crude oil as it came from the well was subjected to a refining process which consisted chiefly of subjecting it to a gradually increasing range of temperatures so that the oil was broken up into its various constituent hydrocarbons, the latter being led off into separate vessels where the vapor was again condensed. For example, the first heat evaporated the naphtha, which was led off to its own condenser; then followed gasoline, which was in turn reconverted into a liquid in another condenser and was itself followed by kerosene, light lubricating oil, heavy lubricating oil, and so on down the scale. This process of refining, however, produced but 5 to 6 per cent of gasoline from the Pennsylvania and Ohio crude oil and so much less from the Texas and California oils that it was hardly worth while to attempt to make gasoline in this manner from them.

The great demand for gasoline led to the improvement of the process by the distillation of the oil under pressure as well as at a high temperature, so that in addition to the effect of the heat in breaking the heavy oil into its components, it was also actually "cracked" by the pressure and a much greater yield of the lighter fuel oils obtained. The Burton and the Rittmann are the two processes generally employed, and their products are sometimes referred to as "cracked oils." These methods produce a fuel that commonly passes under the name of gasoline, but which, owing to the much greater proportion of heavier oil that it contains, is a low-grade fuel compared with the gasoline of ten years ago. Kerosene is the next product, and then follow the various grades of lubricating oil.

Vaporizing Fuel. In order that a fuel may be used in the motor, it must first be converted into a vapor. The requirements of this process depend entirely upon the character of the liquid to be handled. In the case of the very volatile gasoline of which there appeared to be an unlimited supply when the automobile first appeared twenty-five years ago, it is only necessary to expose it to the air, so that the rudimentary carburetors employed on those first automobiles consisted in large part of a receptacle for a pool of gasoline over which the air was drawn to *carburet* it. This air picked up the vapor rising from the surface of the gasoline pool and with it formed an explosive mixture. The mixing process naturally could not be carried out with any speed, and it could not be depended upon to be uniform in its action. Gasoline evidently began to go down the scale very early, since the next step was to provide a heavy wick or similar surface to greatly increase the area exposed to the air current which was to be charged with the gasoline vapor. But gasoline of any grade that could be evaporated in this manner is now a thing of the past.

Spraying Necessary. When a liquid is not sufficiently volatile to evaporate when the surface of a pool of it is exposed to the air, the first step in causing it to evaporate is to break it up into a large number of globules and thus vastly increase the amount of surface exposed to the air. To break a liquid up in this manner, it is sprayed by being forced through a small orifice known as a jet, or nozzle. The different types of carburetor jets, or nozzles, ordinarily employed are illustrated in principle by Fig. 8.

The jet *A* is known as a fixed jet, in that it has no means of adjustment; *B* may be adjusted by means of the screw shown and is commonly referred to as a needle valve. A valve of this type is generally employed in the so-called mixers, which term is merely another name for a device that serves the purpose of the carburetor but is lacking in the refinements of construction of the automobile carburetor. Jet *C* is simply a variation of *B* in which the needle valve adjustment is made from above instead of below, while in *D* a cone takes the place of the needle but serves the same purpose, that is, so adjusting the orifice that the liquid will be broken up into a spray so fine as to be practically a mist. The fixed jet *A*, while used abroad to a greater extent than here, is now becoming more generally used in this country on account of its simplicity.

The principle of all the types is identical, namely, drawing the liquid through a fine orifice, with or without a baffle surface in the form of a needle or cone, so that the liquid, being under pressure, is sprayed out of the opening as a fine mist. The suction stroke, or descent of the piston in the first part of the cycle, supplies this pressure by decreasing the pressure in the cylinder so that the atmospheric pressure on the liquid in the carburetor forces it through the jet.

Mixing Gas and Air. As it comes out of the jet, or spray nozzle, the fuel is in an intermediate stage between liquid and vapor. To convert it into the latter, the descending piston also draws up past the spray nozzle of the carburetor a supply of air. The latter is given a whirling motion by the shape of the chamber it enters, with the result that it picks up the tiny globules or drops of gasoline and breaks them up further. With the volatile gasoline of earlier days this was all that was required to produce a true vapor, but with the lower grade fuel now common, and particularly with kerosene and distillate, the addition of heat is necessary. It is absolutely essential that the fuel mist and the air be thoroughly mixed for the double purpose of converting the fuel into a vapor and of bringing every particle of this vapor into direct contact with an equivalent particle of oxygen in the air, since it is oxygen that makes the rapid combustion of the fuel mixture possible.

Proportion of Air to Gas. Unless there is sufficient air, the result is a slow-burning, or *over rich,* mixture that produces a great deal of black smoke and causes the power of the engine to fall off. It also causes the familiar back fire that is so startling to the beginner. This occurs because the fuel is still burning in the cylinder when the inlet valve opens to admit a new charge and the latter is ignited and blown back through the carburetor instead of being taken into the cylinder. If there is too much air, the mixture is *thin,* or *poor.* In such a case the power falls off and the engine may miss in different cylinders, often jumping from one to another in an erratic manner. A back fire will also occur with a lean mixture since it is likewise slow-burning.

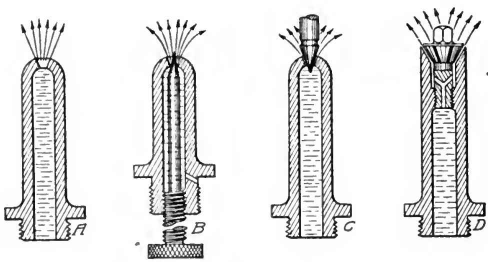


Fig. 8. Types of Carburetor Nozzles or Jets

To produce an explosive mixture requires the mixture of approximately ten to fourteen parts by volume of air to one of fuel vapor, the proportions naturally varying with the character of the fuel itself. But to produce an efficient explosive mixture in a given engine requires a carburetor that has either been specially designed for that particular motor or one that has been adjusted especially with a view to meeting the conditions imposed by that motor.

The amount of air needed for any given fuel or for any motor also varies largely with atmospheric conditions at the time and place in question. It is solely the oxygen content of the air that is of value in helping to burn the fuel mixture rapidly, and at times the air is denser than at others. The denser it is, the more oxygen it contains and the less of it is required to form a good explosive mixture. Just after sundown in spring and fall the air cools off very rapidly, and an automobile engine will run noticeably better at that time than in any other part of the day and for the same fuel consumption the amount of air used can be decreased. The contrary is true of high mountain districts where, owing to the altitude, the air is thinner and contains considerably less oxygen per cubic foot than at the sea level. In climbing from sea level to a height of several thousand feet, it is necessary to allow a greater proportion of air to maintain the given amount of oxygen required for the efficient combustion of the fuel. A tractor engine in Colorado would accordingly require a great deal more air to operate efficiently than would one working in Illinois, the same carburetor and the same fuel being used in both cases.

Details of Spraying Process. Since the difference between the pressure in the interior of the cylinder when the piston is going down on the suction stroke and that of the atmosphere (14.7 pounds per square inch at sea level) is not very great at the beginning of the stroke and as the time interval for charging the cylinder is very short, the spraying of the fuel into the incoming air must begin immediately. This is accomplished by carrying a small supply of the liquid fuel in the *float chamber* of the carburetor. A typical carburetor float chamber is illustrated at the left of Fig. 9, which shows a simple form of carburetor in section. The fuel enters from below through a needle valve, the needle of which passes through the hollow copper float. As the liquid rises in this chamber, the float rises with it and in so doing forces the needle down into its seat by means of the small weighted levers shown. The levers are attached to a collar on the spindle of the needle.

It will be noted that this float chamber communicates with the spray nozzle located in the *mixing chamber* just to the right of it. As a liquid always seeks its own level, the fuel rises to the same height in the spray nozzle as it does in the float chamber and the float is set to close the needle valve at a point where this fuel level is normally but a small fraction of an inch below the opening of the nozzle. The liquid is accordingly sprayed out of the nozzle under the influence of a difference in pressure of less than 1 pound to the square inch; that is, as soon as the pressure above the nozzle due to the suction stroke of the piston becomes less than that of the atmosphere on the supply of fuel in the float chamber, the liquid is forced out of the small opening.

This spray, or mist, is then carried upward through the carburetor and through the inlet valve into the cylinder by the current of air drawn in at the opening below the spray nozzle and extending to the right. Owing to the peculiar form given the chamber surrounding the spray nozzle (known as a Venturi tube), a whirling motion is imparted to the incoming air and its velocity is increased. The result is to mix the spray and air more thoroughly and to convert the mixture more nearly into a true vapor.

Effect of Increasing Speed. It is apparent that as the speed of the motor increases, the suction on the spray nozzle will become greater, and the interval between suction strokes, particularly in a motor having four or more cylinders, will be so short that the spraying action will be practically continuous. This tends to upset the balance of the mixture by causing an excess of the fuel spray so that the proper proportion of fuel to air is no longer maintained and the power output of the motor suffers correspondingly. To overcome this, means for supplying additional air are provided, usually in the form of an auxiliary air valve designed to be operated by the difference in pressure between the inside and the outside of the carburetor. In Fig. 9 an auxiliary air valve of this kind is shown in the upper part of the illustration. It consists of an opening in the carburetor body covered by a diaphragm, or plate, the latter normally keeping the opening closed by means of the spring shown. As the pressure inside the carburetor decreases below a certain point owing to the increasing speed of the motor, the atmospheric pressure on this diaphragm overcomes the spring and allows an additional supply of air to enter and combine with the mixture, which then passes off, through the opening shown at the right, to the intake manifold.

The carburetor shown in Fig. 9 is a single fixed-jet type with a simple auxiliary air valve, and it serves to illustrate the principles upon which practically all carburetors work, namely, spraying the liquid fuel in the form of a fine mist into an incoming current of air to which greater movement and increased velocity are imparted as it passes the spray nozzle. There are a great many different types of carburetors and an even greater number of different makes, but all operate on these basic principles. In some instances two or more nozzles are used, the smaller being in action only while the motor is idling and the larger increasing the supply of fuel when the increased speed of the motor brings a greater pres-

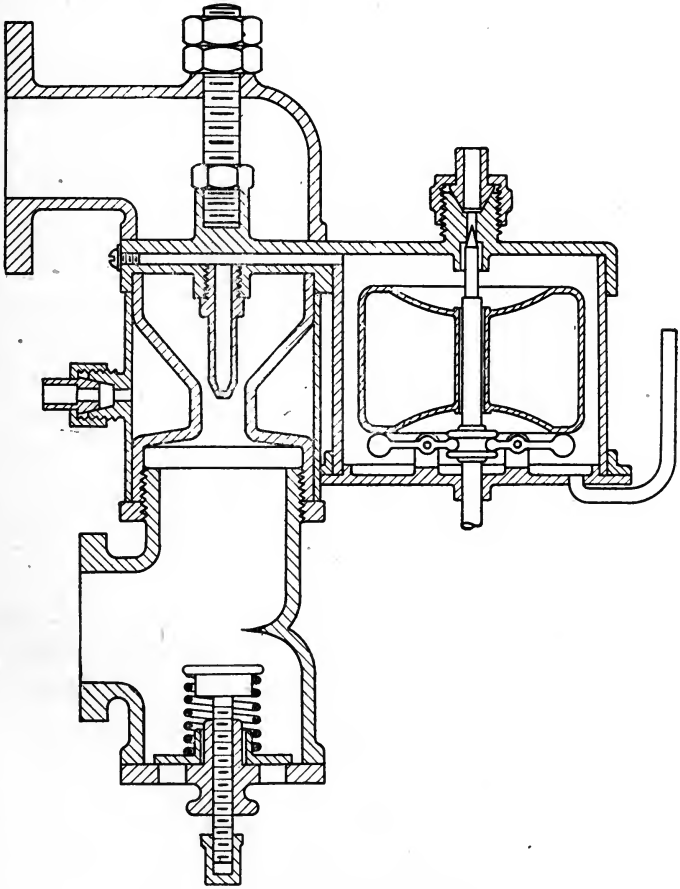


Fig. 9. Section of Typical Fixed-Jet Carburetor

sure to bear and causes them to spray. In this case the principle is that of altering the amount of fuel in the mixture in accordance with the speed, the air intake to the carburetor remaining fixed at all times, while in the single-jet type described above the air supply is increased with increasing speed. Still other types increase both the fuel and the air supply, a needle valve on the jet being connected with the auxiliary air valve, as in the Schebler carburetor shown in Fig. 10. The needle valve, or spray nozzle, is at *E*, and the needle is attached to a bell-crank lever, indicated by the dotted lines, which is attached at its other end to the spindle of the auxiliary air valve *A*. As the auxiliary air valve opens downward under the additional suction of increased motor speed, it lifts the needle *E* and permits a greater amount of fuel to spray through the jet at the same time that an increased supply of air enters through the valve *A*. While it is automatic in its action, this carburetor is also provided with a hand control, the connecting rod of which is attached at *B*. The movement of this adjustment is limited by the boss *D* coming against the stop *C*. When in this position, it is set for running and corresponds to the mark *AIR*, indicating that the full air supply is being given; at the other end the adjustment quadrant is marked *GAS*. This adjustment is used chiefly for starting. In this particular carburetor the float, which is not indicated in the illustration, surrounds the spray nozzle and consists of a shellacked cork ring.

Heating Requirements. The process of converting a liquid into a vapor is one in which considerable heat is rapidly absorbed from the surrounding air, so that the temperature of the resulting vapor is lowered. With the highly volatile gasoline used in early days no artificial heat was necessary to offset this under summer conditions, and the simple carburetors then in use were not provided with any heating devices. But when the car was run in cold weather, it was nothing unusual for the carburetor to become choked up with snow and ice caused by this refrigerating action of evaporation, and this also happened when aeroplanes first reached high levels. The lower the grade of fuel employed, the heavier it is and the higher its temperature of evaporation, so that heat is required even with gasoline fuel nowadays. Kerosene cannot be vaporized unless the temperature is raised very considerably above that of the surrounding atmosphere even on a hot summer day, since this fuel is not at all volatile and will not evaporate at any ordinary temperature.

Gasoline. For a carburetor handling gasoline only heat is ordinarily supplied by water-jacketing the mixture chamber, a small amount of hot water from the cooling system of the motor being circulated around this part of the carburetor. The water-jacket space and connection of the fixed-jet type of carburetor will be noted in Fig. 9. In addition, the main supply of air to the carburetor is heated by clamping a sheet-iron box or "stove" about the exhaust manifold and passing the air over this heated surface before conducting it to the carburetor through a flexible metal tube of large diameter.

Kerosene. While the arrangements mentioned work efficiently on the automobile using gasoline as a fuel, they would not prove

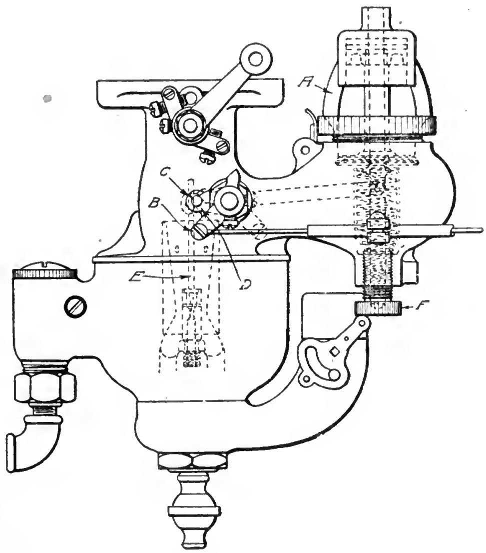


Fig. 10. Interconnected Air and Fuel Feed
Courtesy of Wheeler and Schebler, Indianapolis, Indiana

satisfactory for burning kerosene. A very high temperature is required to vaporize kerosene and the method of applying it is illustrated by the section of the Wilcox-Bennett kerosene carburetor, Fig. 11. The float chamber is shown at the lower left hand, while the mixing chamber, just to the right of it, is equipped with two needle valves. The lower of these is designed to admit water, which is required in the majority of engines using kerosene as a fuel. The kerosene needle valve is just above the water valve, and it will be noted that the mixing chamber above this valve is surrounded by a cast-iron radiator provided with fins. The function of this radiator is to absorb heat from the air passing over the exterior fins and to radiate it to the fuel mixture inside.

The passage in which this radiator is located is connected directly with a damper in the exhaust outlet of the motor, so that the exhaust gases may be passed directly through it and used to warm the air instead of merely utilizing some of the heat of the manifold for this purpose as is done in a gasoline carburetor. In other words, all or part of the exhaust of the motor is used for heating by shunting it through the carburetor instead of allowing it to escape through the muffler in the usual way. The method of accomplishing this in the Wilcox-Bennett carburetor is shown in Fig. 12 which also illustrates the connection of the air cleaner to the carburetor. The details of the radiator itself and the needle valves are shown by the part sectional view, Fig. 13, which illustrates these essentials of the carburetor in the no-load position at the left and in the full-load position at the right. By comparing the sectional views with the illustration of the complete carburetor, Fig. 14, a better idea of the relative positions of its essential parts can be had.

At the right in Fig. 14 there is a horn-shaped device surrounding the exhaust passage and connecting with the mixing chamber of the carburetor just below the needle valves. By referring to Fig. 11 or Fig. 13 again it is seen that the object of this device is to conduct heated air to the mixing chamber. This hot air is required when the motor is running slowly or under light load, as this represents a condition under which a kerosene burning motor will not ordinarily run satisfactorily since it is apt to cool off too much. The passage connecting this hot-air horn to the mixing chamber is designed to be opened and closed by a weighted valve, which is indicated in the drawing by heavy lines. It has already been explained that the suction of the motor varies with its speed and increases very markedly as the speed of the motor increases. At low speeds the force of gravity is more powerful than that of the motor suction, so that the weighted valve remains at the bottom and the hot-air passage stays open; when the motor speed increases sufficiently, the suction lifts this valve and holds it in a position to close the hot-air passage.

Air and Fuel Balanced. The Wilcox-Bennett kerosene carburetor is designed to be automatically controlled by the speed of the engine, the amount of fuel, air, and water admitted being dependent upon the suction, which varies almost directly as the speed.

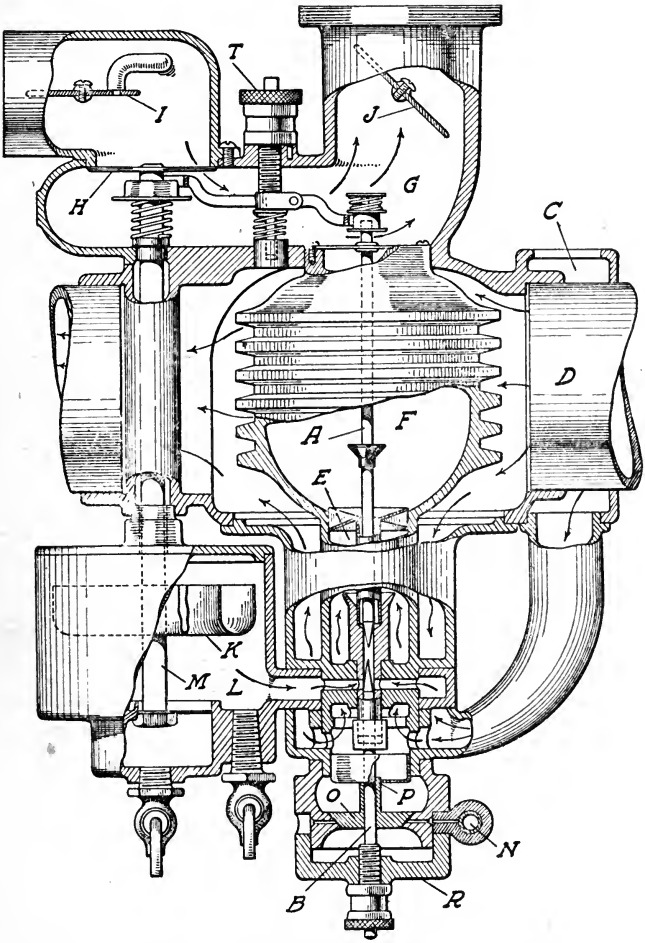


Fig. 11. Section of Wilcox-Bennett Kerosene Carburetor, Shown at Full Speed Position
Courtesy of Wilcox-Bennett Carburetor Company, Minneapolis, Minnesota

It will be noted that the auxiliary air intake and its valve are at the upper left hand and also that this diaphragm valve is directly interconnected with the kerosene needle valve in the spray nozzle. A stand pipe is employed instead of one of the conventional forms of nozzle previously illustrated. The stand pipe consists of a tube whose entire circumference is drilled with a large number of fine holes, through which the fuel is drawn instead of through a single opening at the top. The lines to the right and the left of the kerosene needle in Fig. 11 indicate that the fuel is issuing from these openings. In this illustration are shown the essential parts of the carburetor in the position they assume at full speed: the diaphragm of the auxiliary air valve being depressed, so that there is a flow of cool air into the carburetor at this point; the kerosene needle valve is lifted well off its seat to supply the maximum amount

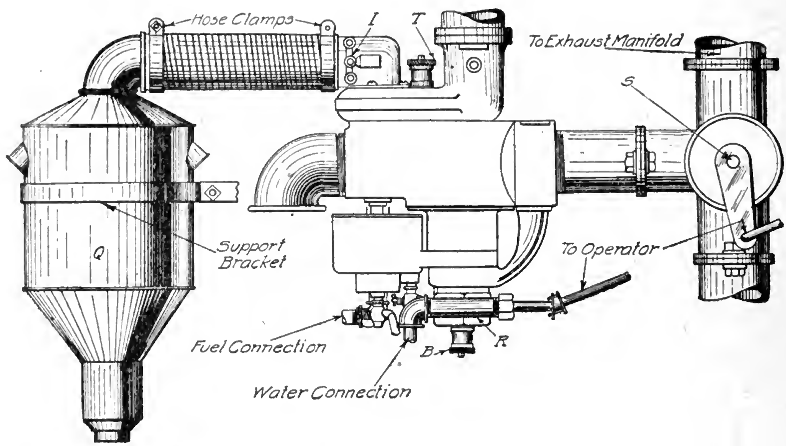


Fig. 12. Method of Employing Exhaust Gases in Wilcox-Bennett Carburetor
Courtesy of Wilcox-Bennett Carburetor Company, Minneapolis, Minnesota

of fuel; the hot-air intake below is closed; and the water intake, also governed by the weighted valve previously mentioned, is open.

It must be borne in mind that under the conditions given the exhaust of the motor is at its maximum both in volume and temperature, so that the kerosene mist, immediately after issuing from the standpipe and being whirled into the radiator chamber by the multi-bladed fan shown in Fig. 13, is at once subjected to a degree of heat reaching at times as high as 900° F. Since this is too hot for efficient combustion, before passing into the cylinder, the temperature of the fuel is lowered somewhat by the addition of the volume of air entering through the auxiliary air valve. The admission of water and its admixture with the fuel vapor in the form of steam serves to provide additional cooling, the necessity for which will depend upon the action of the motor.

Gasoline and Kerosene Carburetor. Since kerosene will not vaporize at ordinary temperatures, it is necessary to use gasoline for starting, the motor being run on this long enough to warm up sufficiently to permit the use of kerosene. The combination gasoline and kerosene vaporizer used on the Fordson tractor is illustrated in Fig. 15. Being designed especially for use on this one machine, it has been made much more compact than types which must be adapted to a number of different motors. Compactness

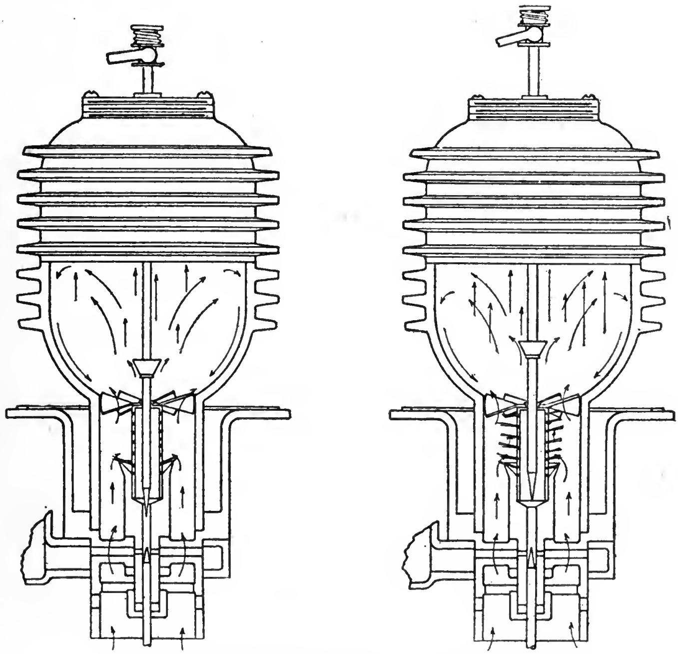


Fig. 13. Detail of Radiator, Wilcox-Bennett Carburetor
Courtesy of Wilcox-Bennett Carburetor Company, Minneapolis, Minnesota

has been obtained by combining the heating unit directly with the exhaust manifold, a shunt valve being provided to by-pass the hot gases as required.

The kerosene carburetor itself is shown at the lower left. It is of the conventional single-jet type, except that instead of being designed to produce a working fuel mixture in the carburetor proper it is only intended to make a heavy kerosene mist, with the result that only a small amount of air is drawn through it from the primary air tube. As shown by the black arrows inside the small white tube, Fig. 15, this rich mixture of kerosene and air is drawn through a heating coil in a chamber provided for that purpose in the exhaust manifold. From that point it passes to a mixing chamber above the inlet manifold, in which it is diluted to the proper consistency by the addition of air through the auxiliary air valve shown at the top of the illustration. This air valve is controlled in the usual way, that is, it varies its position with the speed of the motor itself.

Just below the mixing chamber are located the gasoline connection and passage, which are placed at this point since no heat is necessary for starting on gasoline and since the gasoline spray is converted into a fuel mixture in the same mixing chamber that is used for the kerosene. The gasoline vaporizing device is only in use for a minute or two when starting, the gasoline then being shut off. While gasoline is being used, the exhaust shunt lever is moved to the *ON* position, which permits all the exhaust gases to pass through the vapor-heating tube and gives the maximum heating effect. After the motor has been running on kerosene for a short time, the shunt lever is adjusted to suit the load conditions, the temperature of the mixture being lowered if the lever is moved toward the *OFF* position. When it is desired to run any motor idle on kerosene longer than momentarily, it is necessary to supply the maximum amount of heat and the ignition should also be retarded, as otherwise the plugs are apt to become badly sooted. No provision is made for supplying water directly with the fuel on the Fordson, but an air washer is used which serves the same purpose by moistening the main air supply.

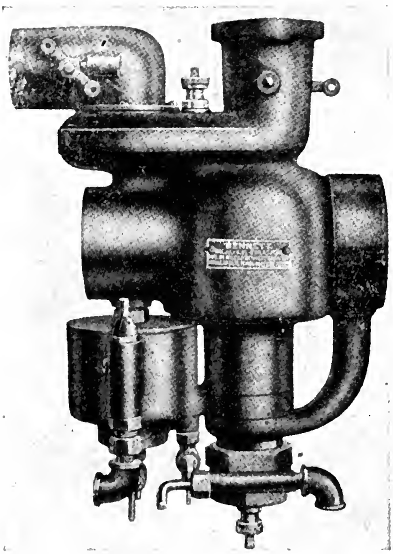


Fig. 14. Assembled View, Wilcox-Bennett Carburetor
Courtesy of Wilcox-Bennett Carburetor Company, Minneapolis, Minnesota

Need for Cleaning Air. About fifteen years ago, when the automobile first began to assume such a degree of reliability where its ignition and carburetion mechanisms were concerned as to permit some degree of attention being given to ailments of other parts of the motor, carbon deposits were discovered on the pistons and in the combustion chamber. Ever since then there has been a great deal of discussion as to the conditions which cause these deposits and the methods of preventing them. A great deal of the discussion and most of the methods adopted have been misguided, if not entirely futile, since an analysis of these deposits made at an early day proved them to consist of road dirt and grit to the extent of 65 per cent or more, the balance being simply burned and partly burned lubricating oil, which serves as a binder and causes the mass to adhere to the cylinder head or piston. In addition to giving rise to these troublesome carbon deposits, which frequently accumulate to such an extent that they cause pounding or even preignition, the fine grit which composes a large part of the dirt drawn through the carburetor also causes the pistons and cylinders to wear very much more rapidly than they would were the air free of this foreign matter. Notwithstanding these discoveries, none of the numerous remedies proposed has ever taken the preventive form of cleaning the air before it is used.

Tractor Air Conditions Very Bad. There are several reasons why the troubles caused by dirt in the air have not assumed such proportions on the automobile that it has been considered necessary to use a preventive. Chief among these is the great improvement that has taken place in many thousands of miles of American roads, which have been made dustless in recent years. The general recourse to heated air taken from a small box, or stove, placed around a part of the exhaust manifold is another reason of equal importance, since this prevents the direct entrance to the carburetor of the air passing through the radiator. Before reaching the opening of the hot-air box on the exhaust manifold it must pass around various curves and strike different obstructions, which cause most of the heavier particles of dust to fall. Since the high speed of the machine permits it to run away from its own dust very effectively, it is only on very windy days, when the atmosphere is generally dust laden, that more than a very small amount finds its way through the radiator.

None of these advantages obtain in the case of tractor operation. Plowing must frequently be carried out under very dusty conditions, with the result that the entire machine operates in the midst of a cloud of dust from which it cannot escape. Under such conditions a large amount of dust and grit is drawn into the carburetor as the suction is very heavy owing to the motor operating under full load most of the time. Unless this intake of dirt is

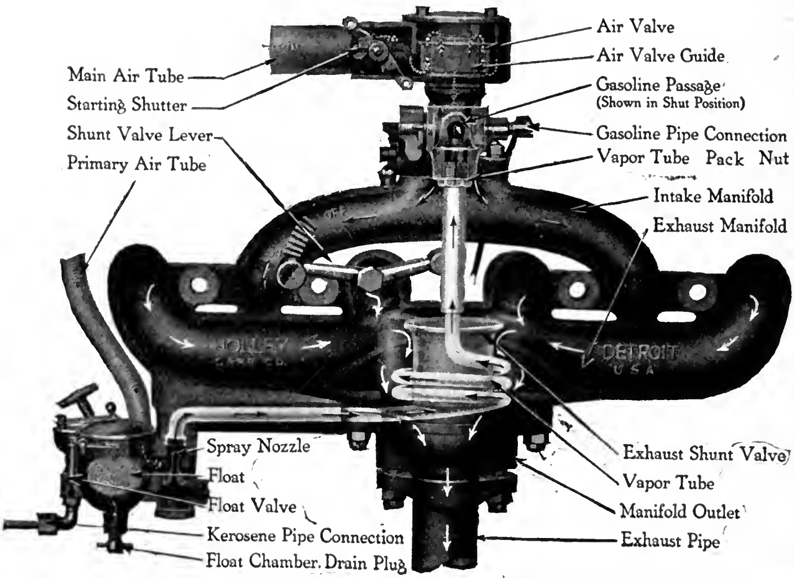


Fig. 15. Holley Combination Gasoline and Kerosene Carburetor as Used on the Fordson Tractor
Courtesy of Henry Ford and Son, Inc., Dearborn, Michigan

guarded against, wear of the moving parts of the motor becomes excessive.

Since, as previously mentioned, approximately fourteen parts by weight of air to each part of liquid fuel are required to make an efficient burning mixture, the equivalent in volume of 10,000 gallons of air is needed for every gallon of fuel. In the case of a tractor burning 20 gallons of fuel in a day's work, a volume of air equal to 200,000 gallons must pass through the carburetor and cylinders in ten hours. The amount of dust that such a great volume of air can hold in suspension under the conditions of tractor operation makes the importance of thoroughly cleaning the air too apparent to call for any emphasis.

Types of Air Cleaners. *Air-Washer Type.* It is apparent that two or three different principles may be taken advantage of to remove dust and grit in suspension from a moving mass of air. The first of these to suggest itself is that of actually washing the air by passing it through a body of water, and a number of air cleaners are based on this idea. The action of the air in passing up through the water is indicated in Fig. 16, and it will be noted that in addition to dropping its dust and other foreign matter the air carries with it quite a percentage of moisture, so that the washing process is a further advantage in those motors that require considerable water to insure cool running when burning kerosene. When using gasoline, however, washing the air is apt to be quite the contrary since the excessive amount of water tends to cool the mixture too much to permit efficient operation. The air washer employed on the Fordson tractor is shown in section in Fig. 17. It consists of a water tank with a central intake tube and an air guide mounted on a float and surrounding the intake tube. The suction of the motor serves to draw air into the washer, and it is then deflected downward into the water by the air guide. In order that the air may pass through a considerable depth of water, the air guide is attached to the float shown so that the air will always enter the water at the same distance below the water level. The float keeps this distance constant by maintaining the outlet of the air guide at the same point at all times regardless of the amount of water in the bowl. The air guide mentioned also serves another purpose in that it serves to cut off the air supply when the water supply is allowed to fall so low that the float rests on the bottom of the bowl.

Centrifugal Type. Mention has already been made of the fact that in compelling the current of air drawn through the radiator of an automobile to pass around several obstructions most of the heavier grit is allowed to drop before the air can reach the carburetor intake. By purposely giving the current of air a whirling movement this effect can be accentuated by taking advantage of centrifugal force to throw the particles of dust to the outer edge of the container, where they drop into a receptacle. This is the principle upon which the air cleaner shown in Fig. 18 is based. By referring to the phantom view of the same air cleaner, Fig. 19, it is seen that after entering, the air is conducted through curved channels, from which it issues to again strike a large central cone, thus acquiring a whirling motion which tends to deposit on the sides of the cone all matter in suspension that is heavier than air. This matter then gravitates down the sides of the cone and finally drops off the edge into the glass receptacle placed below, which permits the operator to note the accumulation of dust and remove it in good season.

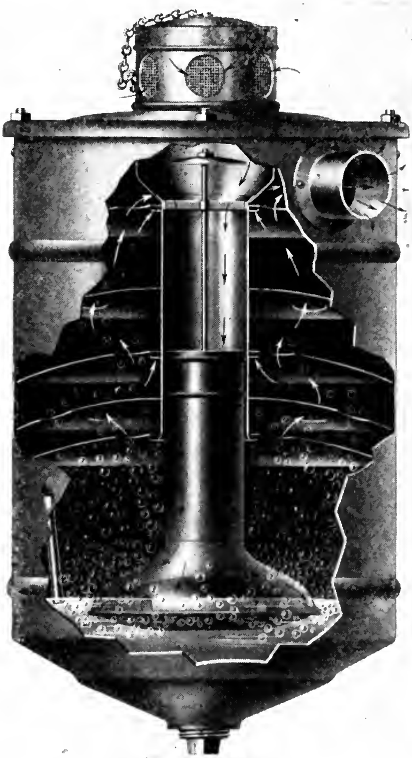


Fig. 16. Sectional View of Parrett Wet-Type Air Cleaner
Courtesy of Parrett Tractor Company, Chicago Heights, Illinois

The same principle is also employed in connection with a receiving vessel, or dust collector, containing water. An air cleaner of this type is shown in Fig. 20, and a sectional view in Fig. 21. In the latter illustration the action of the air currents in entering and striking the central cone is more clearly indicated by the arrows. The air is first drawn into the outer casing and the spiral tubes at *A*. These tubes are set on the inner circumference of the casing, so that the action of the air causes the water to whirl rapidly and assume the position indicated by the dotted line, exactly as any liquid will do in a bowl when stirred in one direction very rapidly. The water, on striking against the lower projecting edges of the spiral tubes, is broken up into a fine spray through which the air passes in being cleaned. The washed air then rises and enters the opening *C* of the inner cleaner, where it is again subjected to a violent whirling. This further tends to throw down any particles of dust or water which may have been carried along with the air, the accumulation of dust being deposited at the bottom of the tube *B*. In a short time enough dirt collects to form a mud seal for this tube, so that if the operator forgets to renew the water supply, the cleaner will continue to operate as a dry type.

Felt Baffle Type. The third principle available in cleaning air is that of the dust screen, and the method of employing this is illustrated in Fig. 22, which shows the device in partial section. It consists of a cylinder of wire gauze on which felt is stretched. The air strikes this in entering, and the dust it contains is repelled by the felt while the air passes through and on to the carburetor by means of a connection with this inner chamber. The vibration of the motor as well as the force of the current of air itself tends to shake particles of dust off the felt and prevent their clogging it, the dust dropping out through the holes shown. In cold weather these holes may be closed to conserve the heat, and the dust then collects in the outer chamber until removed by hand.

Attention Required. Regardless of the type of air cleaner employed, the chief attention required is the frequent removal of the accumulation of dust, or mud in case an air washer is used. Neglect of this precaution simply makes conditions very much worse than they would be were no air cleaner employed, since the accumulation of dirt in the cleaner is apt to be drawn directly into the motor. Where an air washer is employed, the deposit of mud is converted into dust very quickly by the heat of the motor, though the partial shutting off of the air supply causes the motor to miss and lose power, thus providing a warning of the lack of water.

LUBRICATING SYSTEM

Effect of Temperature and Pressure. Where the lubricating system is concerned, as well as regards other essentials, the novice in tractor operation will do well not to rely on his automobile experience to carry him through without a slip that will result in serious damage. There can be no comparison whatever between the 30-hp. automobile motor that runs for ten hours a day and is seldom called upon to deliver 50 per cent of its rated power and

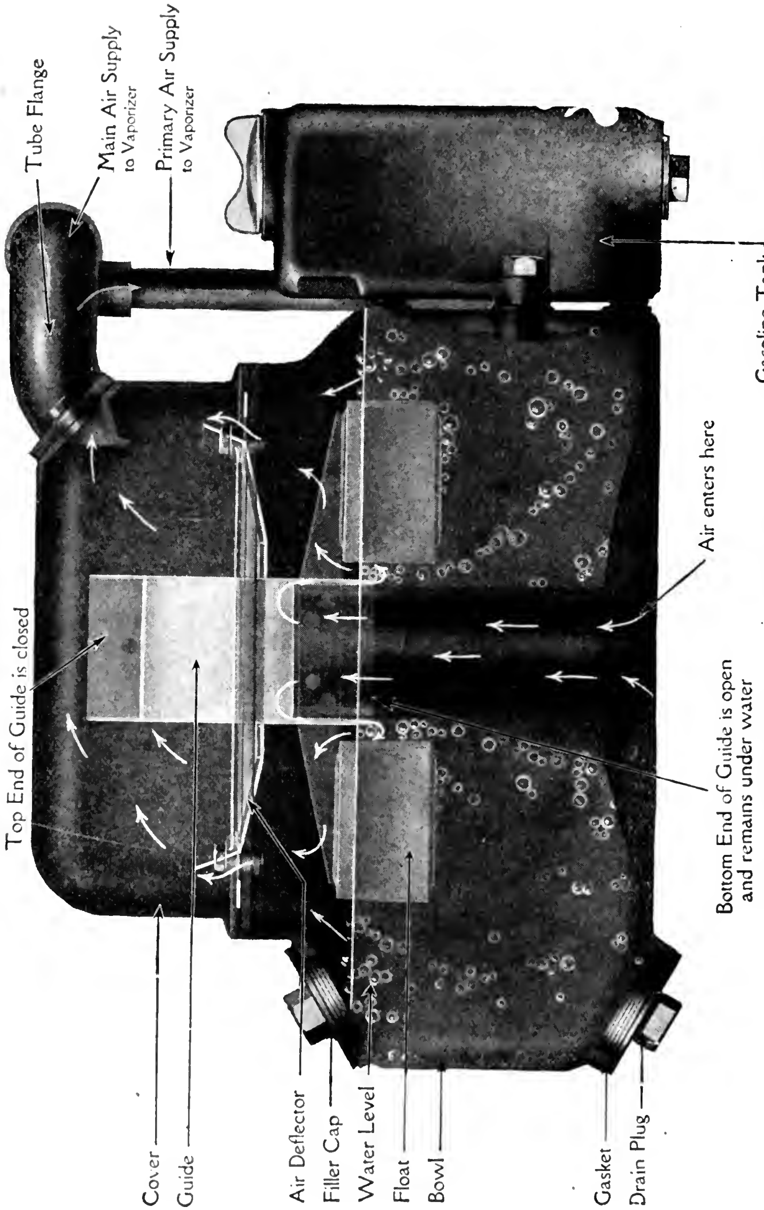


Fig. 17. Air-Washer Type of Cleaner Used on Fordson Tractor
Courtesy of Henry Ford and Son, Inc., Dearborn, Michigan

the tractor engine of the same rating that is delivering 80 to 85 per cent of its rated output all day long.

The sole object of lubrication is to prevent moving surfaces from coming into actual rubbing contact of metal to metal, in other words, to maintain a film of lubricant between the two surfaces on which they may actually be said to float, though the film itself may be only a few thousandths of an inch in thickness.

Fig. 18. Wilcox-Bennett Fry-Type Air Cleaner
Courtesy of Wilcox-Bennett Carburetor Company, Minneapolis, Minnesota

Fig. 19. View Showing Method of Separating Dust from Air by Centrifugal Force
Courtesy of Wilcox-Bennett Carburetor Company, Minneapolis, Minnesota

The problem is accordingly the same in the automobile and the tractor engines, but the ease with which a film of lubricant may be maintained between moving surfaces depends upon the surrounding temperature and the pressure under which the surfaces move in contact. When the temperature of the circulating water is seldom allowed to exceed 165° F., as in an automobile motor running under but a fraction of its maximum load, the vaporizing point of the lubricating oil is seldom reached. But in a tractor engine running for hours at close to its full load the circulating water is seldom much below the boiling point at sea level, 212° F., and the conditions of operation are such that every part of the engine is very much hotter than this. Under the heavy load the pressure between the piston and the cylinder wall is much greater, and the oil tends to squeeze out much more rapidly, so that it must be renewed with far greater frequency than is necessary in an automobile engine.

Types of Lubricating Systems. *Splash System.* The earliest practical type of lubricating system used on the automobile engine was the splash system. The crankcase is filled with oil to a certain level, and the big ends of the connecting rods dip into it and splash it all over the interior of the motor. To keep up the sup-

Fig. 20. Wilcox-Bennett Wet Type Air-Cleaner

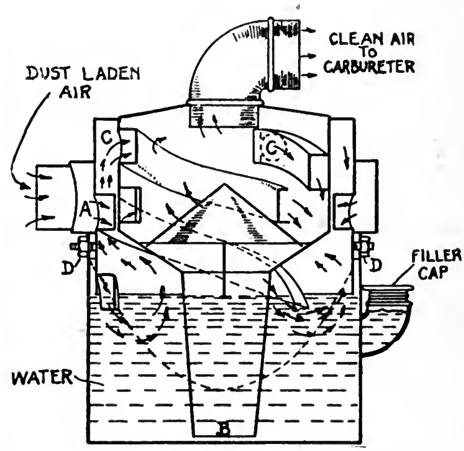


Fig. 21. Method of Operation in Wilcox-Bennett Wet-Type Air Cleaner
Courtesy of Wilcox-Bennett Carburetor Company, Minneapolis, Minnesota

ply, 1 quart or more of oil is added at the beginning of a run, which results in having too much oil at the start and not enough at the finish. Moreover oil is not always oil so far as its lubricating properties are concerned, since they are burned out of it by high temperature. Therefore after a few days' steady use the oil becomes practically useless, and only the extra quart or two added to keep up the level serves as lubricant.

When the motor is run very cool, either with gasoline or kerosene, a certain proportion of the fuel mixture is condensed in the cylinders and finds its way past the pistons into the crankcase, thus thinning the oil out and further reducing its lubricating value. This is particularly true of kerosene, which has the further disadvantage under such conditions of washing the film of oil off the sides of the cylinder walls as it gravitates to the crankcase. One instance is cited in which a manufacturer agreed to deliver a tractor under its own power, but after a few hours running so much kerosene found its way into the crankcase that the main bearings were burned out and the tractor had to be towed back to the shop for repairs before ever reaching its prospective owner. In another case that illustrates the fallacy of depending upon automobile precedents a factory man was called to the assistance of a farmer who reported that the bearings of his motor had burned out before the end of the first week's work. When asked what he had done to lubricate the motor, the farmer said that he had added oil as often as he did on his Ford.

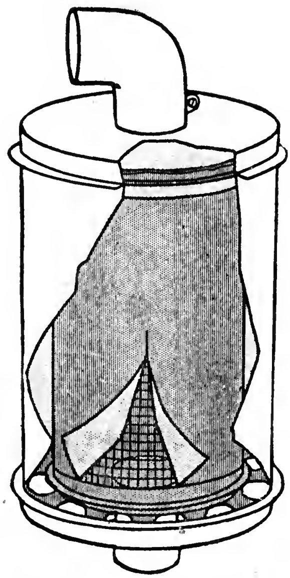


Fig. 22. Orem Felt-Type Dry Air Cleaner

Modified Splash System. The simple splash system of lubrication is accordingly not practical on the tractor engine, though it is successfully employed on hundreds of thousands of automobile motors. A small percentage of the tractors now in use employ this system but as a rule it is improved by the addition of some means of constantly feeding fresh oil to the crankcase or of circulating it over the bearings and depending only upon the overflow from the latter to furnish splash lubrication. The cross-section of a Waukesha motor, Fig. 23, gives an excellent idea of how the dippers on the ends of the connecting rods distribute the oil to every part of the motor. Large receptacles over the main bearings are kept constantly filled, while the spray of oil thrown up reaches even to the valve stems. The crankcase is divided into compartments, as shown in Fig. 24, which illustration also shows the oil pan forming the bottom of the crankcase. The oil is raised by a small pump, forced through the wire gauze screen

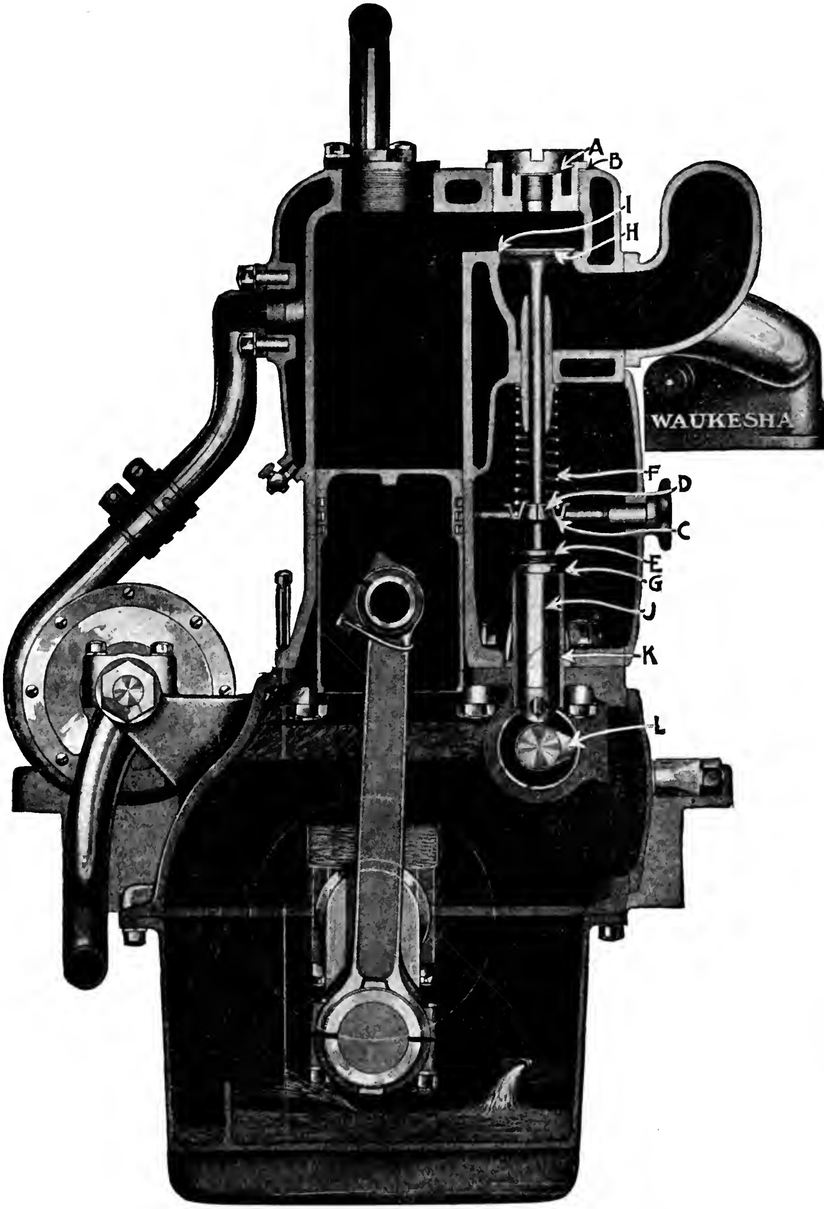


Fig. 23. Sectional End View of Waukesha Motor, Showing Operation and Interior Construction
Courtesy of Waukesha Motor Company, Waukesha, Wisconsin

S, and distributed to the different compartments of the bleeder tube, or pipe having openings *A*, *B*, *C*, and *D*. The overflow returns to the pump and is again distributed, so that this is what

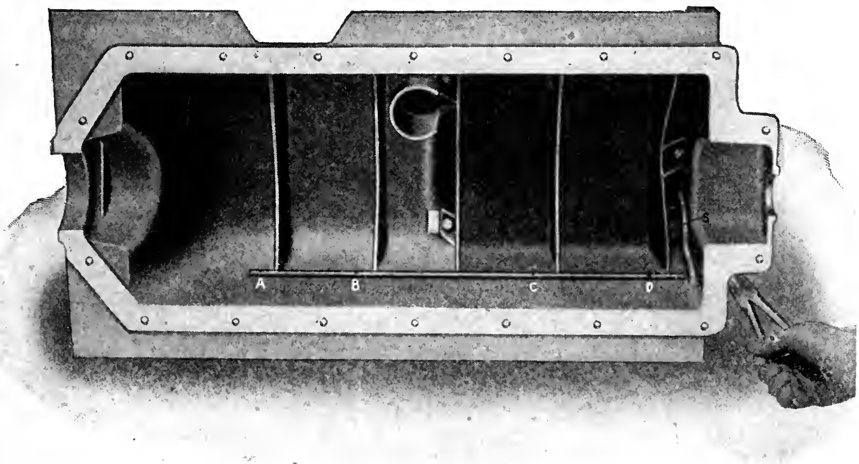


Fig. 24. Crank Case Oil Pan, Showing Compartments and Bleeder Tube
Courtesy of Waukesha Motor Company, Waukesha, Wisconsin

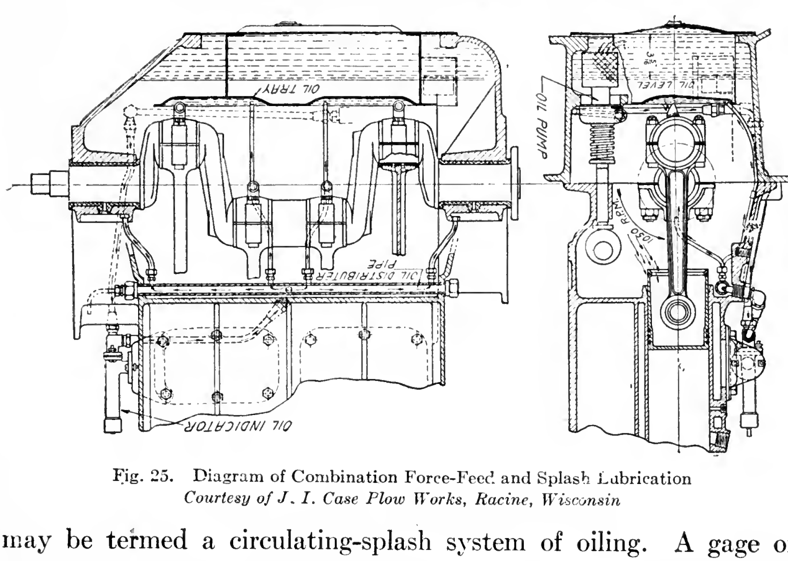


Fig. 25. Diagram of Combination Force-Feed and Splash Lubrication
Courtesy of J. I. Case Plow Works, Racine, Wisconsin

may be termed a circulating-splash system of oiling. A gage on the crankcase shows the level of the oil. In some systems of this kind the stroke of the oil pump is regulated to feed the oil slowly and it remains in the crankcase until consumed.

Force-Feed Splash System. In the force-feed splash system reliance is not placed entirely upon the splash of oil in the crankcase to reach all surfaces in need of lubrication, but a supply of oil is forced directly to the main bearings, camshaft bearings, and timing gears, and the overflow from these points is allowed to collect in the crankcase and serve for splash lubrication for the pistons, piston pins, connecting rods, and cams. Copper tubes are usually placed on the sides of the connecting rods to lead the oil to the piston pins, and in some cases this oil is also relied upon to lubricate the

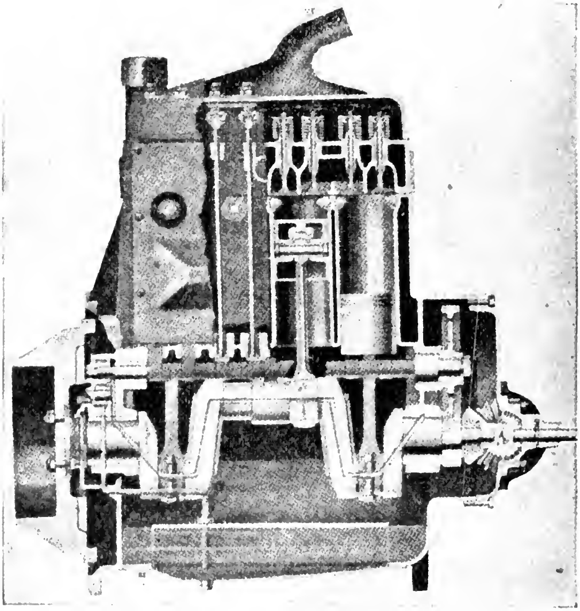


Fig. 26. Moline Circulating Pressure Force-Feed Lubrication

cylinder walls, since it is forced out of the hollow pin on to the cylinder. An indicator in sight of the operator shows whether the oil is being supplied by the force feed. The partial section of the Case engine, Fig. 25, illustrates the details of a system of this type.

Necessity for Discarding Used Oil. One of the chief drawbacks to all forms of splash systems of lubrication for the tractor is the difficulty of educating the farmer up to a realization of the saving that the constant renewal with fresh oil represents in repairs. Lubricating oil is the most expensive single item of supply for the tractor, regarded solely from the standpoint of its cost per gallon, and the farmer dislikes to throw it away no matter how long it has been used. Some tractor manufacturers recommend that the crankcase be drained at the end of every day's work, washed out, and refilled with fresh oil. When oil has been used, its structure is broken down by the high temperature. It is "cracked"—exactly as petroleum is in the pressure distillation process by which all petroleum fuels are produced nowadays—and it has lost its lubricating qualities. By taking a sample of oil

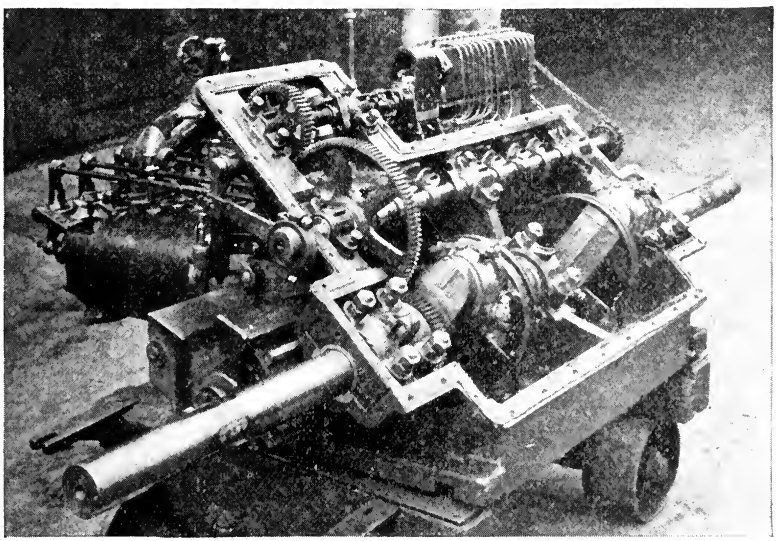


Fig. 27. Combination Force-Feed and Splash Lubrication. Detroit Fourteen-Lead Chain-Driven Oiler
Courtesy of Aultman-Taylor Machinery Company, Mansfield, Ohio

that has been used in the crankcase for several days and rubbing it between the fingers, the great difference between it and a sample of fresh oil will be noted. The average user does not like to drain the crankcase every day, and some practice the false economy of draining it but once a season. It will be found much cheaper at the end of a season's work to have bought plenty of good lubricating oil and used it but once, than to attempt to economize by using it over and over again. Repairs always cost far more than oil. The used oil may be employed to lubricate other parts of some machines, such as the track of a caterpillar tractor.

Pressure-Circulated Lubrication. Following automobile practice, some motors have the crankshaft drilled throughout its length and tubes connecting with this bore rising from the connecting rod bearings, so that the pressure generated by the pump causes the oil to flow over these bearings constantly, the cylinder walls being lubricated by the overflow through the piston pins.

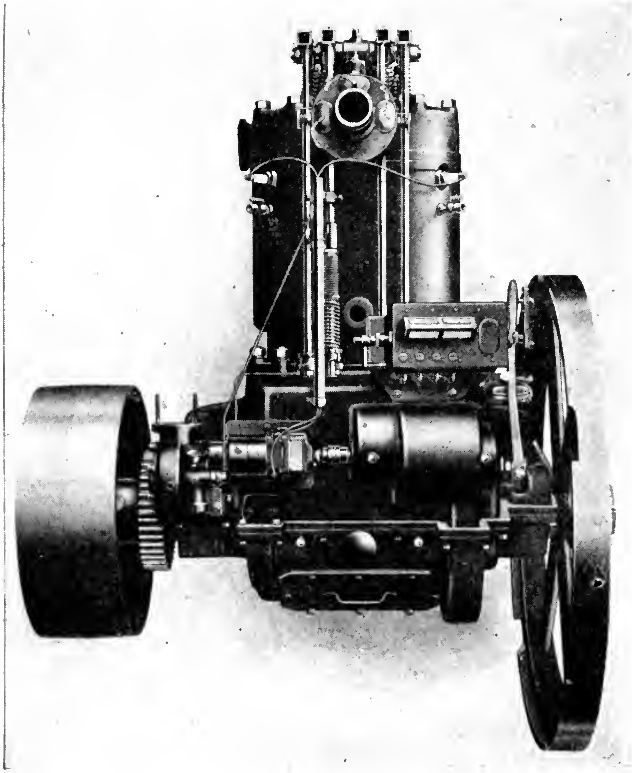


Fig. 28. Force-Feed Oiler of Two-Cylinder Oil-Pull Engine
Courtesy of Advance-Rumely Thresher Company, Inc., Laporte, Indiana

In this system no dependence is placed on splash lubrication, and the connecting-rod big ends are not allowed to dip into the overflow, as shown by the section of the Moline motor, Fig. 26.

This system is also known as the dry-crankcase type in that the excess oil drops into a sump, or well, below the crankcase in which the pump is located, with the result that the entire supply is constantly kept in circulation. More than one pump is sometimes employed for this purpose, so that oil is drawn from different parts of the crankcase at the same time. The advantage of this method is that the location of the machine, as in climbing a hill, has no effect on the quantity of lubricating oil that reaches every part of the motor.

Fresh-Oil System. A very considerable percentage of all the tractors now in use follow steam-engine practice in lubrication by feeding only as much oil as is required by each bearing, so that

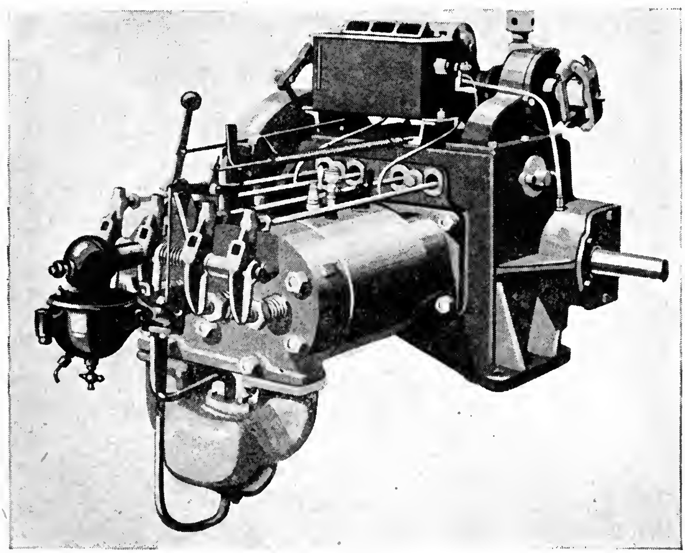


Fig. 29. Eccentric-Driven Force-Feed Oiler
Courtesy of Hart-Parr Company, Charles City, Iowa

the oil is consumed almost as fast as it is fed. This has the advantage of constantly renewing the lubricating film with fresh oil. To provide a factor of safety, however, the supply must actually be fed faster than it is used by the bearings in order that oil may accumulate in the crankcase, and unless this is drained off at frequent intervals, this system is open to the same objection as the ordinary splash system.

The supply of fresh oil for a system of this type is carried in an external reservoir which also serves as the lubricator, in that it is fitted with a number of small plunger pumps, one for each lead, or tube leading to the bearings. The lubricator is driven by a belt, chain, or rod (preferably the last named) from the camshaft of the motor, as shown in Fig. 27, which illustrates the Aultman-Taylor engine equipped with a fourteen-lead Detroit lubricator. Fig. 28 shows a similar lubricator on the Rumely two-cylinder motor, and Fig. 29 a Madison-Kipp lubricator on the Hart-Parr engine, an eccentric or crank and rod being employed to drive the lubricator pumps in both instances.

Frequent Attention Necessary. On an automobile, it is nothing unusual for grease cups to go an entire season without being refilled, and during that time they have only been turned down once or twice. How radically different is the attention required by a tractor may be appreciated from the instructions for oiling an International tractor. When doing belt work, the grease cup on the pulley must be turned down *every hour.* There are eleven bearings on the fuel and water pumps, camshaft, front wheels, rear axle, and clutch that require turning down *every two hours* that the tractor is running. On another group of ten bearings the grease cups must be turned down twice a day, while three others must be turned down once a day.

COOLING SYSTEM

Heat Efficiency of Motors. While the thermal, or heat, efficiency of the tractor motor is high as compared with that of a steam engine, in which it is difficult to utilize more than 8 per cent of the available heat of the coal, it is an unfortunate fact that a very large part of the heat available in gasoline or kerosene must also be wasted since no method that will utilize more of it has yet been discovered. Considering the fuel value of the entering charge as 100, about 40 per cent of this escapes through the exhaust valve at the end of the power stroke and during the succeeding exhaust stroke. An additional 35 per cent that cannot be utilized to drive the piston by its expansion must be absorbed and quickly dissipated or it will soon overheat the motor and bind the pistons hard and fast in the cylinders. Thus only 25 per cent of the real value of the fuel is converted into power. These are simply average percentages which may be made poorer or better by the type of engine, some simple steam engines working in the open in cold weather and poorly protected not showing an efficiency to exceed 3 or 4 per cent, while a condensing Corliss type

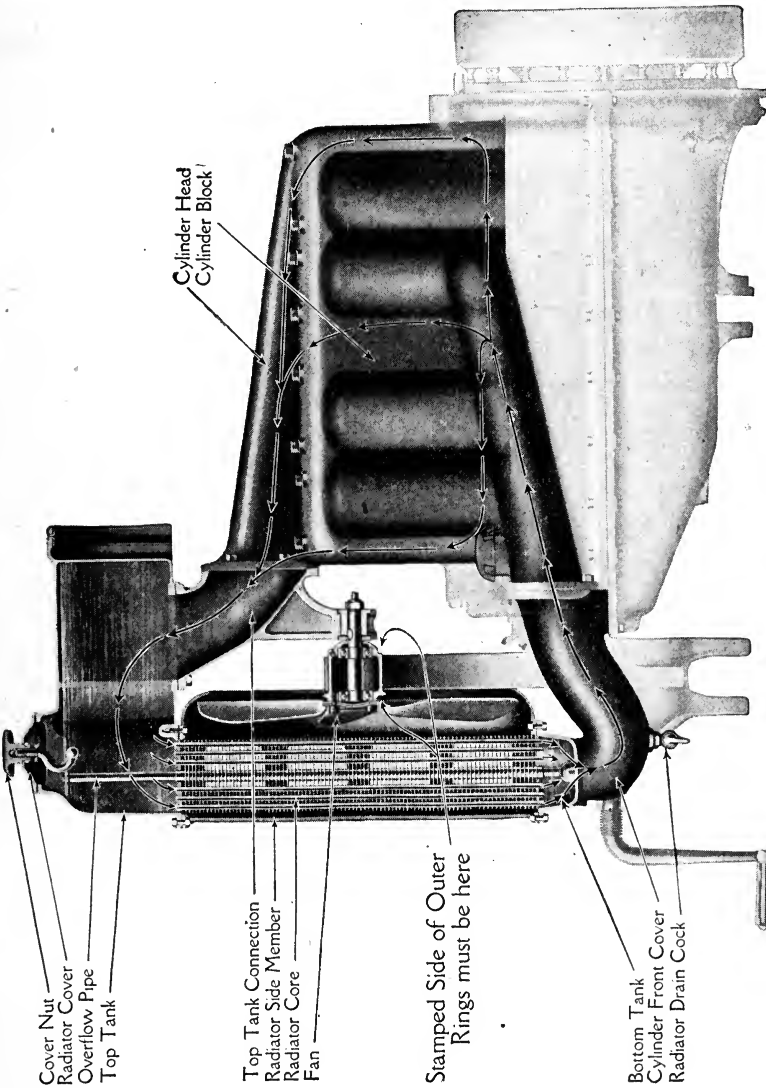


Fig. 30. Thermo-Syphon Cooling System of Fordson Tractor
Courtesy of Henry Ford and Son, Inc., Dearborn, Michigan

unit would reach 17 per cent and a modern type Diesel oil engine 35 per cent or better.

Types of Cooling Circulation. To carry the great amount of excess heat away from the cylinder heads and exhaust valve ports with sufficient rapidity to prevent these parts becoming overheated, a body of cool water is kept in direct contact with them and is replaced by fresh water as quickly as it can absorb the heat. This water is contained in the jackets—spaces cast in the cylinder walls and cylinder head for this purpose. The cool water is conducted to the lowest part of this water-jacket, passed up over the hottest parts of the cylinder, and then led to the radiator consisting of a bank or nest of tubes. These tubes are made of copper, which is an excellent conductor of heat as well as of electricity, and their cooling surface is greatly increased by surrounding them with thin copper fins which give up their heat to the air very readily. The movement of the water between the jackets and the radiator is termed the cooling circulation.

Thermo-Syphon Circulation. The circulation of the water may be effected by the difference in the temperature of the water itself or may be brought about by forcing the water through the piping at high speed by a pump. The first method is known as thermo-syphon circulation and its operation is illustrated by the view of the cooling system of the Fordson tractor, Fig. 30. The radiator is shown in section, while the flow of water through the connecting pipes and the cylinder jackets and head is indicated by the arrows. After passing downward through the radiator, the water issuing at the bottom is considerably cooler than that at the top of the cylinder jackets, which has been absorbing its charge of heat. As water gets hotter, it expands and becomes lighter, so that it tends to rise. The water in the cylinder head jacket accordingly flows toward the radiator and is replaced by fresh water rising through the cylinder jackets. The hotter the water gets, the faster it flows, its movement being controlled entirely by the difference in temperature between the water entering and the water leaving the system at the coolest and hottest points. It will be noted in the illustration how short and direct the connections are and how large their diameter is as compared with the connections on a motor on which a pump is employed to provide forced circulation of the cooling water, Fig. 31.

Forced Circulation. On the majority of tractors a forced type of circulation is employed. In this type the water is moved around through the cylinder jackets and to the radiator and back by means of a centrifugal pump driven from the camshaft or one of the other auxiliary shafts of the motor. The body of water carried, the size of the cylinder jackets, and the diameter of the connecting pipes may all be made much smaller than in systems where the water must move under the force of its own difference in temperature, as in the thermo-syphon system. But it is also apparent that the factor of safety is also somewhat lower in the forced circulation type than in the other. Any failure of the pump, fan, connections, or radiator must be detected and the engine

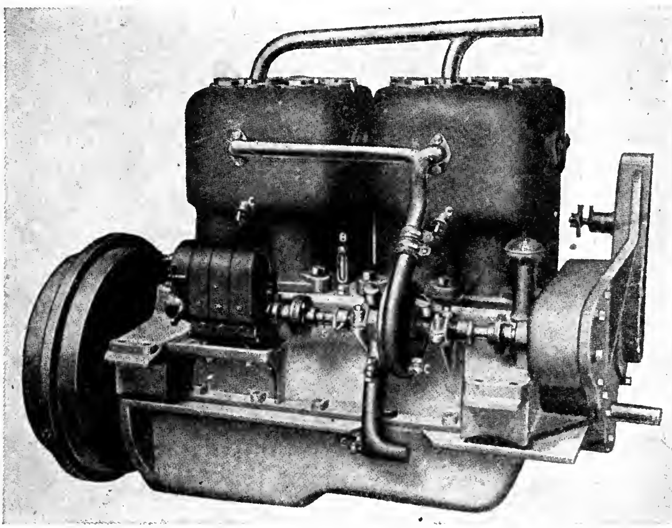


Fig. 31. Pump and Connections of Forced-Circulation Cooling System Used on Heider Tractor Engine
Courtesy of Rock Island Plow Company, Rock Island, Illinois

stopped at once if serious damage is to be avoided. With an engine that is designed to be run constantly under such a high percentage of its maximum load for a number of hours as the tractor engine, the cooling and lubricating systems are of the greatest importance. This is true particularly of the cooling system since any failure in it involves the lubrication system as well, as the moment the temperature rises beyond control, the lubricating oil is burned to carbon and the damage is done.

Protection of Radiator from Stresses. The tubular type of radiator is the most practical for tractor use owing to the necessity for withstanding constant vibration and also jolting and racking, and it is good practice to support the radiator on a flexible mounting so that these stresses cannot affect it directly. This refers particularly to the straining and racking due to the passage of the tractor over very uneven surfaces. To prevent damage from this cause, some radiators are mounted on a pin and trunnion, others have a three-point support, while still others are located at points on the frame where they will be subjected to the least stress from the twisting and bending due to rough going. In the illustrations in the section on motors the pumps and connections used on some of the machines are noticeable so that it is unnecessary to illustrate them here.

Automobile Experience Misleading. When first undertaking the management of a tractor, the average operator is very apt to be guided by his automobile experience and treat the heavier and slower-traveling machine in the same manner. This is apt to lead to serious errors as far as both the cooling and the lubrication are concerned. The tendency of most automobile engines is to run too cool to be efficient. In other words, if they could be run steadily at a higher temperature, less gasoline would be used and the smaller quantity passing through the cylinders would be employed more efficiently. But an automobile engine never runs steadily for any length of time and it is very seldom that more than a fraction of its normal power output is used at all. Except in pulling out of a mud hole or in climbing a very steep hill, it is rare for more than 25 per cent of the output of the motor to be needed in driving the car. Consequently its cooling system is very seldom called upon to work to capacity.

There are few cars built that could climb a two- or three-mile hill mainly on second or even third speed without starting the water to boiling very violently, and if the hill were five miles long, few would be able to get up without a stop on the way to cool off the motor. Compared with the level road service that an automobile is usually called upon to perform, the tractor, particularly when plowing, is performing the equivalent of mounting a steep hill on second or third, with the exception, however, that there is no summit to the hill and no opportunity to cool until the motor is shut down for the day. The cooling system accordingly calls for close attention, any sign of overheating being noted immediately and the engine shut down at once to remedy the trouble. Fan belts and pumps must constantly be kept at a high state of efficiency since slippage at the fan or a leaky pump gland will reduce the cooling ability of the system all out of proportion to the apparent importance of the defect. When working under a heavy load, such as plowing or driving a good-sized thresher, the engine cannot be shut down too quickly upon the first indication of any trouble with the cooling system as under such conditions only a few minutes are required to destroy the film of lubricating oil between the pistons and cylinders and then the damage is done.

With an automobile engine it is seldom necessary to add water to the cooling system even after a long run on a hot summer's day. A tractor cooling system, on the other hand, may need water several times a day, and this is particularly true of the thermo-syphon type of circulation since the water will not continue to circulate unless the entire system is filled to a certain level. The slower speed at which the water circulates in this type keeps it at a higher average temperature, so that evaporation is rapid. The manufacturers of the Fordson, for instance, recommend that the radiator always be filled before starting and replenished every time the machine is stopped for fuel or oil. As regards winter use, the same precautions apply as in the case of the automobile, that is, the radiator must either be drained upon stopping the motor or an anti-freezing solution used. Since the latter reduces the boiling point considerably, evaporation is even more rapid when running under full load on anything but very cold days, so that it is better practice to drain the system.

IGNITION SYSTEM

Importance of Ignition. It has been previously stated that precedence cannot be given to any of the systems upon which the operation of the motor depends since the failure of any one means the stopping of the motor. It will be found in practical service, however, that there are various degrees of importance as far as the order in which the failure of these systems may be responsible for stopping the motor is concerned. Considered from this point of view, the ignition system heads the list in that it is apt to be the cause of failure to operate more frequently than any of the others. There is no function of the motor, a knowledge of which is more important to the operator than familiarity with the principles involved in ignition, since without this knowledge it is always much more difficult to locate and remedy the trouble. Ignition breakdowns do not result in the serious damage that attends a failure of the cooling or the lubricating system, but they involve vexatious delays and the loss of much valuable time when the difficulty cannot be located quickly. The following brief review of electrical principles is confined wholly to those utilized in tractor operation, and they should be thoroughly mastered.

Electrical Principles

Electric Current. Electricity is one of nature's forces possessing many of the characteristics of light and heat plus a number that are peculiar to it alone. Like light and heat, it may be produced by artificial means in a number of different ways. The energy it represents may be utilized in different forms, such as current or as magnetism. For ignition purposes the electric current is either produced by a direct-current generator and chemically converted into another form in a storage battery from which it is taken for producing the spark required, or it is generated by a magneto, which is a simple form of alternating-current generator. Electric current may thus be direct or alternating, and in either case it possesses the property of being able to flow along or in a conductor. In the former case it flows in one direction around what is termed a circuit, the point at which it issues from the generator or battery being known as the positive, or +, pole, and the one to which it returns being the negative, or −, pole. The signs + and − are usually stamped on storage batteries to indicate what is known as the polarity of the battery, and they correspond to the north and the south poles of a magnet. Alternating current, on the other hand, pulsates, or alternates, first in one direction and then in the opposite, so that a pole which is positive at the beginning of an alternation becomes negative at its completion since the current then rises and flows in the opposite direction. A direct current is of uniform strength in addition to flowing in one direction, while an alternating current rises from zero to its maximum and then drops back to zero to rise again in the opposite direction. The majority of tractors are equipped with magnetos, which generate an alternating current, and from the character of such a current, as just outlined, the importance of properly timing the magneto to the engine may be appreciated since the current for producing the spark is only present when an alternation is approaching its maximum, or peak. If the magneto is improperly timed to the engine, no spark will occur at the plug.

Electrical Units. Electricity may be measured in units equivalent to the pressure and the rate of flow of any other form of energy and, carrying out the comparison, it also encounters resistance to its flow. The ampere is the electrical unit of quantity; the volt, that of force, or pressure; and the ohm, that of resistance. The electrical power unit is the watt, equal to the product of 1 ampere times 1 volt. The flow of an electric current may be compared directly to that of water under pressure in a pipe. The number of gallons delivered per minute is the equivalent of the amperes of current; the pressure under which it is delivered corresponds to the voltage of the current; and the resistance to flow represented by the friction of the water against the walls of the pipe corresponds to the resistance encountered by the current in a wire or other conductor. By increasing the pressure on the water, a greater volume is delivered in a given time. By increasing the voltage of an electric current, although no greater volume of current is delivered, the resulting power is correspondingly greater since electrical energy is represented by the product of the number of amperes times the voltage. Moreover when the pressure on the water is increased, a smaller proportion of the total head, or pressure, is lost in friction, and this is equally true of an electric current since the higher the voltage, the smaller the amount of electrical energy dissipated in the wire as resistance.

Conductors. The flow of an electric current is determined by the nature of the material comprising what is known as the circuit. Some materials are very good conductors, such as silver, copper, brass, and aluminum; others are poor conductors, such as iron, nickel, and alloys containing a high percentage of these metals; while still other materials, such as glass, porcelain, mica, rubber, wood, and stone, will not conduct the current at all when dry.

The latter are insulators and are used to prevent the passage of the current where this is not desired; for example, part of the spark plug is made of porcelain. The ability of a material to conduct electric current is determined by its size as well as by its nature. Given two pieces of wire of the same size, one of copper and the other of iron, the copper wire will conduct the current approximately thirty times easier than the iron. By increasing the iron wire to thirty times the size of the copper wire, both will then conduct the same current and voltage with the same amount of resistance. Iron and nickel are accordingly high resistance conductors, preventing the free flow of the current and converting a large part of the energy represented by the latter into heat,

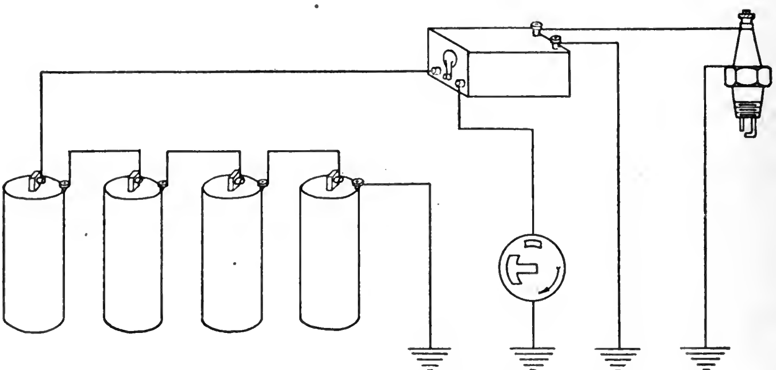


Fig. 32. Simple Series Circuit Representing Ignition System of Single-Cylinder Motor. The Parallel Lines are Ground Return through the Motor

which explains why a piece of iron wire will not serve as well for a magneto or battery connection as the copper wire supplied by the manufacturer. In addition to the insulators already mentioned, no fabric such as silk, cotton, and wool will pass current when dry, while dry air is the best insulator known.

Circuits. It has already been mentioned that a current flows from the positive to the negative pole of the source of energy, but in order for it to do so there must be a complete circuit of conducting material between the two, a current of low voltage being considered in this connection. The presence of any insulators in the path of the current accordingly prevents its flow, and since air is one of the best insulators, any break in the current such as a parted wire or a loose connection admits air and interrupts the flow of current. If the material comprising the conducting path, or circuit, be of high resistance, the flow of current will be either greatly reduced or prevented altogether in the case of the low-tension currents employed in ignition. If a conductor of high resistance, such as a very small piece of wire, occurs in the circuit of a storage battery, it is likely to melt owing to the heat generated by its resistance.

Ignition Circuits. Ignition circuits are of but one kind, that is, series circuits in which all the pieces of apparatus, such as the magneto, the coil, and the plugs, form successive steps through which all the current must pass in order to complete the circuit. Simple forms of series circuits are illustrated in Figs. 32 and 33, which show a dry battery, coil, and plug used as a starting system

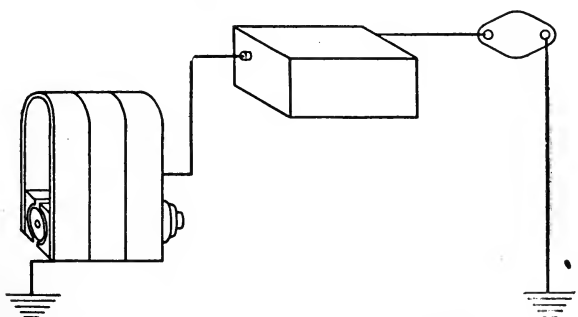


Fig. 33. Series Circuit Using Low-Tension Magneto for Single-Cylinder Ignition System

for a tractor and a low-tension magneto, coil, and plug constituting a complete ignition system. When a battery is employed for lighting to carry on night work as well as for ignition, two independent series circuits may be fed from the same source, the amount of current taken by each being determined by the resistance that it presents to the flow of the current. A multiple, or parallel, circuit is one in which lamps, motors, or other apparatus may be inserted at any point, each unit being connected to opposite sides of the circuit, so that any unit may draw current independently of the others. Connections may be taken at any point on opposite sides of such a circuit to form a branch circuit and the apparatus in the branch circuit connected in series, resulting in what is termed a multiple-series circuit.

Voltage and Amperage. The pressure under which the current flows is termed its voltage, and this may be determined either by the source of supply or by the presence of a transformer in the circuit. In the case of a battery the voltage depends upon the number of cells connected in series with one another, while the amperage, or volume of current, is measured by that of any one cell in the series. For example, dry cells deliver a current at $1\frac{1}{2}$ volts and ordinarily average 15 amperes for short periods. A battery of four dry cells in series would thus produce a current of 15 amperes at 6 volts. If the cells were connected in multiple, that is, all the positives together and all the negatives together, the current would be increased but the voltage would be that of a single cell, so that there would be a current of 60 amperes at $1\frac{1}{2}$ volts.

Storage Battery. In the case of a storage battery which delivers current at 2 volts per cell, the voltage required for ignition, that is, 6 volts, is obtained by connecting three cells in series, while the volume of current depends upon the capacity of the individual cells in the series, and this in turn is measured by their size. For ignition service cells of a battery are always connected in series, so that the positive of one cell must be connected to the negative of the next, and so on throughout the series, one terminal of the battery being positive and the other negative. Any cross connection in the series, such as the connection of the positive of one cell to the positive of the next, would cause one part of the battery to act against the remainder, with the result that no current would be delivered to the outside circuit.

Magneto. The voltage of the magneto or any other mechanical current-generating device is determined by the speed of its armature. The magneto illustrates the fact that electricity and magnetism are different forms of the same force in that one may be readily converted into the other. By moving a magnet close to a coil of wire, a current of electricity is *induced* in the wire, while if a coil of wire is placed about a bar of iron or steel and an electric current is then passed through the wire, the bar becomes magnetic. Steel retains a considerable percentage of the magnetism after the current ceases and is termed a permanent magnet. The fields of a magneto are formed of permanent magnets and supply the magnetism by means of which a current is generated when the wire on the armature is moved past their pole pieces, that is, their north and south poles. Therefore a magneto will generate a current at any speed, but the amount of current and the voltage under which it flows depend upon the speed with which the armature is revolved. The strength of a magnet is represented by imaginary lines passing from one pole to the other, and these are termed lines of force. The voltage of the magneto current is determined by the number of times per minute that the wires of the armature cut through the lines of force between the magnet poles.

Low- and High-Tension Currents. The foregoing brief explanation has been confined to what are known as low-voltage currents, the storage battery delivering current at 6 volts for ignition, while the magneto when running at full speed generates current at approximately 100 to 125 volts. Any current under 500 volts is usually referred to as a low-voltage current. In connection with the explanation of insulators it has been mentioned that the interposition of any insulating material in the circuit, and particularly a break or loose connection which creates an air gap, interrupts the flow of current. This is true of all low-voltage currents; all parts of the circuit must be not merely connected but in firm and positive contact, and the contact surfaces must be clean and bright since dirt is likewise an insulator. This is a principle frequently overlooked in the care of tractor and farm engines, which usually work in very dusty places; it is absolutely necessary to keep all connections clean and tight to insure the satisfactory working of the ignition system.

Since even a loose connection will interrupt the flow of current in a low-voltage circuit, it is not suitable for the production of a spark unless the terminals representing the positive and negative sides of the circuit are actually brought into contact and then separated. What is known as the low-tension system of ignition is employed on thousands of stationary farm engines and also on many tractors having low-speed engines. Most stationary engines are run at low speeds, ranging from 200 or less to 450 r.p.m., while few tractor engines run below 600 r.p.m. at normal speed and most of them operate at much higher speeds.

Types of Ignition Systems

Low-Tension Ignition. While dry cells may be employed for ignition with a stationary engine equipped with a hit-and-miss governor that cuts off the current except on the power strokes, they do not give satisfactory service and therefore a magneto is generally used. The magneto chosen is the simplest type and consists of nothing more than the field pieces, or permanent magnets, and a simple armature having a single winding. It may either be rotated or given a quick partial revolution by a rod and spring, but in any case it must be timed to the engine, so that the current in its armature is at the maximum value when the spark is to occur in the cylinder. While such a magneto produces ample current at a fair voltage it is not sufficient to produce a spark of the desired size for low-tension ignition, and therefore a spark coil is placed in the circuit.

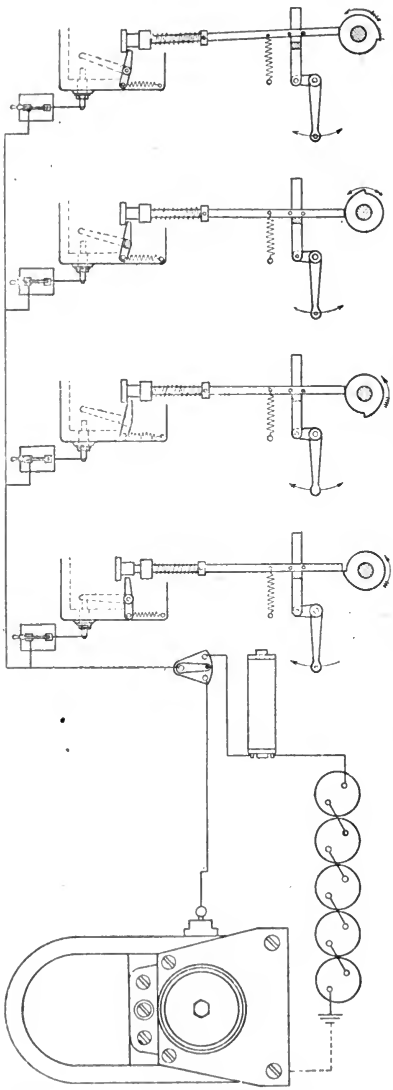


Fig. 34. Details of Low-Tension Ignition System

Spark Coil. The spark coil consists of a single winding of many layers of heavy insulated wire on a thick short core built up of fine iron wire that has been annealed until it is very soft, as in this condition it is capable of being magnetized and demagnetized very quickly. Such a coil acts on the principle of self-induction and produces a much hotter and larger spark than the magneto could unaided. Its working will be clear from Fig. 34, which shows a typical low-tension ignition system. Up to the time it is necessary for the spark to occur in the cylinder, the ignitor has its points in contact, so that the circuit is closed and current flows through the ignitor and the winding of the spark coil. Consequently the core of the coil is magnetized and stores up the equivalent of the current which magnetized it. When the circuit is broken by the sudden snapping of the ignitor, this magnetism is instantly reconverted into electric current and adds its force to that of the current in the winding, and a much hotter spark results at the contacts. In fact, this is really a flash instead of a spark and is usually termed an arc; and it is so hot that it burns the contact points away rapidly, which is one of the disadvantages of the low-tension system.

High=Tension Ignition. In high-tension ignition the ignitor of the low-tension system is replaced by a spark plug with fixed electrodes, or terminals, separated by an air gap. But in order that the current may bridge this gap, it is necessary to raise it to a high voltage. This ranges all the way from 10,000 to 30,000 volts, the higher voltage being necessary when the initial compression of the engine is high since a greater electrical tension is required to create a spark across a gap in compressed air than out in the open.

Induction Coil. In the brief reference given to elementary electrical principles it has been mentioned that when a coil of wire is passed before a magnet, a current of electricity is induced in the wire. This also occurs either when one coil of wire in circuit through which a current is flowing is moved close to another in which there is no current or, the two coils being stationary, when the current is suddenly broken in the first. This is the basic principle of the transformer, or induction coil. As in the case of the spark coil, the effect produced is greatly increased by using a heavy core of soft-iron wire. The character of the current induced in the second coil depends upon the relation that the windings of the latter bear to those of the coil in which the current, termed the primary current, is flowing. If both coils have the same number of turns in their windings, the induced, or secondary, current will be approximately the same in amperes and volts as the primary current. By increasing the number of turns in the secondary winding of the coil, the voltage of the induced current will be increased correspondingly. An induction coil accordingly consists of a comparatively few turns of heavy wire for the primary winding, which is closer to, though insulated from, the soft-iron core. The secondary coil consists of a great number of turns of very fine wire and surrounds the primary winding, but it must also be well insulated from the latter, as otherwise the high tension-current would tend to jump from the windings of one to the other. A coil in which this has occurred is said to be *punctured* and, as it is short-circuited, is useless for ignition until repaired.

Mechanisms to Make and Break Circuit. Where batteries are employed for ignition or the magneto generates a current which, though alternating in its nature, is of such high frequency as to be practically continuous, as on the Fordson tractor, the induction coil must be equipped with a vibrator to make and break the circuit since current is only induced in the secondary winding when the circuit is broken or the current rises and falls from zero to maximum and the reverse, as in an alternating current of lower frequency. In what is known as the modern battery system, employing a storage battery kept charged by a small direct-current generator, a primary contact breaker in connection with the distributor takes the place of the coil vibrator and but one coil is used.

Essential Parts of System. A high-tension system accordingly consists of a source of current, most often a magneto, a coil, a spark plug for each cylinder, and a distributor. The distributor always forms a part of the magneto and is driven by the magneto shaft, and in what is known as the true high-tension type of magneto the coil is also incorporated with it; that is, the magneto generates the primary low-tension current and also transforms it or steps it up to the required high voltage, the armature usually carrying both the primary and the secondary windings. Consequently with a high-tension magneto the complete ignition system consists of the magneto itself, the spark plugs, and the necessary connecting cables, so that the entire system is practically self-contained.

Condenser. A part of the high-tension system with which the operator is not likely to become acquainted unless something goes wrong with it is the condenser. In the form employed for ignition the condenser consists of alternate leaves of tinfoil and paraffined paper, the latter serving to insulate the sheets of tinfoil from one another. The tinfoil sheets are divided into two groups, which are connected to opposite sides of the contact breaker of the magneto, so that the condenser is in multiple with the breaker. (Magneto parts and construction are explained in detail in connection with the description of some of the standard makes employed for tractor ignition.) When parts in contact carrying current are suddenly separated, a flash, or arc, occurs owing to the tendency of the current to continue its flow across the break, as happens in a low-tension ignitor. This not only represents a loss of energy but tends to burn away the parts. To prevent this, a condenser is shunted about the contact, that is, connected in multiple with it. The current, instead of continuing across the gap in the form of an arc as the contacts open, flows into the condenser, which has the capacity to store a charge of electricity. Immediately upon the contact being made again so as to reclose the circuit, this stored charge flows back from the condenser into the circuit.

Safety Spark Gap. In the explanation of circuits mention has been made of the fact that a current divides or flows through different branches of a circuit in proportion to the resistance in those branches. In other words, it will always seek the path of least resistance. Consequently, if the air gap of a spark plug be made so large that it represents a resistance greater than the insulation of the windings of the coil, whether this coil be separate or on the armature of the magneto, the current will break down the insulation and short circuit the winding. The current burns away the electrodes of the spark plugs and the gap must be adjusted from time to time to correct this; at the most the gap should not exceed the thickness of a visiting card, or $\frac{1}{32}$ inch. As the gap widens, the spark becomes thinner and loses its heat value so that the ignition is less and less satisfactory. When at last the gap becomes so wide as to present a greater resistance than the coil insulation, the spark will jump across the safety spark gap provided to protect the coils. This gap is designed with an opening having a resistance that is considerably less than that of the coil insulation so as to allow an ample margin of safety for the coils. It is usually located under the arch of the magnets of a high-tension magneto and is mounted on the distributor of a modern battery ignition system. The occurrence of a spark across this gap is an indication that one or more of the spark plugs have been burned open too far, though this will usually be evident from the poor ignition resulting.

Low-Tension Magneto. Magneto ignition has proved the most dependable as well as the most enduring for tractor work since the excessive vibration and jolting make the use of the storage battery practically out of the question. Dry cells are of little value in any case for ignition, except where starting is concerned, and the necessity for them has been eliminated by the development of the impulse starter on the magneto, as described

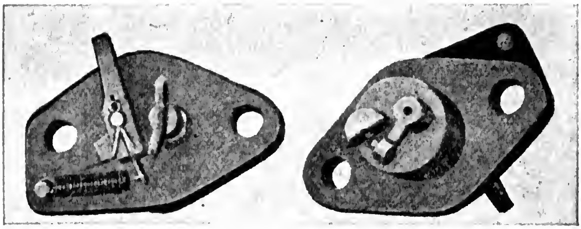


Fig. 35. Inside and Outside Views of Low-Tension Ignition Plug Used on Oil-Pull Tractor

later. There are several types of magnetos in general use on the tractor and a brief reference is made to each of them.

On tractors employing low-speed horizontal engines, low-tension ignition is standard equipment. It has the advantage of being extremely simple and all its parts can be made amply strong enough to withstand the strenuous treatment of tractor service in the field. Its chief disadvantage is the more or less frequent necessity for attention to the ignitors, though the hot flash produced by the latter is better adapted to ignite low-grade fuels than the high-tension spark produced by a plug. The magneto employed with the low-tension system has but one winding and no contact breaker nor distributor. It is connected in a simple series circuit with a spark coil and the ignitors. The Bosch low-tension magneto is the type employed on the Rumely tractor.

In Fig. 35 are given two views of an ignitor, the view at the left showing the tripping mechanism outside the cylinder, while that at the right shows the details of the fixed and movable

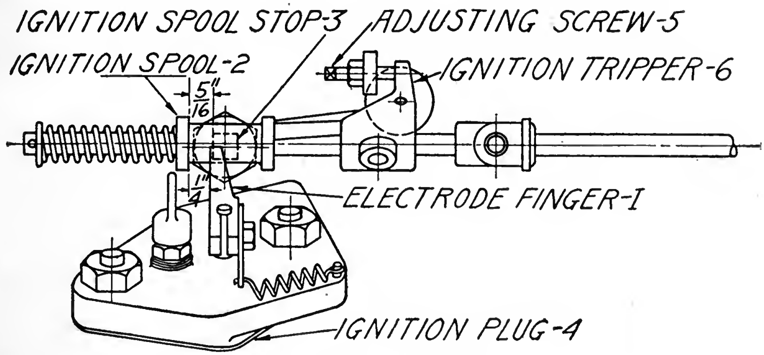


Fig. 36. Tripping Mechanism of Low-Tension Ignitor, Electrodes in Contact before Sparking

electrodes between which the spark occurs when they are suddenly snapped apart. In Figs. 36 and 37 are shown the details of the tripping device, the former illustrating the mechanism with the electrodes in contact just before sparking.

Timing of Low-Tension System. Since the magneto is directly connected in a simple series circuit with each ignitor, it is evident that both the latter and the magneto itself must be timed to produce the spark at the proper moment for the explosion. The

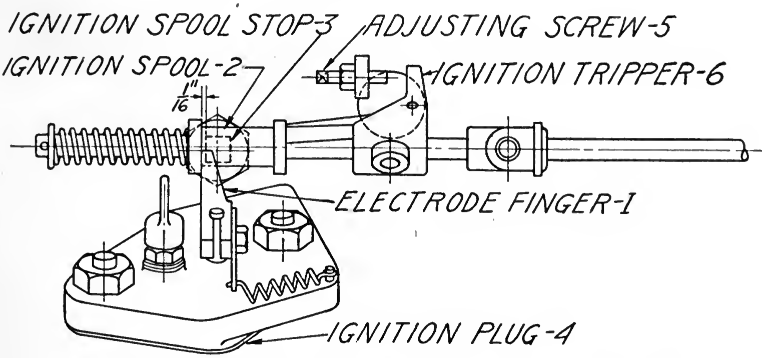


Fig. 37. Low-Tension Ignitor Tripping Mechanism, Showing Adjustment Spacing

ignitor is tripped by a push rod and cam on the camshaft in exactly the same manner as the valves are operated, while the magneto itself is timed to the motor in much the same manner as is necessary in the case of a high-tension magneto. In the section on elementary electricity it has been explained how an alternating current rises from zero to maximum in one direction and then subsides and rises again in the opposite direction. This is termed a sine-wave current and is illustrated by Fig. 38. The only part of this current that is of value for ignition is represented by the few degrees in the revolution of the armature that are indicated by the peaks of the alternations. In a simple magneto with an **H** armature, Fig. 39, this peak occurs at the point shown in the illustration, that is, the point when the core of the armature is entering the tunnel formed by the pole pieces attached to the field magnets at their lower ends.

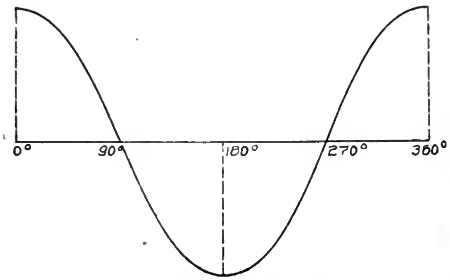


Fig. 38. Sine Wave Alternating Current as Generated by Magneto

In Fig. 39 the armature is turning to the left and has just left the right-hand pole piece by $\frac{1}{16}$ inch. From this point until the center of the core of the armature is on a line with the upper part of the pole piece, the value of the current is close to the peak and is rising. The further revolution of the armature causes it to fall, and when the core reaches the lower part of the tunnel, it reverses and starts upward in the opposite direction. The armature of the magneto must accordingly be set so that it is in the position shown in the illustration when the ignitor is about to trip. This is not the maximum, as the armature cuts the greatest number of magnetic lines of force a few degrees further around and thus produces the current of the greatest value at that point. This setting allows for the necessary advance

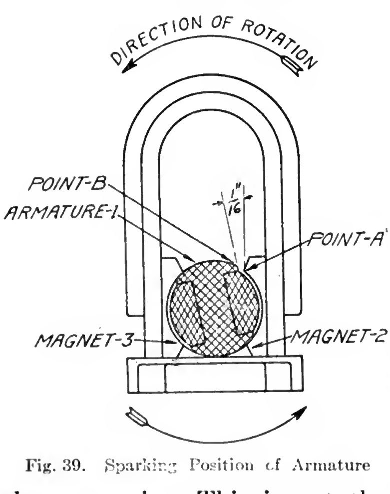


Fig. 39. Sparking Position of Armature

of the sparking time, which causes the latter to coincide with the point of maximum value just mentioned.

Causes of Trouble Few. There being only a current of very low voltage in any part of the system and only a single short wire being necessary to conduct this low-tension current to the ignitors, electrical troubles are rare with the low-tension system and are confined chiefly to failure of the ignitors, or make-and-break plugs, to spark owing to an accumulation of carbon, or soot, on the electrodes. Apart from this, any shortcomings of the system are apt to be purely mechanical rather than electrical. The tripping mechanism and springs must necessarily be light, but at the speeds at which they operate wear is more or less rapid, so that considerable attention is required to maintain them in efficient operating condition. This is the chief reason why the low-tension ignition is not applicable to the high-speed type of motor.

As before stated, most of the electrical difficulties experienced with the low-tension system involve the ignitors, or make-and-break plugs. Unless the fuel is being burned very efficiently by the engine, they short-circuit very quickly through a deposit of carbon, although this also occurs at regular intervals even where it is not possible to improve upon the running of the engine. Another cause of trouble is the sticking together of the electrodes by what is practically a form of electric welding. Carbon deposits must be scraped off carefully, electrode contact surfaces filed or scraped bright, and the remainder of the plug cleaned with kerosene. After a considerable time in service the mica insulation of these plugs may become so impregnated with carbon dust or a mixture of oil and carbon dust that it is impossible to prevent it short-circuiting, in which case it is necessary to replace the mica insulation. The plugs are the source of the trouble in about 85 per cent of the cases, but when they are in good condition, the magneto should be tested, first, to note whether it is generating or not and, second, to see whether it is properly timed to the engine. To provide sufficient current at a good voltage, the plug must snap, or *break*, just at the moment when the current in the armature of the magneto is close to the peak, Fig. 39. The maximum current and voltage are generated when the armature has turned a few degrees further.

Testing Low-Tension Magneto. To test the armature to find out whether it is generating or not, attach a short piece of copper wire to its terminal, place the bare end of this wire against the field magnet, and rotate the armature. Pull the wire away from time to time, and a good spark will follow if the magneto is in good order. If this proves to be the case and the spark still fails to occur at the plug, the position of the armature should be noted at the moment that the plug breaks, and if this does not correspond with the position shown in Fig. 39, the magneto should be retimed. The plug itself may be tested by taking it out and laying it on the cylinder. With the magneto running, the electrodes may be snapped apart. Should they fail to spark, all other parts of the system being in good working order, it is usually due to the insulation of the plug. A spare plug should be inserted and the insulation of the old one replaced as soon as the opportunity arises. By carrying spares, much valuable time in the field may be saved.

High-Tension Magnetos. *Two Types.* Two types of high-tension magnetos are employed for tractor ignition: one in which both windings are placed directly on the core of the **H**-type armature, so that the windings, core, and condenser rotate together; and the other, the so-called inductor type in which the winding is stationary while the rotor in two parts revolves on either side of it. The first type illustrates the elementary electrical principle that rotating a coil of wire through the lines of force of a magnetic field will induce a current in the wire. The current thus induced in the primary winding of the coil on the armature is transformed to one of high voltage by the secondary winding which is also on the armature. The gear shown at the right-hand end of the armature is for the purpose of driving the distributor disc, the function of which is explained later.

The rotor and winding of an inductor type of magneto, the K–W, are shown in Fig. 40, while a phantom view of the complete machine is given in Fig. 41. It will be noted in Fig. 40 that the rotor consists of two blocks of iron placed at right angles to one another with the winding between them. In Fig. 41 the condenser is at the left of the winding, while the contact box and the distributor of the magneto are at the right. The operation of the inductor type of magneto is based on the principle that rotating a magnet so that its lines of force cut the winding of a coil will induce a current in the latter. The magnet in this case is the rotor, the members of which form part of the magnetic circuit of the machine. They are most strongly magnetic when in the position at which the current of any magneto is at the maximum, as previously explained in connection with the low-tension magneto. The rotor takes its magnetism from the permanent magnets of the field in the same way that an ordinary horseshoe

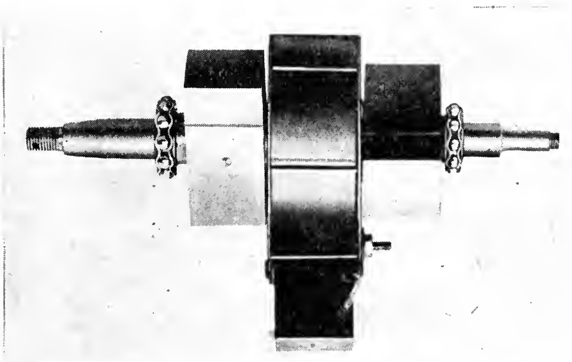


Fig. 40. Rotor of K-W Inductor Motor
Courtesy of K-W Ignition Company, Cleveland, Ohio

magnet will render an iron nail magnetic as long as they are in contact.

High-Tension Circuit. The wiring of a true high-tension magneto, that is, one that has both the primary and the secondary windings embodied in the magneto itself, is almost as simple as that of the low-tension type already described; in the high-tension system one wire is necessary for each plug and in the low-tension system a single cable connected to a busbar in contact with all the ignitors is needed. But in the high-tension system these wires carry current at very high voltage and the slightest defect in the insulation or the presence of dampness is apt to permit this high-tension current to leak away, usually without giving any sign of its escape.

The primary circuit of a high-tension system consists of the primary winding on the armature, whether stationary or rotating, the condenser, and the contact breaker. The secondary circuit consists of the secondary winding (whether located on the armature of the magneto itself in the form of a coil placed under the arch of the magnets in the magneto or placed independently of the magneto), the distributor, the cables leading to each of the spark plugs, and the safety spark gap. It will be noted that each case represents but one side of a circuit. The other side is grounded, that is, the current returns through the metal of the magneto in the primary circuit and through that of the motor

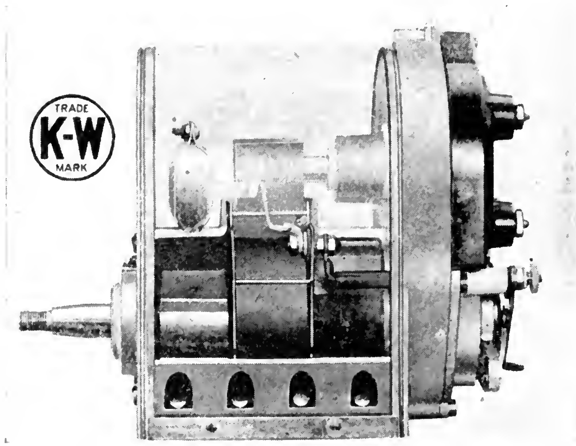


Fig. 41. Phantom View of Complete K-W Inductor Magneto
Courtesy of K-W Ignition Company, Cleveland, Ohio

and the magneto in the secondary. Thus a spark plug with a cable attached completes the circuit when it is screwed into the cylinder.

Contact Breaker. Regardless of detailed differences in their construction or design, all high-tension magnetos operate on the same principles, and in every case the contact breaker is the part of the magneto on which its continued operation depends. In Fig. 42 is shown a complete high-tension ignition system consisting of a K-W magneto and its connections for a four-cylinder motor. The contact breaker details are plainly shown just below the distributor of the magneto: C is a cam carried on the end of the magneto armature shaft; R is a roller carried at the center of a hinged arm which is pivoted at its right-hand end and is designed to minimize wear on the cam. At its left-hand end this same hinged arm carries a platinum contact point designed to make contact with a similar point that is held stationary, but is adjustable for wear. The hinged arm and the stationary contact point are attached to the contact breaker box *A*, which may be turned through a partial revolution in either direction to advance or retard the time of sparking.

The circuit through the primary winding on the armature is completed when the contact points *P* are together, and it will be

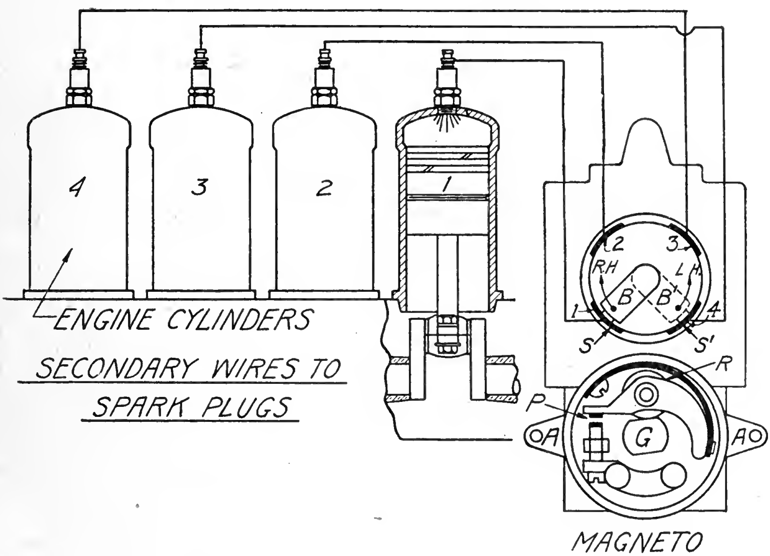


Fig. 42. Ignition Circuit of Four-Cylinder Motor
Courtesy of K-W Ignition Company, Cleveland, Ohio

noted that they are in contact with each other as long as the cam *C* is horizontal, so that current is flowing in this circuit. When the cam *C* turns so that it becomes vertical, it corresponds to the position of maximum current in the armature winding and the circuit is suddenly opened at that moment. This breaking of the current provides the impulse necessary to induce the maximum current and voltage in the secondary winding. At the same moment that the contact breaker opens, provided the motor is designed to turn to the right, or clockwise, the distributor contact *B* is passing close to *S*, which is the terminal representing the spark plug of cylinder 1. If it is a left-handed motor, the distributor contact B will be at the sparking point for cylinder 4 at S'. There is accordingly a path open for the high-tension current to the spark plug. As the distributor is driven directly from the armature of the magneto by gearing, Fig. 43, the distributor contact is at a point corresponding to the cylinder that is to be fired each time the contact breaker opens.

Firing Order. While these points on the distributor are numbered consecutively from 1 to 4, the cylinders of a four-cylinder motor cannot be fired in that order since the cranks of a four-cylinder four-cycle motor are spaced at 180°. In other words, there are two in one plane and the other two are in the plane

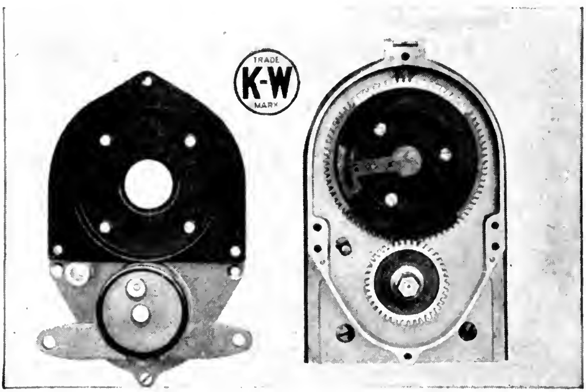


Fig. 43. Distributor End of K-W Magneto
Courtesy of K-W Ignition Company, Cleveland, Ohio

opposite, or half a revolution away. Consequently, cylinders in the same plane cannot follow one another in firing. This is made plain in the circuit diagram, Fig. 42. From this illustration it is evident that cylinders 1 and 4 have their cranks in the same plane, so that the cylinder to fire after cylinder 1 must be either 2 or 3. It will also be noted that contact 3 of the distributor corresponds to cylinder 4 of the motor, so that the firing order of this motor is 1, 2, 4, 3. The firing order most commonly adopted for four-cylinder motors is 1, 3, 4, 2 since this produces a somewhat better impulse balance by distributing the successive explosions among cylinders at equidistant points on the crankshaft. In checking up the ignition or making any repairs it is important to know what the firing order of the motor is, and this will usually be found stamped on it in some conspicuous place.

Care of Magneto. Since modern high-tension magnetos have their shafts mounted on ball-bearings, they require very little oil and that only at infrequent intervals. A few drops once a week in the case of some and once in two weeks with others is all that is necessary so far as lubrication is concerned.

The contact breaker is the most important part of the magneto and is the one that should be looked to first whenever the magneto fails to deliver a spark at the plugs, all other essentials of the system being in good condition. Long continued operation at full load is apt to burn the contact points away to such an extent that they do not come together when the cam is in the horizontal position. Or they become so pitted and covered with oxidizing material, which insulates them, that the current cannot pass even though they make contact. The contact points should be kept true and bright with a very fine thin file or with a strip of fine sandpaper, taking care to remove all traces of dust from the contact box by cleaning it out with gasoline or kerosene. Since the points are made of very expensive material, when they are trued up no more metal should be removed than is necessary to bring the surfaces squarely together. Much better service will be obtained from the magneto if this operation is carried out at frequent intervals, say once a month when the tractor is being used steadily, instead of waiting until the points get in such a condition that the magneto will not operate at all. If the contact points burn away very rapidly, it is an indication that the condenser has broken down and should be replaced. This is usually a job that must be referred to the magneto manufacturer. Apart from the attention required by the contact breaker, the only care that it is necessary to give the magneto is to keep it clean and well-oiled and see that its connections are always tight.

Spark Plugs. Regardless of how well every other part of the ignition system is working, a spark will not occur in the cylinder unless the spark plugs are in good condition. The spark plug is the business end of the entire system since its failure will render useless the perfect functioning of every other part. As will be noted in the sectional view, Fig. 44, a spark plug consists of two electrodes with a gap between them across which the current must jump in order to ignite the fuel in the cylinder. One of these electrodes is the outer shell of the spark plug itself and completes the circuit through the *ground return* when it is screwed into the cylinder head. The other, or central electrode, is connected directly with one of the points on the high-tension distributor of the magneto, so that the path of the current is down through this central electrode, across the gap to form the spark and back through the body of the motor to the magneto, which is also grounded by being bolted to the motor.

Importance of Insulation. No spark plug can be any better than the insulation which separates the two electrodes since the entire operation of the plug depends upon its preventing the escape of the current before reaching the gap. Like any other force under pressure, electricity will always seek the line of least resistance, and as compressed air has a higher electrical resistance than any solid insulator, the slightest leak in the insulation will open a path for the current and no spark will occur at the gap.

Fig. 44. Sectional View of a Spark Plug

Heat, vibration, hot oil, and soot are all enemies of the insulation, and under their combined attack it is bound to break down sooner or later. Soot, or carbon, which is an excellent conductor of electricity, is the commonest cause of spark-plug failure, but it does not necessarily put the plug out of commission for good. It is particularly difficult to prevent the accumulation of carbon on the ends of the plugs in an engine burning kerosene, but a good cleaning with a fine wire brush and plenty of gasoline is usually all that is necessary to restore them to service.

Common Plug Troubles. Apart from the difficulty of short-circuiting due to carbon collecting on the ends of the plugs, the commonest causes of trouble are due to a hidden breakdown of the insulation and to the burning away of the electrode points, so that the resistance of the gap becomes too great for the current to bridge. Porcelain is one of the best insulators known for the purpose, but it is difficult to make a porcelain that will withstand the intense heat and the vibration indefinitely, particularly as the material is already under stress due to the screwing down of the gasket nut of the plug in order to make it gas tight. When it becomes intensely hot, the vibration and pounding are apt to open fine invisible cracks in the body of the porcelain. The carbon is forced into these and forms a conducting path for the current. As this carbon cannot be cleaned out, the plug is useless until a new porcelain has been inserted.

In the same manner, the hot oil carrying a considerable percentage of carbon particles is forced into the mica insulation of a plug until it becomes so impregnated with this conducting material that it will no longer spark. Only the replacement of the electrode and its insulator will cure the trouble. Failure to spark due to the electrode points having been burned too far apart sometimes makes itself apparent by the current visibly passing over the outside of the plug. That is, instead of jumping the gap inside the cylinder, the current finds a path of less resistance across the surface of the insulator. This will sometimes occur when a plug gets extremely hot, even though the points are properly spaced, and since water is a good conductor, it will always take place if the slightest amount of moisture is allowed to fall on the porcelain of the plugs. Dirty oil will also provide a conducting path. When the electrode points have burned too far apart and no indication is visible at the plug itself, the spark will be noticed jumping the safety spark gap on the magneto.

Under the continued heavy service of a tractor engine that is being used for plowing ten hours a day and six days a week, it will be nothing unusual to have to adjust the spark plug points two or three times a week, particularly where cheap plugs are used, since the electrodes are of common iron and burn away very quickly. It is poor economy to buy cheap spark plugs, though it is not so great a sin as to buy cheap lubricating oil. The latter besides damaging the motor in other ways will cause added trouble with spark plugs of any kind owing to the excessive amount of carbon that accumulates in the cylinders. Leakage of compression through the plugs must be prevented by turning down the nut at the base of the porcelain to seat it on the gasket, but this must be done carefully or the porcelain will break.

Wiring. Moisture and oil are also enemies of the insulation of the high-tension cables that connect the distributor terminals of the magneto with the plugs. These cables must be kept clean and dry and their terminals at both ends must be kept tight with the cables in a position where they do not come into contact with one another or with the body of the engine as far as possible since despite the thickness of the rubber and the cotton insulation the high-voltage current will find a path through it at the slightest opportunity. When the cables have become soaked with oil and dirt, it is better to discard them and replace them with an entire new set as the value of the insulation has been destroyed to a large extent.

In order to make the cables flexible, they are made up of a large number of fine copper wires stranded together. When the cables become frayed at the ends next to the plug terminals, particularly, it is nothing unusual for one or more of these very fine strands of copper to project against the body of the plug or some other metal and thus cause a short-circuit that is not noticeable. Both ends of the cables should be well taped at the terminals to prevent this. Contact with any moving parts must be avoided as even a slight amount of wear on the insulation will lower its resistance to a point where the current will find a path through it. This is particularly true of cuts that penetrate both the cotton and the rubber, but which may be so small as to be imperceptible. Despite their size the current will leak through them if the cables come in contact with any metal parts since almost any path of this kind will present less resistance than does the gap of the spark plug, especially when the latter has been burned open too far.

Magneto Impulse Starter. Owing to the fact that it is not found practical in the majority of instances to carry a storage battery on a tractor, while the average tractor motor cannot be cranked fast enough by hand to start it with the ordinary magneto, an attachment has been designed for the latter by means of which it may be caused to generate sufficient current for a hot spark regardless of the speed of the engine. This is known as an impulse starter. It consists of a spring mechanism, which, when the engine is cranked, is automatically released, causing the magneto armature to turn through a partial revolution much more rapidly than the crankshaft.

Bosch. The details of the Bosch impulse starter are shown in Fig. 45, while Fig. 46 illustrates the magneto complete as equipped with the starter. Referring to the detail view Fig. 45, it will be noted that a dish-shaped flange is attached to the armature shaft and that this flange carries two cams on its periphery. In the view at the right is shown the crossbar member which forms an integral part of the starter driving shaft. The squared ends of this bar fit the openings of the flange mentioned. This bar *floats* on the helical springs shown, which are held in a circular recess and are secured to the starter shaft, which is also the main driv-

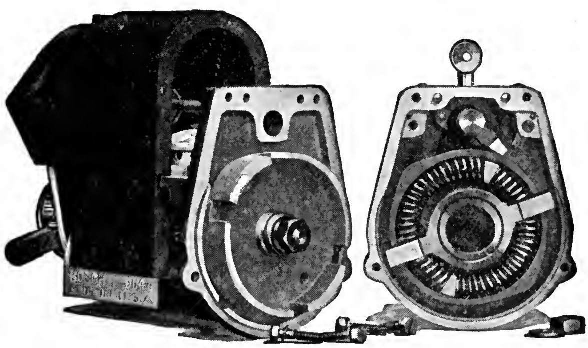


Fig. 45. Details of Bosch Impulse Starter
Courtesy of American Bosch Magneto Corporation, Springfield, Massachusetts

ing shaft, as is made clear in the assembled view of the magneto. The operation of this starter is controlled by a latch forming part of the external engagement lever, which is shown projecting upward. When it is not desired to operate the impulse starter, this latch is held away from the cams by a trigger. Releasing the trigger drops the latch, and the starter, or coupling shaft, is revolved, causing the spring to be compressed. Since the crossbar is held stationary, the armature does not revolve. By moving the small lever to the *release* position, the springs are freed and they give a rapid partial turn to the magneto armature. When the engine speed exceeds 150 r.p.m., the speed at which the cams strike the lever is sufficient to cause it to fly up out of the position where it is held by the trigger, so that the magneto operates in the usual manner. For starting large engines, it is customary to prime the cylinders with gasoline; the impulse starter lever is then moved over to the *engaged* position and let go. The engine is cranked to bring the piston in a cylinder that is about to fire a few degrees beyond the upper dead center on the firing stroke, and then the starter lever is pushed to the release position, causing a spark to occur in the cylinder under compression. To facilitate starting in this manner, a check mark may be made on the flywheel to indicate the starting position.

Eisemann. In Fig. 47 is illustrated the mechanism of the Eisemann magneto impulse starter, in which a spiral spring is employed as the driving element. For greater clearness, this

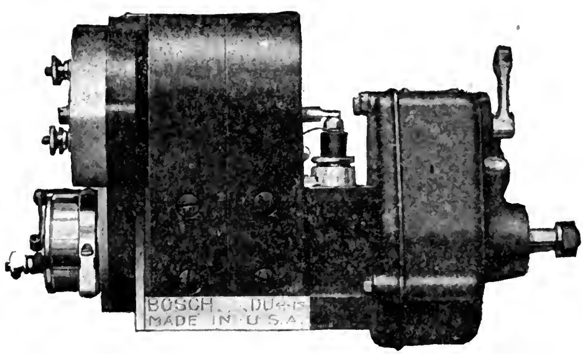


Fig. 46. Bosch Magneto Equipped with Impulse Starter
Courtesy of American Bosch Magneto Corporation, Springfield, Massachusetts

spring is indicated by dotted lines. The spring *S* is attached to the members *H* and *C*, the former being the housing attached to the magneto shaft and the latter the driving member; *B* is a fixed bar which is mounted on the base of the magneto; and *T* is a floating member, or trigger. When the motor is cranked slowly, the trigger *T* drops by gravity, engaging the bar *B* and temporarily preventing the rotation of the housing *H*. Since *C* is driven by the engine, cranking causes it to compress the spring, or wind it up, until the cam on *C* strikes the wedge *W*. This forces the trigger upward until it slips off the lower bar, thus releasing the housing *H* and causing the spring to give the armature a sharp partial turn. The right-hand illustration shows the relation of the members after the spring has been released and the magneto starter is in its normal running position. Stops are provided on the housing and the outer part of the driver *C* to prevent the armature from being turned past the position it must maintain to be properly timed to the engine. To hold the starter out of operation while the engine is running, *T* is heavily counterbalanced and as a result the action of centrifugal force on it draws the part *T* further in until the detent on it, shown just above the trigger

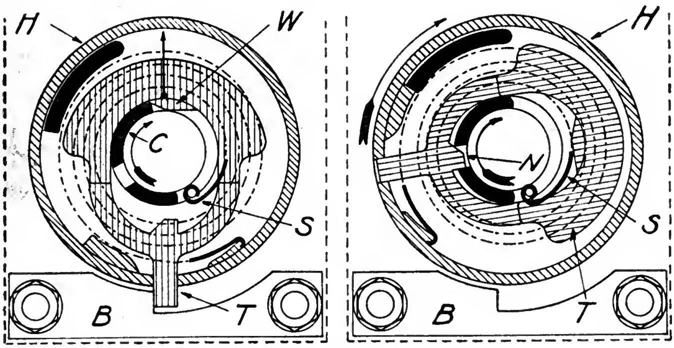


Fig. 47. Impulse Starter on Eisemann Magneto
Courtesy of Eisemann Magneto Company, Brooklyn, New York

itself, enters the notch *N* in the driving member *C*, where it is held as long as the magneto runs at its normal speed. As this notch provides a positive drive for the magneto independently of the spring, the starter acts merely as a coupling when running.

TYPES OF MOTORS

Wide Range of Types. When gasoline-driven tractors were first placed on the market with a view to providing a machine that could be more widely used than the steam tractor, they consisted of little more than a single-cylinder stationary gasoline engine on wheels. While tractor design has advanced considerably since that time, it is still a long way from having reached any standard as far as the power plant is concerned. Meanwhile, the automobile engine has undergone tremendous improvement, while its manufacture is now carried out on a scale that was not dreamed of fifteen years ago. As a result, the tractor engine has been developed under the influence of two widely separated standards, first, that of the stationary engine builder and second, that of the automobile engine manufacturer. There is, consequently, a wide

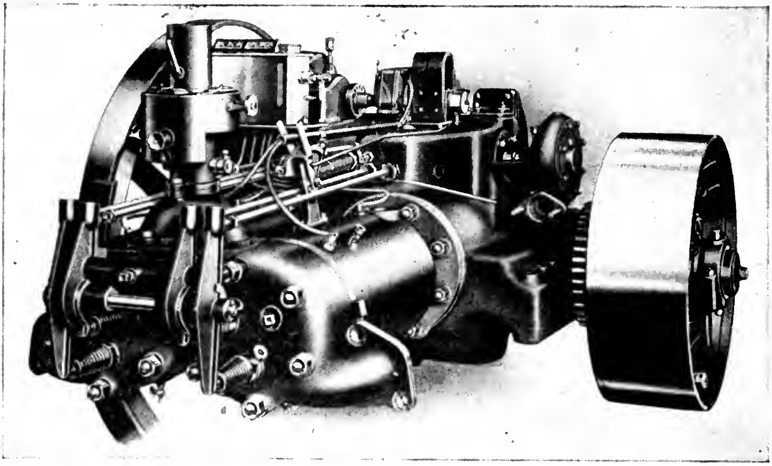


Fig. 48. Two-Cylinder Horizontal Motor Used on 20-40 Oil-Pull Tractor
Courtesy of Advance-Rumely Thresher Company, Inc., Laporte, Indiana

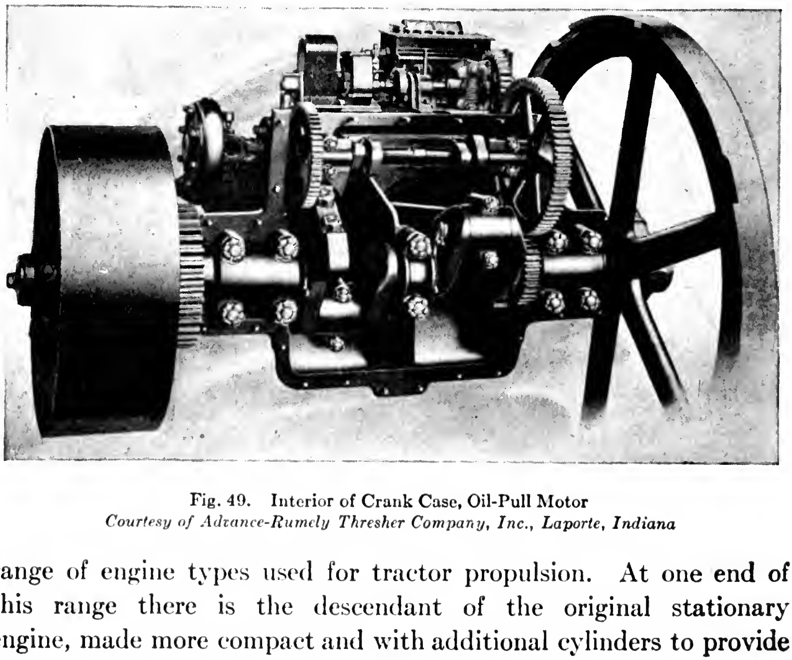


Fig. 49. Interior of Crank Case, Oil-Pull Motor
Courtesy of Advance-Rumely Thresher Company, Inc., Laporte, Indiana

range of engine types used for tractor propulsion. At one end of this range there is the descendant of the original stationary engine, made more compact and with additional cylinders to provide the needed extra power without excessive weight, while at the other extreme there is the light, high-speed, multi-cylinder motor, which to all intents and purposes is practically an automobile engine.

Horizontal Engine. *Oil-Pull.* To a large extent the horizontal engine is an outgrowth of stationary engine practice. A repre-

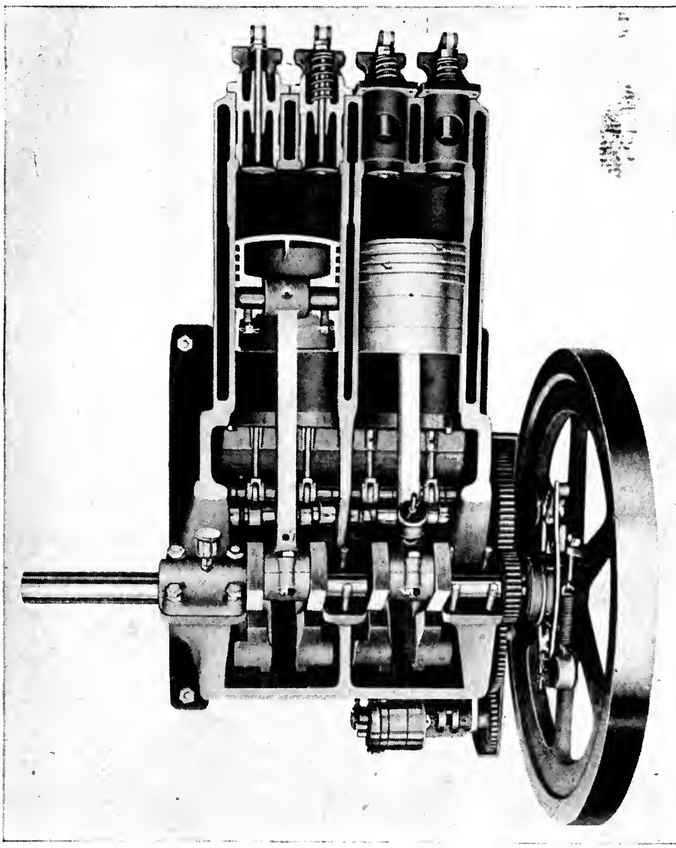


Fig. 50. Section of Eagle Two-Cylinder Horizontal Motor
Courtesy of Eagle Manufacturing Company, Appleton, Wisconsin

sentative example is illustrated in Fig. 48, which shows the 20–40 Oil-Pull engine. The cylinders are cast with separable heads and the valves, located in the latter, are operated by rocker arms. The carburetor, or fuel mixer, the magneto, the force-feed oiler, and the circulating pump are all placed on top of the motor for greater accessibility. Since splash lubrication cannot be used owing to the position of the cylinders, force-feed oilers with leads directly to each of the bearings are commonly used on this type of engine. In Fig. 49, is shown a head-on view of the same motor with the crankcase removed, showing the crankshaft and bearings, the camshaft and timing gears. The magneto, the circulating pump, and the force-feed oiler are also driven by the gears. In this engine the cylinders are slightly offset to reduce the pressure on the cylinder walls during the firing stroke.

Eagle. A clearer idea of the internal details of this type of engine is obtainable from the sectional view, Fig. 50, showing an

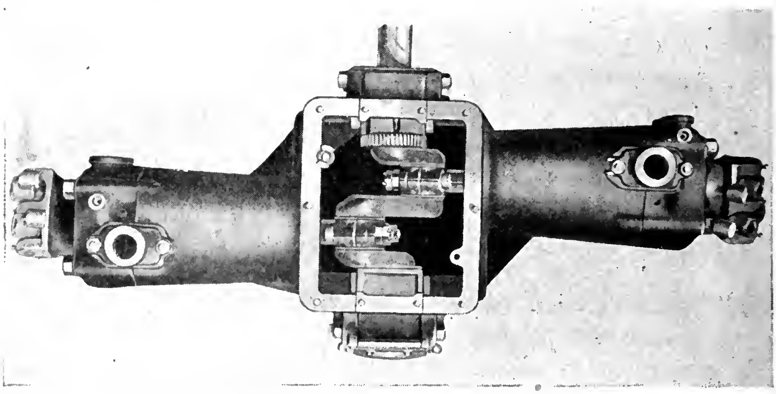


Fig. 51. Avery Two-Cylinder Horizontal Opposed Motor
Courtesy of Avery Company, Peoria, Illinois

Eagle two-cylinder motor. The upper cylinder has been sectioned through the center line of the piston, showing the piston pin and the inside of the valve cages, while the lower one illustrates the complete piston with its rings and the removable valve cages in the cylinder head. Whether it be horizontal or vertical, one of the advantages of the valve-in-head type of motor is the ease with which the valves may be kept in condition, grinding-in being an operation that must be carried out at frequent intervals on a tractor engine.

Horizontal-Opposed Avery. The horizontal opposed type was largely used on automobiles for several years during the early period of their development in this country. It provides better impulse and mechanical balance than the two-cylinder type in which

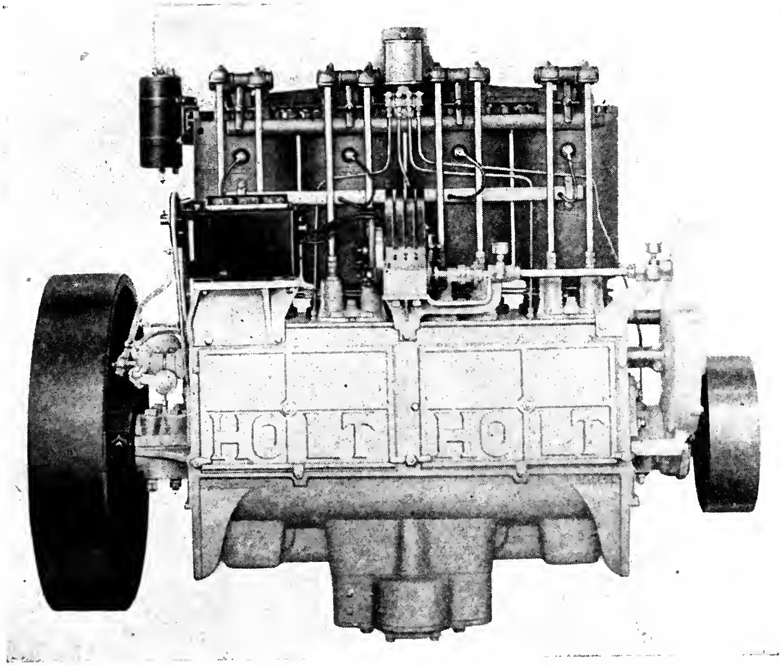


Fig. 52. Engine of Holt Caterpillar Tractor
Courtesy of Holt Manufacturing Company, Inc., Peoria, Illinois

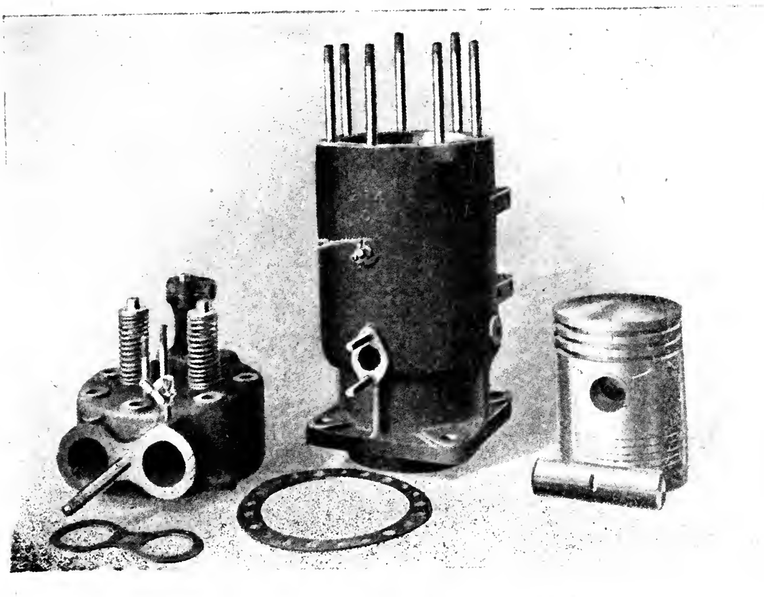


Fig. 53. Parts of Tracklayer Tractor Engine
Courtesy of C. L. Best Gas Tractor Company, San Leandro, California

the cylinders are placed side by side and is accordingly freer from vibration. In Fig. 51 is illustrated the Avery two-cylinder motor of this type, which is also built with four cylinders in the larger sizes. A novel feature of the Avery motor that overcomes the disadvantage to which this type was subject on the automobile is

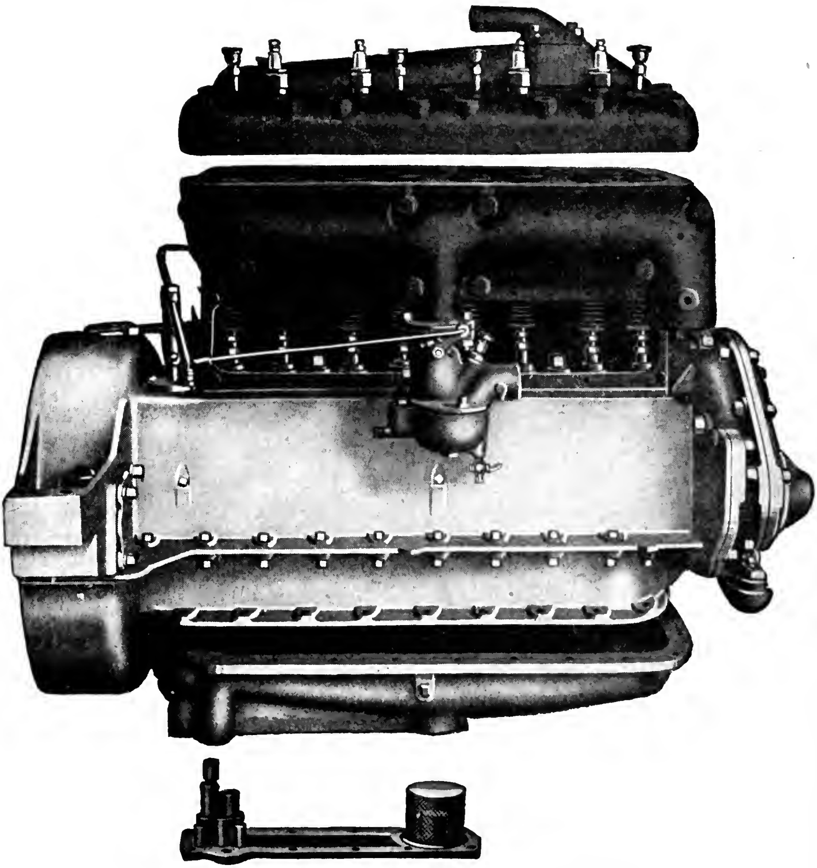


Fig. 54. Automobile Type Engine of Parrett Tractor
Courtesy of Parrett Tractor Company, Chicago Heights, Illinois

the use of removable cylinder liners. Owing to the weight of the piston resting on the lower half of the cylinder wall the latter wore out of round more rapidly than would the cylinders of a vertical engine in the same service. This destroyed the compression and involved the reboring of the cylinders and the fitting of oversize pistons. The Avery cylinder liners are cast of harder metal than the cylinders themselves and may be given a part turn from time to time so as to distribute the wear over the entire wall, while the liner itself may be replaced readily.

Vertical Motors. *Holt and Tracklayer.* All the horizontal motors described are specially designed for tractor service by the manufacturers of the tractors themselves and produced in their own shops. With comparatively few exceptions, most of the vertical types of tractor motors are the products of the various large

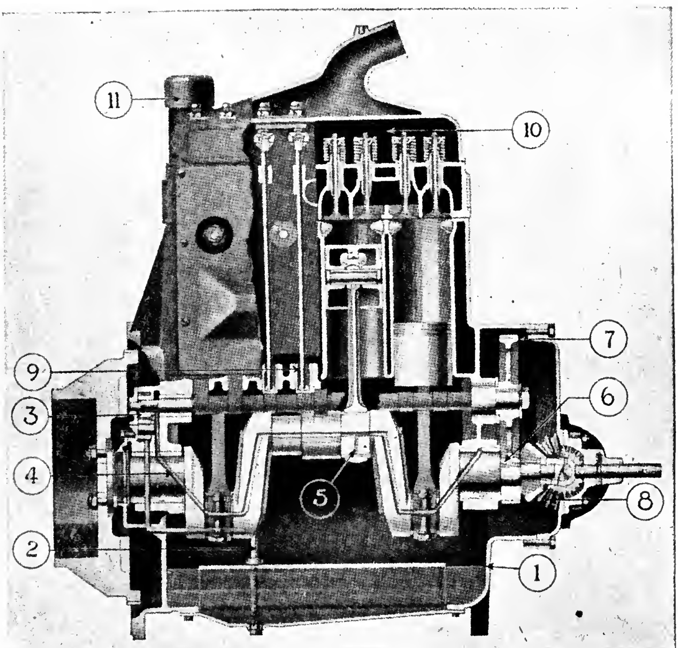


Fig. 55. Section of Moline Four-Cylinder Motor
Courtesy of Moline Plow Company, Moline, Illinois

automobile motor factories and are designed along lines that closely follow practice in the automobile field. One of these exceptions is the Holt motor shown in Fig. 52, while another of very similar design is the power plant of the Tracklayer tractor. Some of the construction details of this motor are shown in Fig. 53, which illustrates a cylinder casting, cylinder head with valves, piston, piston pin, and the cylinder head and manifold gaskets. Both of these motors are specially designed and built for tractor service and are of the slow-speed type best adapted for carrying a large percentage of their maximum load continuously.

Parrett. The Parrett motor shown in Fig. 54, while also designed for this service, follows automobile practice more closely. It is shown with the cylinder head casting and the crankcase oil pan removed to illustrate the accessibility thus obtained. Its smaller size and greater compactness is accounted for by the fact that it is a high-speed type, designed to produce its normal rated output at 1000 r.p.m.

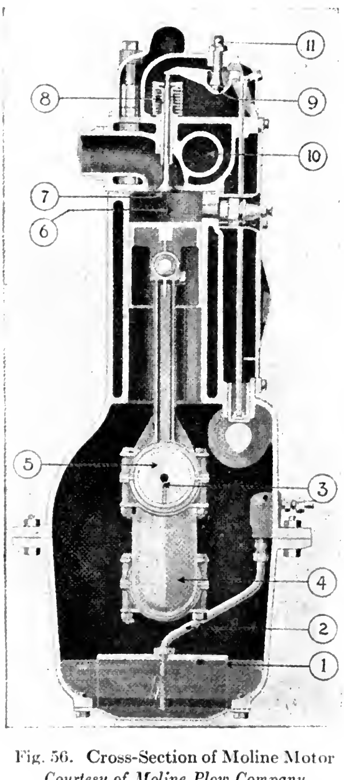


Fig. 56. Cross-Section of Moline Motor
Courtesy of Moline Plow Company, Moline, Illinois

Moline. Another motor of this class is the Moline, which is shown in longitudinal section in Fig. 55 and in cross-section in Fig. 56. These illustrations are taken from the Moline instruction book and the identification figures serve to make clear the functions of the various parts of a motor. From *1* to *5* in Fig. 55 they refer to the lubricating system, as follows: *1*, oil level in crankcase; *2*, suction pipe to oil pump; *3*, oil pump; *4*, oil conduit drilled through the crankshaft; and *5*, oil lead to crankpin bearings. Numbers *6* and *7* are the driving pinion and gear of the timing gear; *8*, a bevel gear for the belt pulley of the tractor; *9*, a valve tappet; *10*, the valve mechanism chamber; and *11*, the oil cap filler and *breather*. The latter admits air to the crankcase and is a necessary feature of all motors but is usually located directly on the crankcase itself. It is one of the points that must be carefully guarded against the entrance of dust and grit to the interior of the motor.

In Fig. 56 *1* is the oil screen; *2*, the suction pipe to the oil pump; *3*, the oil hole to the crankpin bearing; *4*, the crankshaft;

5, the crankpin; *6*, the combustion chamber of one cylinder; *7*, a valve; *8*, the valve spring; *9*, the rocker arm of the valve linkage; and *11*, the rocker arm stud; *10* is the intake passage. The details of the crankshaft and piston assembly are shown in Fig. 57, in which *1* is the oil outlet hole from the drilled crankshaft at the forward crankshaft bearing; *2*, the oil intake hole at the rear

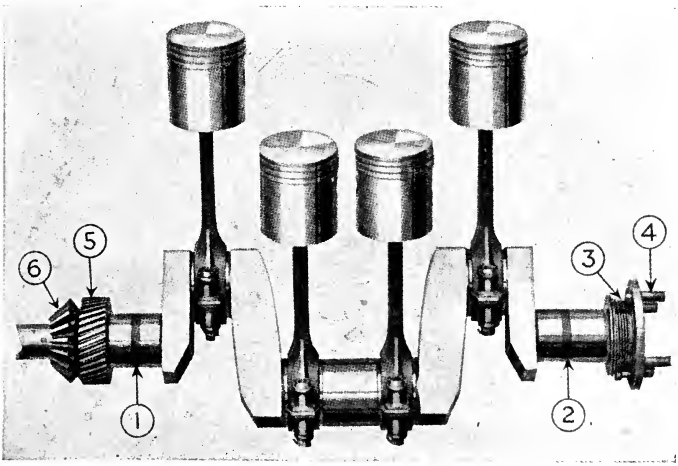


Fig. 57. Crankshaft and Piston Assembly of Moline Motor

crankshaft bearing; *3*, a series of threads designed to work the oil backward into the crankcase and prevent its entrance into the clutch housing; *5*, the helical half-time gear for driving the camshaft and auxiliaries; and *6*, the bevel pinion for driving the belt pulley. The bolts for fastening the flywheel to the crankshaft flange are identified by *4*.

FARQUHAR FOUR-WHEEL TYPE TRACTOR
Courtesy of A. B. Farquhar Company, Ltd., York, Pennsylvania

GASOLINE TRACTORS

PART II

CONTROL SYSTEM

ENGINE GOVERNORS

Need of Governors. *Plowing.* In order that a tractor may be operated most economically, it must be capable of one-man control since, in plowing, conditions are continually encountered where the driver's attention must be centered on the management of the plows and the steering of the machine to the exclusion of everything else. Moreover the demands upon the engine are continually varying even when the soil conditions are apparently uniform for long stretches. Stones, roots, and extra heavy patches of sod all impose considerable extra load on the engine that can be met satisfactorily only by an automatically controlled throttle if a uniform plowing speed is to be maintained.

Belt Work. A far greater load variation is encountered in belt work than in plowing, as in the former the engine may be running practically idle at one moment and be almost choked down by overloading the next, whereas in the latter there is always a load on the engine and therefore the danger of racing is absent. Irregular speed under changing load, racing of the idle engine, and tardy opening of the throttle to meet the increased load, all of which are unavoidable with hand control, represent conditions of operation which not only reduce production at the machine being driven but are very bad for the engine itself as they result in overheating, prevent proper lubrication, and, not infrequently, result in burned-out bearings. In any case the provision of a governor on the engine releases a hand for other and more productive labor. The majority of tractors go into service in the hands of an unskilled operator, and unless there is a governor on the engine, his course of instruction is likely to be marked by the occurrence of more or less damage that automatic control would prevent.

Centrifugal Governors. Despite almost innumerable attempts to displace it, the centrifugal principle first taken advantage of more than a century ago to control the speed of a steam engine is still in almost universal use for this purpose. Most tractor engines are equipped with what is commonly termed a fly-ball governor, though the details of the mechanism and the character of the throttle valve it is employed to control differ more or less. In its simplest form such a governor consists of two weights on the end of oppositely placed arms which are pivoted on a spindle connected to the throttle valve, either directly or through suitable linkage, so that any movement of the weights is communicated directly to the throttle. On a stationary engine the governor may

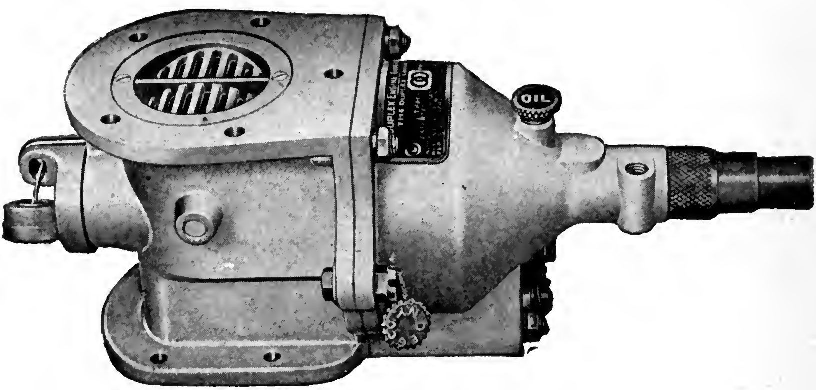


Fig. 58. Simplex Engine Governor
Courtesy of Duplex Engine Governor Company, Brooklyn, New York

be placed upright and is not subjected to vibration or jolting, so that gravity alone may be depended upon to keep the weights in their normal position, but on the tractor springs are usually employed, and the governor may then be placed in any position. When running below a certain speed, either gravity or the pull of the spring is sufficiently strong to keep the weights together against the shaft or close to it. But as the speed increases, centrifugal force acts on the weights and tends to make them assume a position at right angles to the shaft. The faster the engine runs, the closer the weights approach to this position, but as their movement brings about a proportionate closing of the throttle, the engine is not given an opportunity to increase its speed. A well-balanced governor of this type will operate so sensitively that there will be practically no perceptible change in speed between idling and full load. So far as the tractor is concerned, centrifugal governors are of two general types, those that are an integral part of the design of the engine and are built right into it and those that are in the nature of auxiliary devices designed to be attached to the inlet manifold between the carburetor and the intake valves.

Auxiliary Types. The Simplex governor, shown in Fig. 58, and the Pierce, illustrated in Fig. 59, are examples of governors designed to be adapted to any make of motor, the only modification necessary depending upon the details of the drive, since the governor must be driven directly from the motor itself. In the

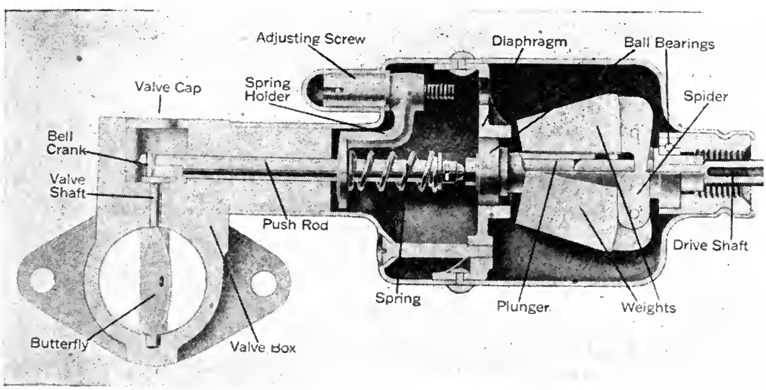


Fig. 59. Section of Pierce Engine Governor
Courtesy of Pierce Governor Company, Anderson, Indiana

Simplex the governor weights, which are housed in the casing just under and to the left of the oil plug shown, operate a grid valve the openings of which appear in the intake manifold flange at the left. The driving attachment, designed in this instance for a flexible shaft drive, appears at the right. Fig. 60 shows the attachment of a Simplex governor to a Continental motor, the drive in this case consisting of a solid shaft and bevel gears operating from the camshaft. The governor is set for the maximum speed to which the motor on which it is mounted is best adapted and is then sealed, as shown at the left end. As the governor mechanism runs in a bath of oil, it requires no attention except to replenish the oil from time to time.

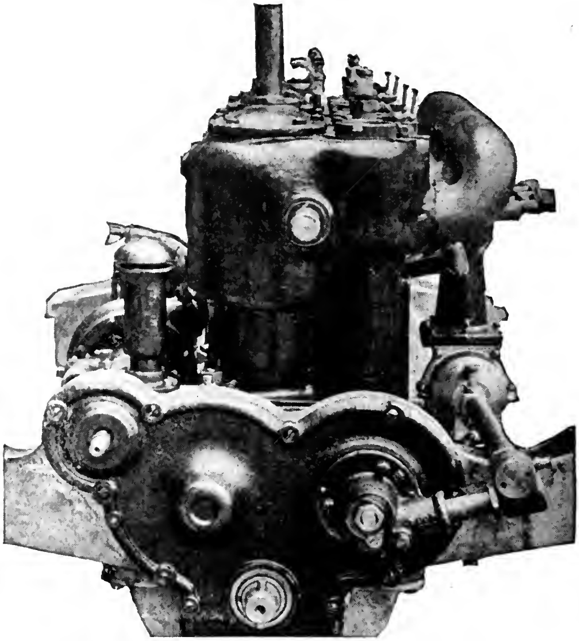


Fig. 60. Installation of Simplex Governor on Continental Motor of Bullock Tractor
Courtesy of Bullock Tractor Company, Chicago, Illinois

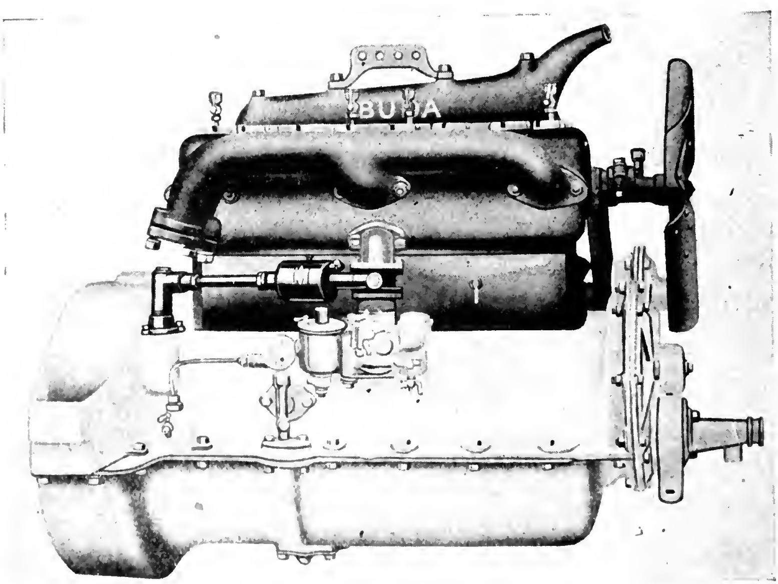


Fig. 61. Installation of Pierce Governor on Buda Motor
Courtesy of Pierce Governor Company, Anderson, Indiana

The Pierce governor, which is shown in horizontal section, operates a conventional butterfly type of throttle valve such as is used in the majority of carburetors. This valve is shown at the left, while the weights and the driving attachment are at the right. Between the two is the spring against which the centrifugal force of the revolving weights must act to close the throttle. Just above

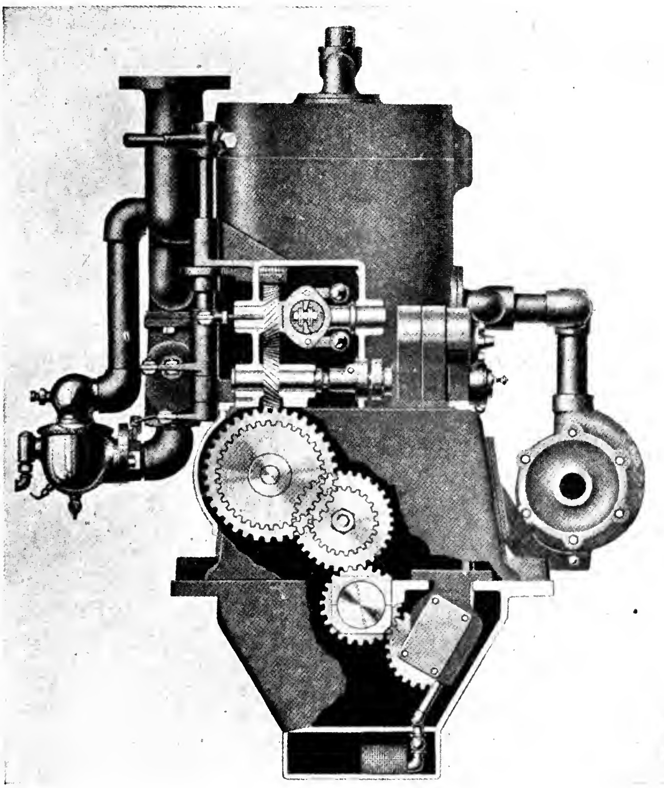


Fig. 62. Built-In Governor of Creeping-Grip Tractor
Courtesy of Bullock Tractor Company, Chicago, Illinois

the left-hand end of this spring will be noted a screw adjustment by means of which the speed for which the governor is set may be altered. Increasing the tension of the spring by screwing this in permits an increase in the speed of the motor since the weights must then revolve at a higher speed in order to overcome the pull of the spring. This is the principle upon which the adjustment of all centrifugal governors is based. One method of attaching the Pierce governor is illustrated in Fig. 61, which shows it mounted on a Buda motor and driven through bevel gearing from the camshaft.

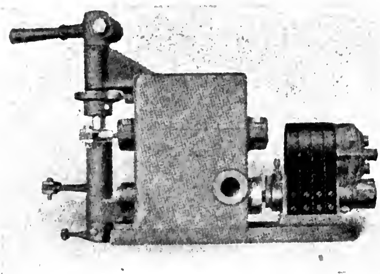


Fig. 63. Governor and Magnetic Unit of Creeping-Grip Tractor Motor
Courtesy of Bullock Tractor Company, Chicago, Illinois

Built-In Types. The part sectional end view of the engine of the Creeping Grip tractor, Fig. 62, illustrates an excellent example of a built-in governor. This is driven from a transverse shaft which takes its power through helical cut gearing from the timing gear of the motor, the same shaft also serving as the magneto drive. In expanding, the revolving weights draw in the sliding shaft shown, which is linked to a bell-crank lever at its outer end. The lever is attached to the throttle, which will be noted just to the right of the carburetor. This bell-crank lever is also attached by linkage to a dash pot to prevent the governor from "hunting," or "surging," as it is

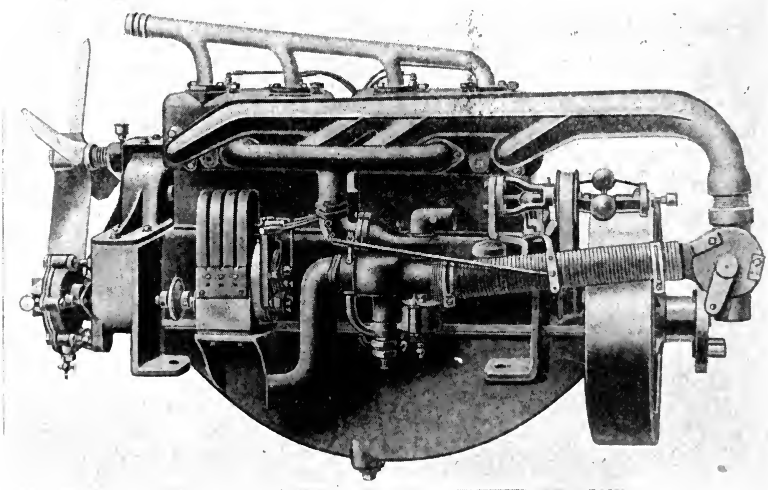


Fig. 64. Emerson-Brantingham Motor, Showing Governor
Courtesy of Emerson-Brantingham Company, Rockford, Illinois

variously termed, that is, fluctuating violently over a wide speed range. This governor is designed to control the speed of the motor between a minimum and a maximum of 400 to 700 r.p.m. and is adjustable by means of the hand lever shown in Fig. 63, which illustrates the combined governor and magneto unit before attachment to the motor.

In Fig. 64, which shows the complete power plant of the Emerson-Brantingham 12–20 tractor, is illustrated another type of built-in governor, the details of which are clearly shown. This governor is driven by a belt and is of the usual steam-engine type in which the weights are carried on leaf springs, the movement being transmitted to the throttle through the linkage shown.

TRACTOR CLUTCHES

Functions of Clutches. Since the internal combustion motor cannot be started under load and will stall if the load be applied too suddenly, even though the engine is developing its full power, it is necessary to employ a means of picking up the load gradually as well as of connecting or disconnecting the motor from the load as desired. This means is the clutch; and clutch problems on the tractor are the same in kind but greater in degree than those encountered on the automobile since the load to be started is so much greater. An automobile need start its own weight only and in doing so it encounters but slight rolling resistance, whereas the tractor must not only get a very much greater weight under way but in starting it must overcome the far greater resistance represented by the plows or other load and also that of the ground itself.

As a general rule the types of clutches employed on tractors are the same as those used on automobiles, but they are given a considerably increased area of contact surfaces and these surfaces are held together under much higher spring pressures in order to carry the heavier load. Regardless of its type, the principle of the friction clutch is based upon holding the driving surface (directly connected to the motor) and the driven surface (directly connected to the transmission or speed reduction gear) in contact under a pressure per square inch that is greater than that exerted by the engine in carrying the load. When the pressure required to carry the load exceeds that exerted by the clutch spring, the contact surfaces slide upon one another and the clutch is said to *slip*. Unless this slipping took place, some one of the links in the transmission between the wheels or tracks and the engine would have to give way or the engine itself would be stalled by the load. It is accordingly the function of the clutch to slip, first, to insure gradual engagement in picking up the load and, second, to prevent damage to the transmission or the motor when the load becomes excessive. The latter function, however, is more important in theory than in practice since an excessive load almost

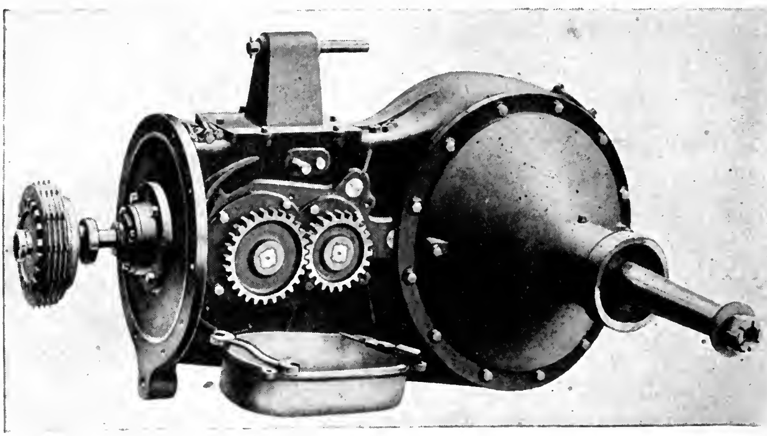


Fig. 65. Transmission Unit of Illinois Tractor Showing Multiple-Disc Clutch
Courtesy of Illinois Tractor Company, Bloomington, Illinois

invariably stalls the motor before the clutch begins to slip, unless its surfaces have become glazed through wear or its spring has weakened.

Types of Clutches. In practically every case the flywheel of the motor itself forms the driving member of the clutch. The driven member may be a cone faced with asbestos-wire fabric, a plate faced with similar friction fabric, or a contracting band similarly faced which is mounted so as to contact with the rim of the flywheel itself or with that of a smaller drum attached to the flywheel; or friction-faced shoes may be arranged to expand against the inner face of the flywheel. The moving force in every case is the clutch spring. In the order mentioned, these types are known as the cone, plate, contracting-band, and expanding-band, or expanding-shoe, clutches. Where a greater contact area is desired than is afforded by the diameter of the flywheel, a series of plates or discs is employed. These plates are divided into two groups, one of which is carried on spindles or bolts attached to

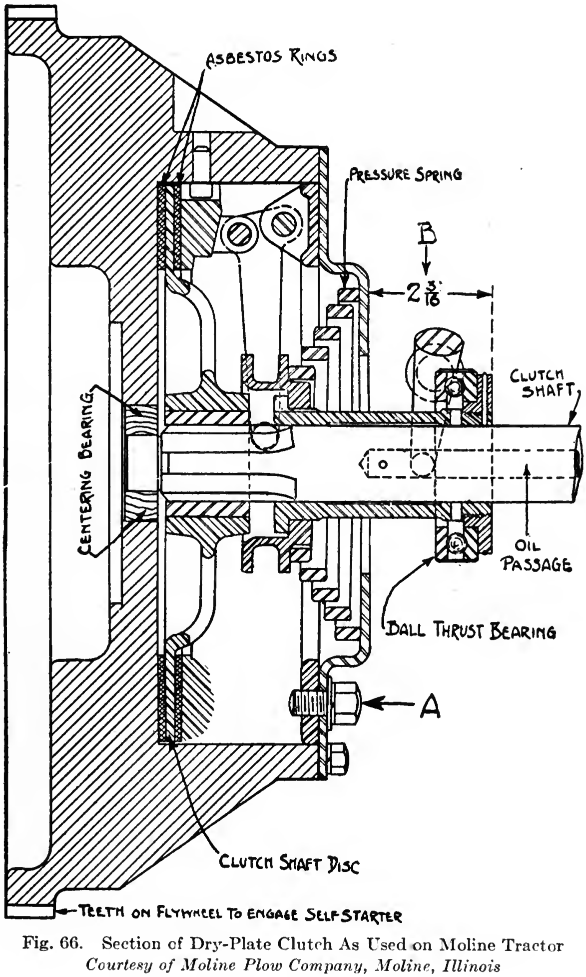


Fig. 66. Section of Dry-Plate Clutch As Used on Moline Tractor
Courtesy of Moline Plow Company, Moline, Illinois

the flywheel and forms the driving member, while the second group is similarly mounted on members attached to the clutch shaft and forms the driven member. When in engagement, the two groups are pressed together by the clutch spring in the same manner as in other types of clutches. This clutch is known as the multiple-disc type, and in some instances it operates in a bath of lubricating oil, the latter being squeezed from between the plates as they come in contact, thus ensuring gradual engagement. In Fig. 65 is shown the multiple-disc clutch of the Illinois tractor, the clutch being the small group of plates shown at one end of the transmission unit.

Plate Type. The sectional diagram, Fig. 66, not only serves to illustrate the details of the dry-plate clutch but also makes clear the principles of clutch operation. This is the Borg and Beck clutch as used on the Moline tractor. One of the asbestos

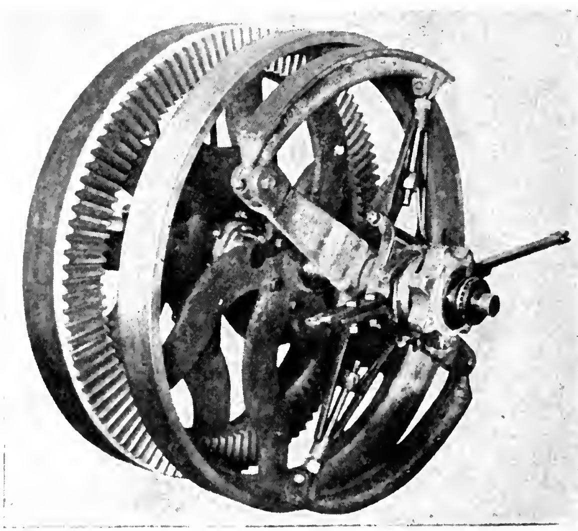


Fig. 67. Main Clutch of Holt Caterpillar Tractor
Courtesy of Holt Manufacturing Company, Inc., Peoria, Illinois

rings shown is attached to the flywheel, while the second ring is carried on the driven clutch member, while between the two is the clutch disc, which is a ring or disc of steel also attached to the clutch shaft. By means of the collar and toggle levers which multiply the force exerted by the spring, this clutch disc is clamped between the two asbestos rings when the clutch is engaged. The backward pressure, or reaction of the spring, is taken on the ball thrust bearing shown, this being an essential of all types of cone or plate clutches since otherwise this back pressure of the spring would cause considerable frictional resistance to the revolution of the clutch shaft. The screw marked *A* is an adjustment to maintain the distance *B* indicated, this distance being necessary for the complete release of the clutch when disengaged.

Expanding-Shoe Type. The Lauson tractor clutch affords an example of the expanding-shoe type which calls for very little

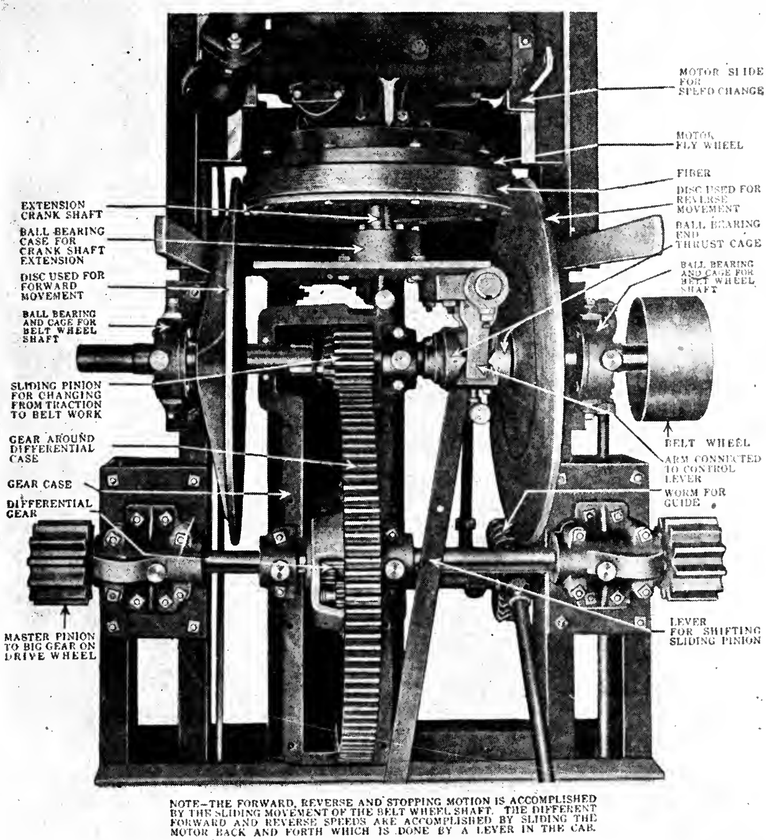


Fig. 68. Friction Transmission of Heider Tractor
Courtesy of Rock Island Plow Company, Rock Island, Illinois

explanation. Against the inner face of the flywheel are two pivoted shoes which are counterbalanced. These shoes are faced with asbestos brake lining and are designed to be held in contact with the inner face of the flywheel rim by means of the toggle mechanism shown. The spring has the same location as in other types of clutches, while its purpose, like that of other clutches, is to hold the clutch friction surfaces together under a pressure greater than that exerted by the engine in driving the tractor under load. The main clutch of the Holt caterpillar tractor is of a similar type, Fig. 67.

Contracting-Band Clutch. Neither the contracting-band nor the cone clutch calls for much description. The contracting-band clutch is practically a duplicate of the usual brake mechanism in which a friction-lined band is pressed against a revolving drum to bring the latter to a stop. In the case of such a clutch the object is to bring the contracting band to a stop on the drum, which is

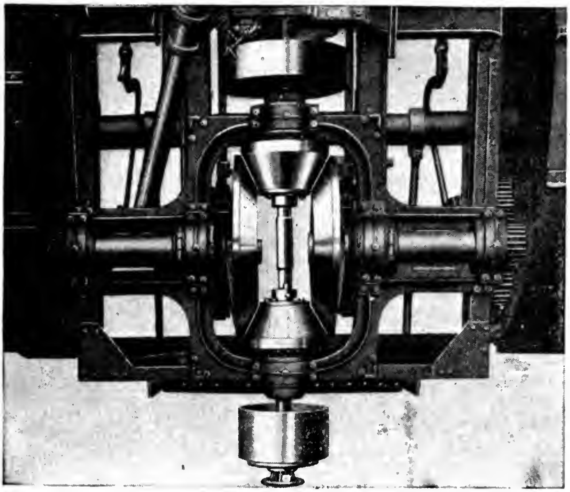


Fig. 69. Bevel Friction Transmission of Square Turn Tractor
Courtesy of Square Turn Tractor Company, Norfolk, Nebraska

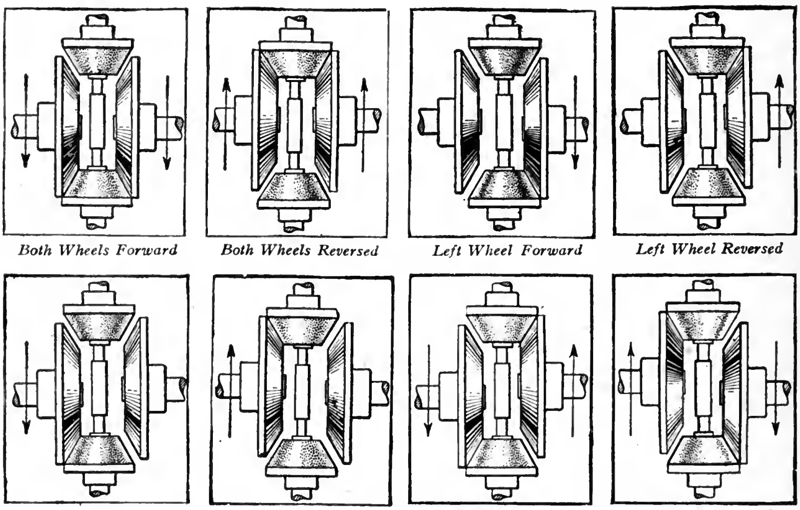
the flywheel, so that both the band and the flywheel revolve together, this really being the only difference between the brake and the clutch mechanism. The contracting band is attached to the clutch shaft, or driven member, and when in operation, revolves with it, thus carrying the load. This clutch is used in connection with a planetary type of transmission and is accordingly familiar through its employment on many thousand Fords.

Cone Clutch. In the cone clutch the inner face of the flywheel is turned to a bevel of approximately 30 degrees to form the driving member into which a cone-shaped member with the same bevel and lined with asbestos or other friction facing is pressed by the spring. Owing to the necessarily limited area of friction contact in this type of clutch, a high spring pressure is necessary where a heavy load must be transmitted.

On the automobile this spring pressure is very much less than on the tractor owing to the slight resistance encountered by the machine in starting, so that the clutch may readily be disengaged with the foot through the medium of a short lever and pedal, but on any tractor except a very light one the effort required to do this would be excessive. The usual method of clutch operation on the tractor is accordingly by means of a long hand lever provided with a ratchet or locking detent, so that the clutch may be held out of engagement. Since it does not benefit the spring to keep it compressed, the clutch should not be locked out of engagement any longer than is necessary to shift the transmission gears to neutral, when the clutch should again be allowed to engage. Holding the clutch out of engagement overnight or while the tractor is standing in the field subjects the clutch spring to abuse and will soon result in weakening it to the point where the clutch slips whenever any extra load comes on it.

Friction Drive. While all the types of clutches mentioned are, in a sense, a friction drive in that friction is depended upon to transmit the power, the so-called friction drive is one in which the load transmitting members revolve independently of one another except for a single point, or line, of contact. This is made clear by the illustration of the friction transmission of the Heider tractor, Fig. 68. The flywheel is the driving member, as usual, but in this case its entire outer rim is covered with a special friction facing consisting of hard fiber. The flywheel rotates between two large steel discs, either one of which may be pressed against it. In this instance the left-hand disc is used for forward movement and the right-hand disc for backing, or reverse. It is also apparent that the point at which the flywheel makes contact with the disc determines the speed at which the latter and the tractor itself are driven.

In the position shown the tractor speed will be the lowest provided, since the flywheel is in contact with the outer edge of the disc, so that the relation of the two is that of a small gear to a large one and the speed of the latter is reduced. As the flywheel moves toward the center of the driven disc, the relationship between the two becomes that of driving and driven gears which approach closer and closer to the same size, so that the speed of the driven member is increased. This movement of the flywheel is accomplished by mounting the motor itself on slides on the frame and moving it backward or forward by means of a large hand lever. The direction of movement of the tractor depends upon which disc is pressed against the flywheel.



Right Wheel Forward *Right Wheel Reversed* *Right Wheel Forward—Left Wheel Reversed* *Left Wheel Forward—Riget Wheel Reversed*

The two views above show positions of Bevels and Cones in making quick short turn either direction

Fig. 70. Details of Operation of Bevel Friction Transmission
Courtesy of Square Turn Tractor Company, Norfolk, Nebraska

Bevel Friction Drive. The form of friction drive employed on the Square Turn tractor is shown in Fig. 69. In this drive the principle is exactly the same as already outlined, except that friction-faced (fiber) conical members take the place of the flywheel as the driving member and corresponding cones of iron are the driven members. The design is also modified to permit of driving either rear wheel independently or both in different directions at the same time in order to turn short corners. The small diagrams showing the different relations in which the driving and driven members may be placed, Fig. 70, explain the operations much better than a description. A separate hand lever controls each of the driven discs, or traction members. Moving both of them forward drives the machine ahead through both driving wheels; pulling them back reverses the movement; and each may be used independently, so that one drives forward while the other is backing, thus turning the machine as if on a pivot.

TRACTOR TRANSMISSIONS

Speed vs. Weight. The power generated in an engine, whether by the expansion of steam or that of the ignited gases in an oil engine, is converted into mechanical energy by applying it to the movement of weight, and the power itself is represented by the extent of that weight and the number of times per minute that it is moved. Hence, for a given power the slower the speed at which the engine runs, the heavier must be the weight moved since it is set into movement a smaller number of times per minute. By increasing the speed, or number of impulses per minute, the weight moved can be correspondingly reduced. This fact explains why 25 hp. may be generated by a single cylinder stationary gas engine running at 250 r.p.m. or by a four-cylinder motor running at 1000 r.p.m. and why one motor is scarcely more than one-eighth the size of the other, although their power output is the same. The single cylinder engine will weigh 2 tons or more and will have flywheels of large diameter weighing more than the total weight of the smaller engine, but both move the same amount of weight per minute.

Automobile Practice. On the automobile the object of the designer is to keep the total weight down as much as possible consistent with reliability, so that light high-speed motors running up to 2000 r.p.m. or higher are employed. Such motors are practical for automobile use because the speed ratio between the driving and driven members—the motor and the rear wheels—is not excessive despite the high speed of the motor.

Tractor Practice. But on the tractor, where the maximum speed in plowing cannot exceed three miles per hour and is preferably less than that (2⅓ miles per hour is recommended by the Society of Automotive Engineers and most tractors are designed to plow at 2½ miles per hour), the higher the speed of the motor, the greater the number of steps required in the gear reduction, and each step represents a loss of power in friction as well as additional parts to wear out. Since the tractor is not subject to the same weight limitations as the automobile, there is no advantage in employing a light high-speed motor. Generally speaking, the slower the speed of the motor consistent with the avoidance of excessive weight, the better adapted it is to tractor use. The slow-speed motor running at 450 to 750 r.p.m. also has the further advantage of subjecting its moving parts to less rapid wear in service and, other things being equal, should require less attention to keep in satisfactory running condition.

Function of Transmission. In the section on tractor motors it has been pointed out that the types in general use belong to two distinct classes: those which have developed with the stationary engine as a basis; and those that are an outgrowth of automobile practice. In either case the engine will only develop its normal rated power when allowed to run steadily at a rate close to its maximum speed. A gear reduction must accordingly be interposed between the motor and the driving members of the tractor; the speed of the motor determines how great this reduction must be, while the space and the limit of weight available determine what form it will take. Whether consisting of a compact unit such as is used on the automobile or of large pinions and gears occupying the entire space between the frame members of the tractor, this speed reducing mechanism is usually termed the transmission. This name includes everything between the clutch and the final application of the power to the wheels or the tracks, which is termed the final drive.

Wide Range of Types. Since tractor motors differ so widely, there is naturally a correspondingly wide range of types of transmissions, the latter varying all the way from what is practically a duplicate of the gear train used on heavy steam tractors, or road rollers, to the light and compact gear box used on high-speed automobiles. A few illustrations of typical examples of each class will suffice to give an idea of how widely this feature of the tractor varies on different designs. In comparing these, it should be borne in mind that while increased width of gear face affords a larger wearing surface to carry the load and large gear diameter means fewer steps in the reduction, these advantages may be offset by the exposure of the gears to dirt and mud.

The great differences in size and weight, in many cases where the same amount of power is to be transmitted, are accounted for by a similarly great difference in the character of the materials used. Small pinions and gears running at high speeds must be made of alloy steels, hardened and toughened by heat treatment, and must be run in a bath of oil. Large broad-faced gears, on the other hand, may be made of steel castings or even cast iron, and it is the usual practice to run them to a great extent without protection.

Speeds. Since the speed range of the average farm tractor is necessarily very low, its requirements are usually covered by the provision of but two forward speeds and one reverse. A few machines are provided with three speed transmissions, but this is the exception and is due to the use of either a high-speed motor or an automobile-type transmission. On low gear, which is equivalent to a forward speed of about one mile per hour, the speed reduction between the motor and the driving wheels of the tractor may range all the way from 40–1 to 80–1, that is, the motor makes 80 revolutions to a single turn of the driving wheels in the second case mentioned. Such a great difference between the motor speed and that of the machine itself necessitates a number of gear reductions, each one of which involves a power loss in itself and also presents an extra wearing surface that needs replacement sooner or later. Generally speaking, the lower the speed of the motor consistent with the avoidance of excessive weight, the less loss there will be in the transmission of the power to the rear wheels or tracks, as the case may be. The point below which it does not pay to reduce the motor speed appears to line between 400 and 500 r.p.m., as beyond that the weight increases all out of proportion to the advantage gained, while the upper limit lies between 700 and 800 r.p.m.; that is, a low-speed motor would govern between these limits, say 450 to 750 r.p.m., and its transmission would be designed to take care of the difference between 750 r.p.m. and the number of turns per minute made by the driving wheels, which would depend upon their diameter.

A high-speed motor, on the other hand, would run at 1000 to 1200 r.p.m. and its power would fall off very rapidly the moment its speed dropped below 800 r.p.m. To avoid an excessive number of gear reductions, the driving wheels of a tractor equipped with a high-speed motor would usually be made comparatively small,

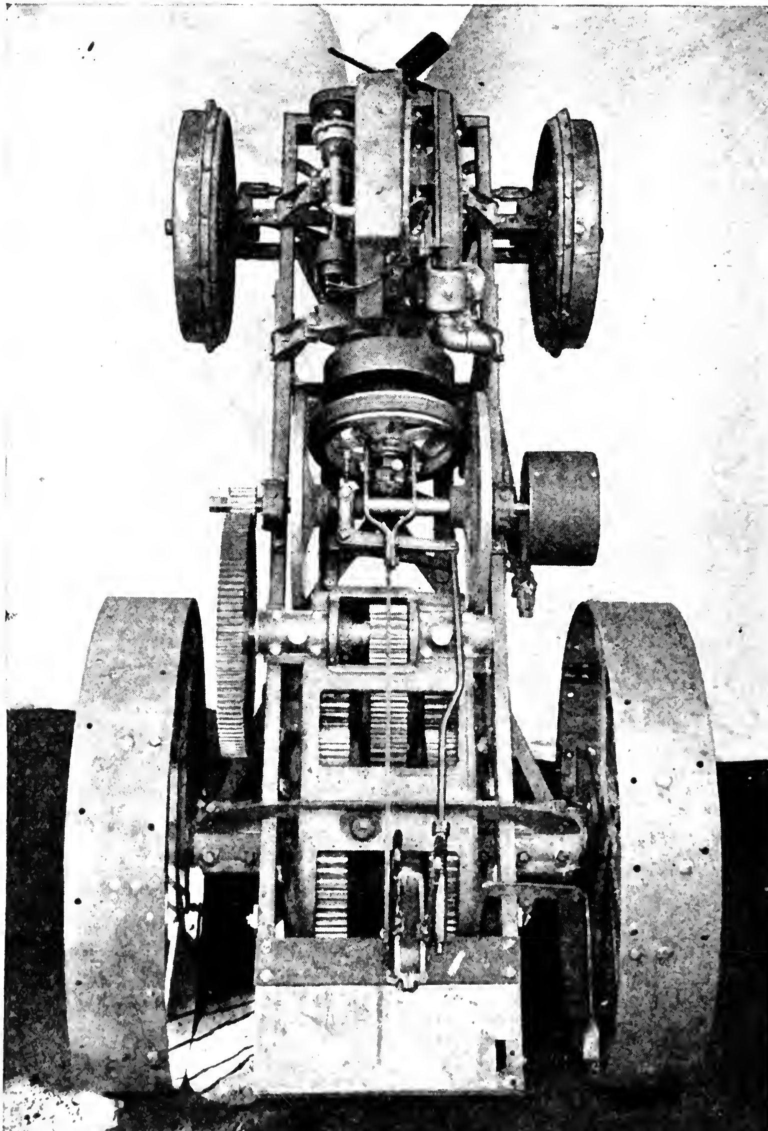


Fig. 71. Friction Drive of the Port Huron 12-25 H.P. Farm Tractor
Courtesy of Port Huron Engine and Thresher Company, Port Huron, Michigan

which is a disadvantage since such a tractor is constantly climbing the grade formed by its small wheels sinking into soft earth, or depressions, and is accordingly expending a large fraction of its

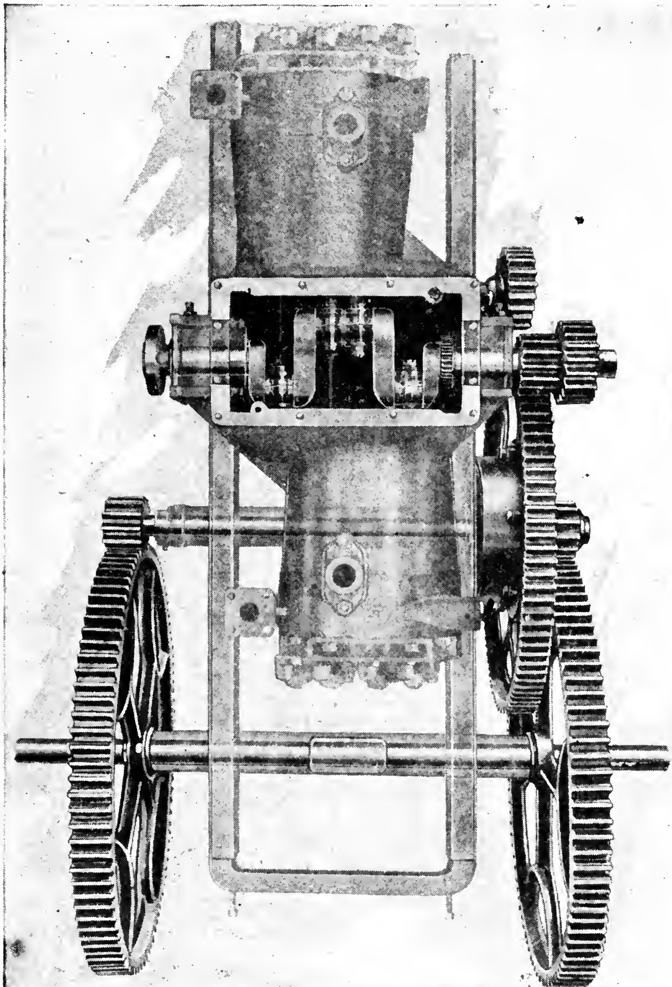


Fig. 72. Plan View of Avery Transmission
Courtesy of Avery Company, Peoria, Illinois

power in lifting itself rather than in driving ahead. It does not necessarily follow that a tractor equipped with a high-speed motor always has small driving wheels, since the reduction in speed required may be taken care of in the final drive.

Heavy Types. Those transmissions which, as already mentioned, represent a continuance of the practice followed for years on heavy steam tractors and road rollers are known as heavy types. Such a transmission is shown in Fig. 71, which gives a plan view of the Port Huron 12–25 friction-driven tractor. It also affords an example of a tractor with a comparatively high-speed engine equipped with large driving wheels. There are three gear reductions in all: the first will be noted at the left; the second is from this transverse shaft to a central gear on a shorter transverse shaft which also carries two small pinions meshing with the bull

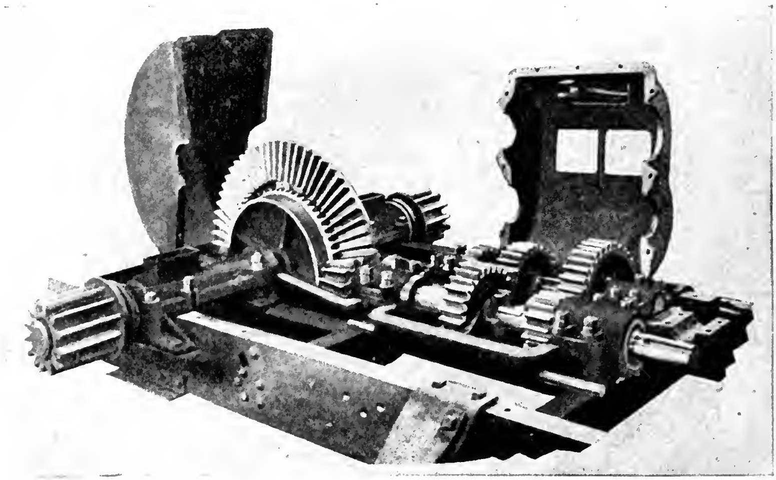


Fig. 73. Transmission and Differential of 75 HP. Tracklayer Tractor
Courtesy of C. L. Best Gas Tractor Company, San Leandro, California

gears. Ordinarily the bull gears are attached directly to the driving wheels, but in that location it is difficult to protect them, while in the present design they are completely encased.

Since a tractor must make very short turns and both wheels must be driven when going straight ahead, a differential is indispensable. When rounding a short turn, it will be evident that the wheel on the outside of the curve must travel a much greater distance than that on the inside and that if both were driven at an equal speed, one would be forced to slip and impose a heavy strain on the machine. If the ground condition were such that the wheel would not slip, rounding the turn would be difficult.

In the Port Huron tractor illustrated the differential is located in the second transverse shaft which carries the pinions meshing with the bull gears. As changes in speed are effected through the friction drive, the gears of this transmission are constantly in mesh.

The Avery transmission shown in Fig. 72, is another example of the heavy type, the illustration showing the relation of the horizontal motor to the transmission. The two forward speed reductions are represented by the two pinions of different sizes carried directly on the crankshaft of the motor, while the reverse speed is the pinion just forward of these. The transverse shaft just under the rear end of the motor embodies the differential the housing of which will be noted at the right. This shaft also carries the pinions meshing with the bull gears. The complete power plant is carried on a sliding frame, and the different speed changes are effected by moving the motor so as to bring the different pinions into mesh with the large gear carrying the differential.

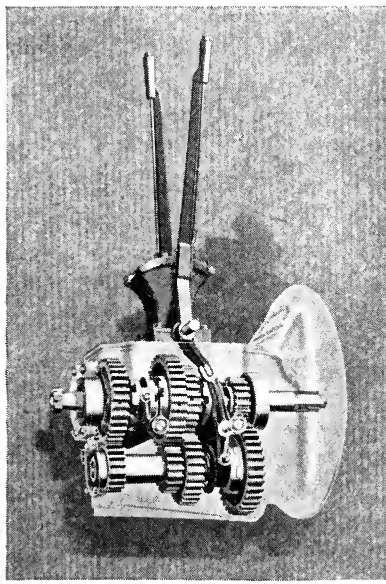


Fig. 74. Cotta Automobile Transmission of Dog-Clutch Type As Used on Four-Drive Tractor
Courtesy of Cotta Transmission Company, Rockford, Illinois

Intermediate Types. Between the heavy types just described and what is practically a motor-truck transmission, there are a number of transmissions that conform to some degree with automobile gear-box practice but are built on much heavier lines, for example, the transmission of the Best 75 hp. tracklayer type tractor shown in Fig. 73. Sliding gears are employed for the speed changes, and a bevel pinion and driving gear on the counter-shaft which incorporates the differential, the internal bevel gear of which shows plainly in the illustration. A typical automobile-type transmission is the Cotta, Fig. 74, as used on the Four Drive tractor.

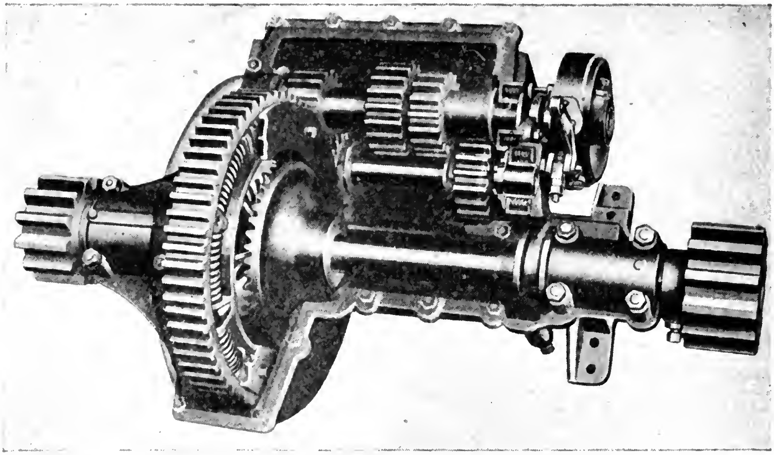


Fig. 75. Transmission and Spring Drive Differential of 16-30 Oil-Pull Tractor
Courtesy of Advance-Rumely Thresher Company, Inc., Laporte, Indiana

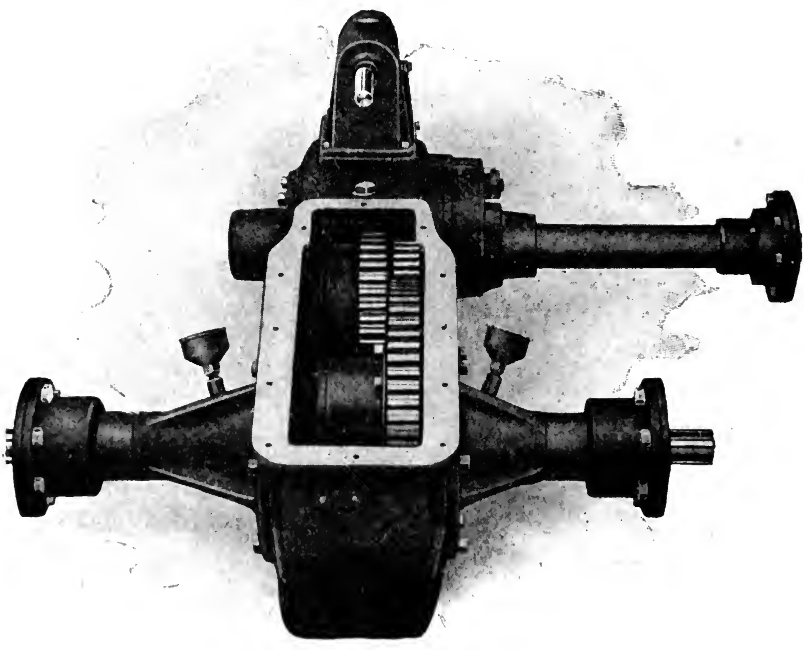


Fig. 76. Transmission of Turner Tractor
Courtesy of Turner Manufacturing Company, Port Washington, Wisconsin

A clearer view of the details of the mechanism of a differential is shown in Fig. 75, which illustrates the Rumely 16–30 transmission. One of the features of this differential is the use of a series of eight springs for taking up the shock of starting which will be noted just inside the large gear. Upon engaging the clutch, these springs must first be compressed before the load falls upon the gear teeth, thus cushioning the latter. Other similar transmissions are the Turner, Fig. 76, the Hart-Parr, Fig. 77, and the Nilson, Fig. 78.

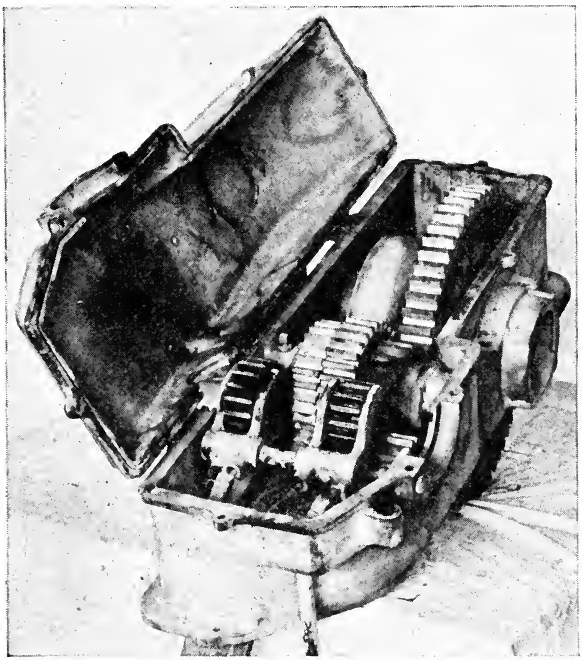


Fig. 77. Transmission of Hart-Parr Tractor
Courtesy of Hart-Parr Company, Charles City, Iowa

Special Types. In Fig. 79 is shown a plan view of the transmission of the Twin City 25–45 tractor, a feature of which is the use of toothed, or *dog*, clutches, the details of which are clearly shown. This view also shows the contracting-band clutch used on this machine. The dome just to the right of and forward of the flywheel houses the engine governor. Automobile practice is closely approached in the Yuba transmission, Fig. 80, and in the Holt caterpillar transmission, the gear box of the 10-ton Holt

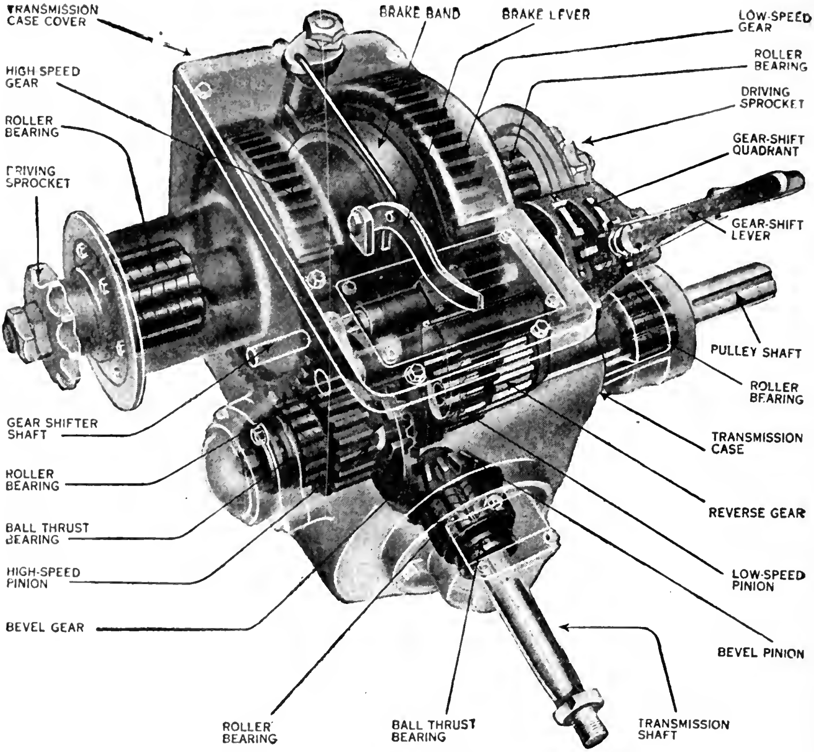


Fig. 78. Transmission of Nilson Tractor
Courtesy of Nilson Tractor Company

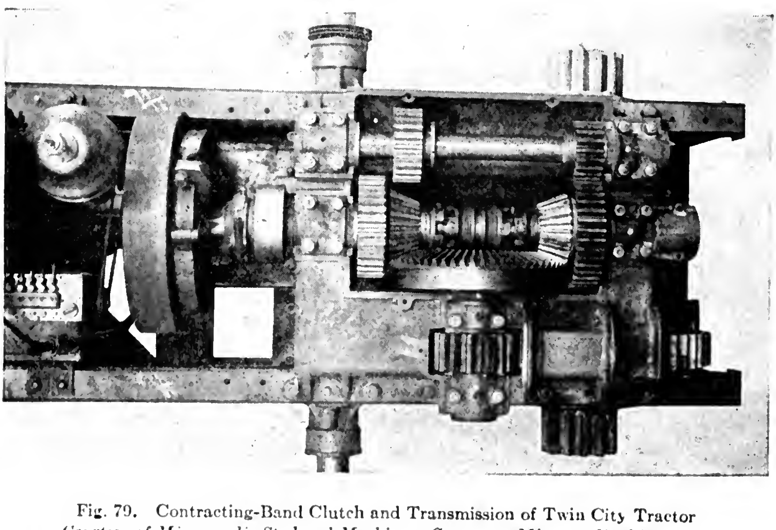


Fig. 79. Contracting-Band Clutch and Transmission of Twin City Tractor
Courtesy of Minneapolis Steel and Machinery Company, Minneapolis, Minnesota

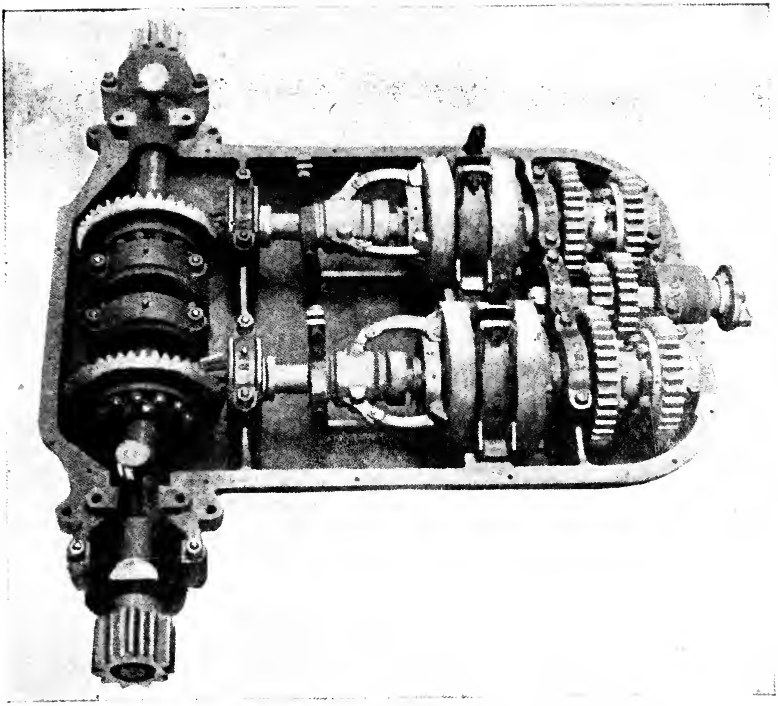


Fig. 80. Dual Automobile Type Transmission of Yuba Tractor
Courtesy of Yuba Manufacturing Company, Marysville, California

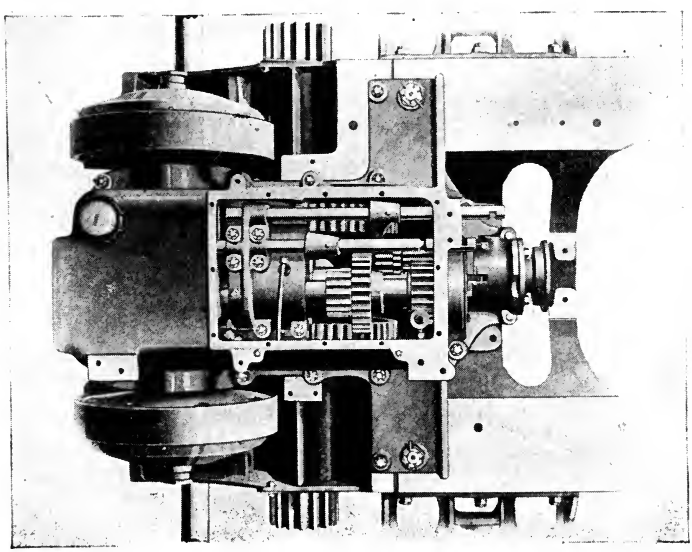


Fig. 81. Transmission of 10-Ton Holt Caterpillar
Courtesy of Holt Manufacturing Company, Inc., Peoria, Illinois

tractor being shown in Fig. 81. Both these types are of the selective sliding-gear type generally used in automobiles, the Yuba

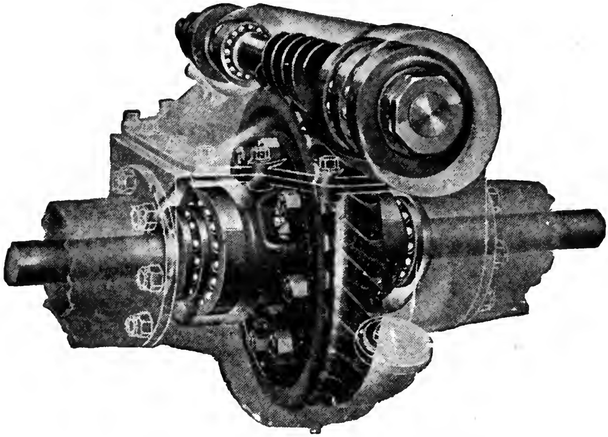


Fig. 82. Worm Drive of Sandusky Tractor
Courtesy of Dauch Manufacturing Company, Sandusky, Ohio

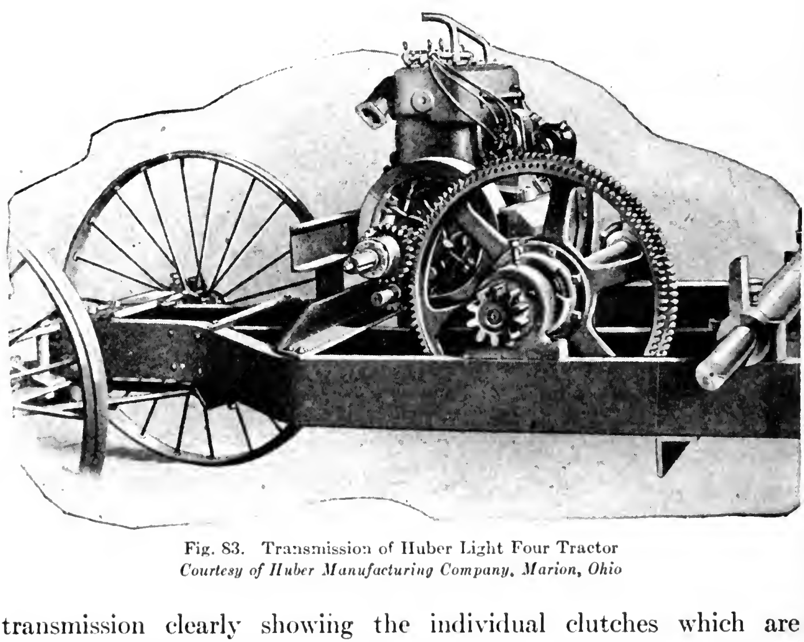


Fig. 83. Transmission of Huber Light Four Tractor
Courtesy of Huber Manufacturing Company, Marion, Ohio

transmission clearly showing the individual clutches which are used in the tracklaying machine to enable the operator to drive either track separately when turning. A feature taken directly from automobile practice is the use of the worm drive, Fig. 82. The Huber, Fig. 83, is a type that is in a class by itself. Its details and method of operation are clearly indicated in the illustration.

Final Drive. As in the case of the automobile there is a further speed reduction between the engine and rear wheels in the final drive, but as the speed reduction between the tractor engine and its driving members, whether the latter be wheels or tracks, is so great, this cannot take the form of a small pair of bevel

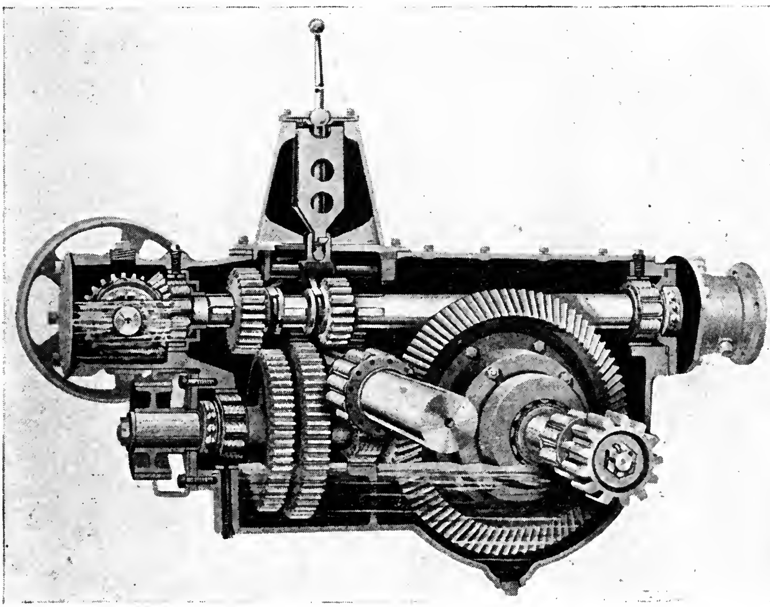


Fig. 84. Sectional View of Emerson-Brantingham Company Transmission, Showing Oil Level
Courtesy of Emerson-Brantingham Company, Rockford, Illinois

gears. The usual method is to employ bull gears, or internal gear rings of large diameter which are bolted to the driving wheels and with which small pinions on the ends of the transverse shafts of the change-speed gear mesh. In some instances automobile practice is followed by using a live axle. This is a combination of a sliding change-speed gear of the selective type with a planetary gear. The sectional view of the Emerson-Brantingham transmission, Fig. 84, clearly shows the relation of the selective sliding gears and the oil level necessary for lubrication.

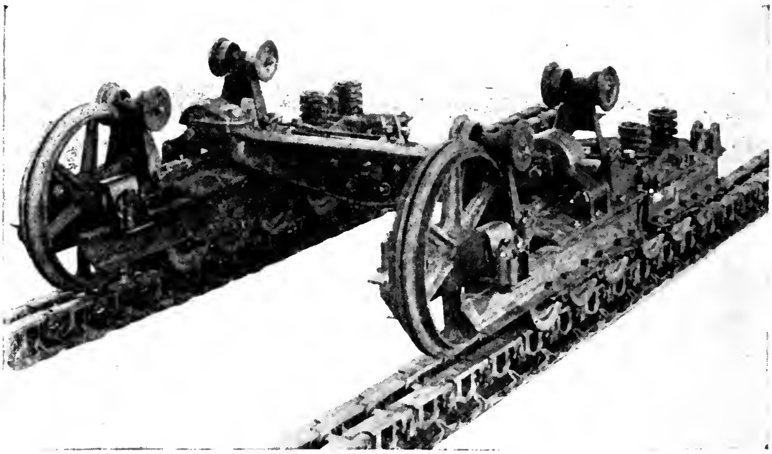


Fig. 85. Details of Final Drive, or Track of Holt Caterpillar Tractor
Courtesy of Holt Manufacturing Company, Inc., Peoria, Illinois

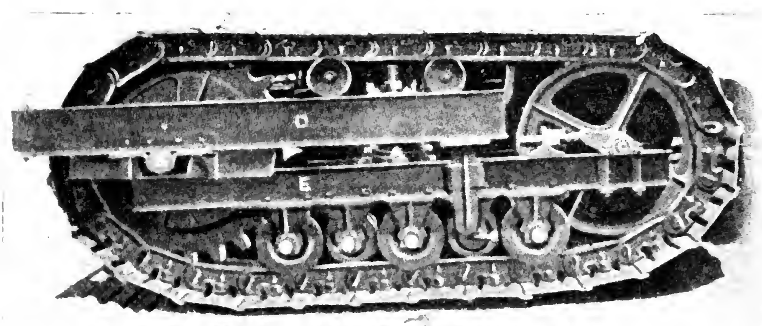


Fig. 86. Final Drive of C. L. Best Tracklayer Tractor
Courtesy of C. L. Best Gas Tractor Company, San Leandro, California

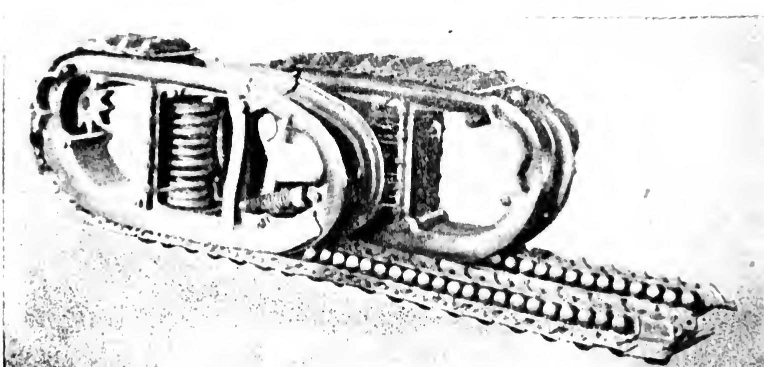


Fig. 87. Details of Final Drive of Yuba Ball-Tread Tractor
Courtesy of Yuba Manufacturing Company, Marysville, California

Final drive in tracklaying machines is usually through large sprockets on the ends of the transverse shaft, these sprockets meshing in the track itself. The track runs on rollers or balls and passes around an idler at the end of the tread, this idler being made adjustable so as to vary the tension on the continuous track. The details of the Holt caterpillar, the Best tracklayer, and the Yuba ball-tread machines of this type are shown in Figs. 85, 86, and 87, which make the principles of operation so clear that further explanation is unnecessary.

Only a brief mention has been made of a few of the different types of transmissions and final drives employed on tractors, there being so many that it would be out of the question to attempt to describe all of them, particularly since not a few have numerous special features. The foregoing examples, however, cover the principles employed in practically all tractor transmissions and suffice to make clear the manner in which these principles are applied.

TRACTOR OPERATION

GENERAL INSTRUCTIONS

Tractors Different in Design but Alike in Care Required. In the foregoing pages an attempt has been made to outline briefly the principles of tractor operation with just sufficient references to actual types to make the text clear. At the present stage of development it is hardly possible to select any one manufacturer's product as typical of tractor design in general or as embodying throughout those features of design which are most likely to become standardized during the next five years of development. There are so many different makes on the market and frequently so many models of each make that it would require a volume larger than the present one merely to give a brief description of all of them. Consequently, no extended descriptions of any tractors are given here.

While designs and details of construction differ so widely and so frequently, all oil or gas engine tractors are based on certain underlying principles and all call for the same kind of care. The remainder of this article is accordingly devoted to an outline of the methods of handling tractors in service with a view to pointing out clearly just the kind of care the machine needs to keep it running efficiently. To facilitate reference, this information is put in the form of questions and answers grouped under the particular subjects which they cover.

Degree of Care Necessary. Before taking up the detailed consideration of tractor operation it is well to revert for a moment to the comparison between the automobile and the tractor in order to emphasize the great difference in the conditions of operation of the two. It is a great mistake for the owner or operator of a tractor to conclude that because he can keep his car running for weeks at a time and subject it to the severest kind of service without being called upon to give it more than passing attention at infrequent intervals, the same amount of care will suffice to keep the tractor running equally well. The most severe service to which an automobile can be subjected is trifling compared to what a tractor must undergo in plowing ten hours a day. No comparison between the two is possible. The attention demanded in running a tractor is really only comparable to that required by a marine engine which is run steadily at full power.

It is naturally impracticable to employ more than one man to run the average tractor so that the single operator must assume the combined tasks of the oiler, engine-room attendant, and engineer on watch in the engine room of a steamer. He must see that every part is constantly lubricated, must watch all moving parts in sight from time to time and keep all his senses on the alert all the time to detect the first indications of overheating or faulty operation as evidenced by the sounds produced.

Parts Giving Most Trouble. Over two thousand tractor owners sent in reports in answer to a questionnaire forwarded to them by the Department of Agriculture. In answer to the question "What part of your tractor gives you most trouble?" more than seven hundred mentioned some part of the motor and of that number considerably over one-half gave the ignition as the chief source of delay. A leading tractor manufacturer substantiates this by stating in his instruction book that the motor is responsible for fully 75 per cent of all tractor troubles and that

70 per cent of the motor trouble is due to the ignition. A resumé of the answers sent in to the questionnaire follows:

Magnetos	299	Cylinders and pistons	61
Spark plugs	110	Clutch	59
Gears	108	Valves and springs	43
Carburetor	104	Lubrication	29
Bearings	80	Starting	28

The figures given in each case represent the number of tractor owners who gave the part in question as the chief cause of their troubles in operation. These figures do not, however, give any idea of the relative importance of the parts as sources of trouble. Failure of the magneto, or even of a spark plug, brings the tractor to a halt, but the trouble may usually be remedied in a very short time and no damage is caused, whereas a breakdown due to faulty lubrication, or to the failure of the cooling system, which is not mentioned at all, will usually involve the loss of anywhere from a day to a week besides a heavy repair bill.

Supply of Spares Necessary. The cost of an ample supply of spare parts is small compared with the time that is saved when the part most needed is right at hand and can be installed without delay, so that a number of spares of the most necessary parts should be considered part of the investment and be bought at the same time as the machine. Unless it be an ocean-going steamer, there is hardly another piece of machinery that performs such strenuous service so far from a repair and supply base as does the tractor. It would be just as foolish for the chief engineer of a steamer to leave port without any spare parts in the storeroom and still expect to arrive at his destination, regardless of what happened, as it is for a farmer to purchase a tractor and expect to get through his first, second, or any other season of plowing or threshing without vexatious delays unless he has on hand spares of the parts most frequently needed.

Manufacturer's Service Poor. While it would not be just to generalize by saying that the service rendered the purchaser by every manufacturer of tractors is poor, this is true in many cases and must always remain so for the farmer who is located miles from the nearest dealer representing the factory. It is nothing unusual to waste from half a day to a day, telephoning and waiting for a part to be sent out or driving in for it. The dealer may be off for the day in some other part of the county, making a demonstration or closing a sale, and there may be no one in his place of business to render the desired service. Meanwhile, the machine is standing idle. There are few replacements that the experienced driver of a tractor cannot make without other assistance than that provided by the usual farm shop, so that if the parts are on hand little time will be lost in getting the machine under way again.

Parts Needed. While the make of the tractor in question will determine the character of many of the spares that should be carried by its owner, there are some that are needed with all makes. These are valves, valve springs, and small parts needed in connection with the valves, ignitors, or make-and-break plugs for low-tension ignition systems, also ignitor trip rods, or rather the small parts which compose the fittings of the rod rather than the rod itself, since the latter is not subjected to wear. Spare connecting cables cut to length and fitted with terminals, whether for high- or low-tension systems, will often be found valuable. Extra fan belts and spark plugs should hardly be called spare parts in this connection since they are absolute necessities at comparatively short intervals. Hose connections between the motor and the radiator are also in the same class. Where a motor is equipped with die-cast main bearings or connecting-rod bearings, a spare set will often prove to be worth many times its cost in the saving of plowing or threshing time, since even well-attended machines do suffer breakdowns from burnt-out bearings at times. Extra piston rings as well as an extra piston and a connecting rod are likely to be called for sooner or later. The magneto is a pretty expensive piece of equipment and, moreover, it is usually so reliable that it will continue to work season after season without giving any trouble. But when it does break down, it is sometimes beyond the ability of the tractor operator to make the repair. Where two or more tractors are operated on a farm and the same magneto is standard on all of them, it would pay to invest in a spare, though at any time but the height of the season the laying up of one tractor would probably not cause any trouble.

The foregoing discussion has been confined to enumerating motor parts or accessories that should be carried as spares since they are common to practically all motors. So far as the rest of the machine is concerned, the owner must either learn from experience what parts are likely to wear out rapidly and need replacement at short intervals, or he must depend upon the manufacturer's representative to give him this information. Naturally, the maker and his salesmen do not wish to give the impression that any of the machine's parts will need replacement in a short time, and in a good many instances they are as much in the dark as the purchaser is, since it may be that the model has just been placed on the market and there has been no opportunity to learn its weak points in actual service.

Both the time spent in getting information of this kind and the money invested in the necessary spare parts will return very substantial dividends when the occasion arises to use the parts. There are some parts that may never be used, such as a steering knuckle. Get the manufacturer's representative to give you a frank opinion. Point out your position, when isolated, and do not content yourself with his first recommendations. Insist on finding out what are the weak parts of every important unit. The factory man has a good line on this by the extent of the demand for certain replacement parts. It will usually be found a paying investment to purchase a stock of almost all of them rather than take chances on getting the particular part most needed at a time when the tractor is worth a good many dollars an hour to you.

LUBRICATION

MOTOR LUBRICATION

Q. What grade of lubricating oil should be used for a slow-speed tractor motor; for a high-speed type?

A. Every responsible tractor manufacturer goes to considerable expense to determine just what grade of lubricating oil is best adapted to his own engines. His investigation covers everything from a chemical analysis and flash test of every grade of oil recommended for his use to actual tests in service extending over considerable periods of time. The tractor owner should accordingly never use anything but the oil recommended by the manufacturer.

Q. In a motor having any form of splash lubrication, that is, one in which part of the supply is carried in the crankcase pan, how often should the oil be drained from the crankcase?

A. The recommendations of different tractor manufacturers range all the way from every day to once in two weeks, many giving one week as the maximum period of time the same oil should be used.

Q. How often should the oil in a circulating system be completely replaced with a fresh supply?

A. It should be replaced at the intervals given above for a splash system since the service demanded of the lubricant is the same.

Q. Does oil lose its lubricating qualities through use, and how can this be determined?

A. High temperature and pressure completely change the character of lubricating oil and destroy its lubricating qualities. The lubricating quality of an oil depends upon its viscosity, that is, its *body*, upon which depends its ability to hold apart surfaces under pressure by a film of lubricant. Dip the finger ends in some old oil from the crankcase and rub together under pressure. The oil will have a thin watery feeling and the finger tips may be pressed into close contact through it. Try the same experiment with some fresh oil, and it will be noted that a sliding film is formed between the fingers despite the greatest pressure that can be put upon them to squeeze it out.

Q. What influence has the effect of high temperature and pressure on the length of time during which the oil should be allowed to remain in the crankcase?

A. Both the temperature and the pressure conditions differ widely in different engines so that in some the oil literally *wears out* much faster than in others and should accordingly be replaced oftener. The tractor manufacturer has learned from experience the proper period of time for his motors, and his recommendation is based on a desire to avoid having his customer pay for the same experience.

Q. Next to labor and fuel, lubricating oil is the most expensive item of tractor maintenance. Is it really economy to

replace what appears to be good oil as often as the tractor manufacturer recommends it?

A. The cost of repairs due to a single breakdown from failure of the lubrication would usually buy anywhere from one to five or more 50-gallon barrels of oil, without taking into account the loss of time due to the tractor being out of service. It is the highest form of economy to follow the maker's instructions in this respect; if these are to discard the oil at the end of every day's service, it will be found far cheaper in the end to do so. Many tractor owners do not regard it as necessary to clean out the crankcase more than once or twice a season, but instead of saving oil they are simply running up repair bills.

Q. What other causes tend to destroy the lubricating quality of the oil?

A. Another cause is leakage of the fuel past the pistons so that the supply of oil in the crankcase is thinned out by the gasoline or kerosene. This is particularly true of kerosene, especially if the motor be run at a low temperature so that the kerosene vapor condenses into a liquid. The admixture of carbon and dirt with the oil also tends to destroy its lubricating quality. Compare the color of oil that has been used for some time with fresh oil; the difference is due entirely to the foreign matter that has become mixed with it.

Q. What attention does a force-feed lubricator require?

A. The sight feeds should be watched frequently to note whether oil is constantly passing through them or not. To make certain of this, dirt should be wiped from the glasses at least once a day. While this type of lubrication has the great advantage of constantly feeding fresh oil to the bearings almost as fast as it is consumed, its factor of safety is not so high as that of the splash or circulating type. In other words, failure of the part is apt to follow immediately upon a stopping of the feed since it usually receives no lubrication from any other source. The lubricator must accordingly be watched closely and the engine stopped at once if any of the feeds has become clogged.

Q. How often should such a lubricator be supplied with fresh oil?

A. The maker's instructions may be followed but a still better practice is to get into the habit of keeping the lubricator constantly filled; that is, of filling it twice or oftener a day, if necessary, rather than waiting until the supply runs low. A gage glass on the side of the lubricator shows the amount in it. The plunger pumps which force the oil to the bearings will always work better when there is an ample supply.

Q. What other precautions should be taken with a force=feed lubricator?

A. When it is driven by a belt, close watch should be kept on the belt to see that it does not become too loose, since any slackening of the belt slows down the pumps and supplies less oil to the bearings.

Q. How often should a force=feed lubricator be cleaned out?

A. Two or three times a season should ordinarily be ample, but this will depend to some extent upon the care that is exercised in handling the supply of oil itself. Unless the oil supply is kept in a covered oil tank, more or less dust and other foreign matter is bound to find its way into it. The presence of dirt in the oil will make itself apparent by clouding the inside of the sight-feed glasses, making them difficult to read. Oil having visible foreign matter, such as small specks of grit, short ends of straw, or chaff, in it should never be put into the lubricator without straining, as it is liable to clog the pump valves.

Q. How is a force=feed lubricator cleaned out?

A. By disconnecting the leads and flushing it out thoroughly with gasoline or kerosene. The leads should be disconnected at both ends and also flushed out, blowing through them to see that they are clear from end to end.

Q. Are some of these leads more apt to clog up than others?

A. Those that supply oil to the pistons are most likely to clog owing to an accumulation of carbon in the ends opening into the cylinder. They should be taken off at shorter intervals and all carbon removed in the tube itself as well as in the opening through which the oil passes through the cylinder wall.

Q. What attention does a circulating system require?

A. A circulating system requires replenishing of the entire supply after washing out at intervals, as directed in the manufacturer's instructions; examination at short intervals of the oil pump; and frequent washing off of the oil pump screen. Keep the sight-feed glasses clean and shut down immediately if an oil stream fails to appear in any of them (some tractors have but one, others several).

Q. What general precautions should be observed in cleaning out a lubricating system of any type and in handling oil?

A. Always avoid the use of waste or rags from which lint will detach itself in wiping out the crankcase or any part of the system, since these threads will invariably clog an oil pump or feeder tubes. All cans or other vessels used in handling oil should be kept covered to prevent dust falling in them and should be wiped clean before using. Dust is simply fine grit, and its presence in the oil converts it into a grinding compound which will quickly cut away bearing surfaces.

Q. What other lubrication does the motor require?

A. This will depend entirely on the type of motor. Where it has overhead valves as used on many tractor motors, the rocker arm spindles and pin should be oiled at least once or twice a day with a hand oiler. This applies as well to any other external moving parts not lubricated by the oiling system of the motor. The grease cups on the fan and on the pump should be turned down at least once a day. Some tractors are equipped with gravity oilers for this purpose.

CONTROL SYSTEM LUBRICATION

Q. How is the clutch lubricated?

A. On some tractors it is enclosed in the same housing as the motor and runs in a bath of oil. Where it is not housed in, grease cups are usually provided on the clutch, and these should be turned down at least once a day. No oil should be allowed to fall on the facing, as this would reduce the holding power of the clutch and cause it to slip.

Q. What attention is required to keep the transmission properly lubricated?

A. When the transmission is of the enclosed type, running in oil, it should be kept filled to the height given in the maker's instructions and with the grade of lubricant recommended. Don't attempt to use cup grease, or a home-made compound of grease and oil or graphite, as the different materials will separate, nor should heavy steam cylinder oil be used, since it contains animal fats and will become acid, attacking the steel faces of the gears. The pressure between the gear teeth in a transmission is very high so that the oil *wears out* in time and should be replaced at intervals of two to three months. Watch the transmission housing for leaks and renew felt washers or other provision for preventing leaks.

Q. How are open transmission gears lubricated?

A. Where gears are run without a housing, they are not intended to be lubricated and care should be taken to see that no oil or grease gets on them as it will hold dirt and grit and cause the teeth to wear out much faster. The gears should be kept free of mud and dirt, but an oily rag or waste should never be used for this purpose. This also applies to the bull pinion and gear except where completely housed in.

Q. What attention is required to lubricate other moving parts of the tractor?

A. Grease cups are usually provided on all other moving parts, and they should be turned down as instructed by the maker. In some instances the directions are to screw these cups down as often as twice a day; in others, once an hour.

ENGINE PARTS

ENGINE BEARINGS

Q. How long will motor bearings run without developing sufficient play to require adjustment?

A. This will depend largely upon the motor itself and the service demanded of the tractor. If it is being run constantly with an overload, they will need attention much sooner than when the machine is not called upon to carry more than 75 per cent of its load for the greater part of the time. In any case the bearings should be examined at least once a week; some makers recommend that they be tested for looseness as often as twice a week when in constant service.

Q. How can the bearings be tested for looseness?

A. They should always be examined just after the motor has been shut down and is still hot; the amount of play will be greater when all the parts are cold but some of this will be taken up by the thickened oil film then present and their condition cannot be determined as satisfactorily. The connecting-rod bearings are the first to show signs of looseness. Take the handhole covers off the crankcase and turn the motor until two of the connecting-rod ends are close to the openings. If there is much play, it will be evident upon grasping the connecting rod and attempting to lift it, but this amount would usually cause a knock in operation. Take a small bar and pry the bearing upward from below, keeping the other hand on the rod to detect any movement. Do not confuse the side play of the bearing with looseness of the bearing itself as a small amount of side movement is allowed on all connecting-rod bearings. Apply this test to the other two connecting rods also. A bar may also be used to detect any looseness of the main or crankshaft bearings.

Q. Will it do any harm to allow a certain amount of play in these bearings?

A. Nothing will be apt to run up a big repair bill quicker than running the motor with the bearings too loose. Every reversal of movement pounds the crankshaft and in time will cause crystallization of the steel with consequent breakage of the shaft. The resulting vibration is also detrimental to every other part of the motor.

Q. How are the bearings adjusted when a test reveals play in them?

A. Most motor bearings are provided with shims, that is, small strips of metal placed between the halves of the bearing and through which the bolts pass to hold the bearing together. Take off one or more shims on each side of the bearing and screw down the nuts again tightly. To obtain a proper adjustment, you must be able to set up these nuts as far as they will go without binding the shaft. Open the pet cocks or the compression release, where one is provided on the engine, and try the adjustment by cranking the motor by hand. It will be very difficult to turn the motor over if the bearings are too tight. They should be adjusted so that the motor turns easily, indicating that there is sufficient space between the bearing halves and the shaft to permit the formation of an oil film between them. The shaft should be tested for play, as already described, to prevent making the adjustment too loose.

Q. When a bearing is too tight, is it good practice to ease off the nuts and let the shaft run that way?

A. A bearing is not properly adjusted unless the nuts can be set up hard on the bearing caps, all adjustments being made by removing or re-inserting shims, or laminations of metal only a few thousandths of an inch thick. One or two shims should be removed from each side at a time and the adjustment tested. Care must always be taken to see that the bearing cap is replaced on the bearing from which it was taken and that it is *put back in the same way*.

Q. Is it ever necessary to adjust the piston=pin, or wrist=pin, bearing?

A. This is the bearing which holds the upper end of the connecting rod in the piston and if the motor is properly lubricated with clean oil, it will seldom require any attention. In some motors the pin is held fast in the sides of the piston and the connecting rod moves on it, and shims are provided on the connecting-rod bearing for adjustment. In others the upper end of the connecting rod is clamped fast to the pin, and the pin moves in bronze bushings in the sides of the piston or bears directly on the piston walls. Allowing the big-end connecting-rod bearings and the crankshaft bearings to become too loose so that the motor knocks is the chief cause of lost motion in the wrist-pin bearing. Where the pin bears in the piston walls this may wear the holes out of round so that they have to be rebored and bushed to make a good bearing.

Q. When the connecting rod or crankshaft bearings of a motor require adjustment at frequent intervals, what is the cause of the trouble?

A. The cause is faulty lubrication: failure to clean out the crankcase at the proper intervals, with the result that the oil loses its lubricating qualities and the dirt that becomes mixed with it cuts away the bearing surfaces.

Q. Where bearings have become worn to the point where it is no longer possible to adjust them properly, is it practical for the average operator of a tractor to replace them with new bearings?

A. It is not practical unless he has had experience in the work, since it requires accurate lining up and scraping in of the bearings to a close fit. Unless this is carried out properly, such heavy stresses will be imposed on the crankshaft that it will break sooner or later. Therefore it is poor economy to attempt this repair without actually having had experience in making it; it is one of those things that cannot be learned from an instruction book. It is necessary to see it done in the shop more than once and the first attempt should be made under the supervision of one who has had experience.

VALVES

Q. What attention is required to keep the valves in good operating condition?

A. The valve stems must be lubricated one or more times a day, except on motors provided with special means for doing this automatically. The clearance between the valve tappet and push rod, or between the end of the rocker arm and the valve stem, depending upon the type of motor, must be adjusted at frequent intervals and the valves themselves must be ground as often as is necessary to keep them tight.

Q. Why is adjustment of the clearance necessary, and what should this be?

A. The constant hammering of the tappet or rocker arm against the valve stem tends to increase this clearance as well as to wear away the parts, thus increasing the distance. The greater this distance is the less the valve will lift when operated, so that less fuel is admitted on the intake stroke and some of the exhaust gases are left in the cylinder on the exhaust stroke, thus cutting down the power. This clearance should be just sufficient to allow the valve to close completely under the pull of its spring when the tappet or rocker arm is released by the cam. It should be tested and adjusted with the motor hot, since, if made very close when cold, the expansion of the parts is apt to prevent the valve from closing properly. An ordinary visiting card or a piece of tin plate makes a good gage; it should be possible to slip this between the tappet and stem easily. In any case the clearance should not exceed $\frac{1}{32}$ inch.

Q. How often should the valves be ground?

A. When a tractor is being used ten hours a day and six days a week, they will doubtless require grinding once every four to six weeks, depending more or less on the motor itself; some motors run very much hotter than others and in some the provision for cooling the exhaust valve is inadequate, so that more frequent attention is necessary.

Q. How may the valves be tested for leakage without taking the motor down?

A. Turn the motor over by hand about one-third of a revolution, until two of the pistons are within an inch or two of the upper dead center. At this point the pressure in the cylinder that is then on the compression stroke should be highest. Hold the piston up against this pressure, just exerting sufficient pull to cause the piston to move if the compression leaks away. In a motor that is in good condition, there should be no perceptible movement due to leakage in the course of two or three minutes, and if the pull of the hand is slackened, the piston should tend to push the starting crank down again under the influence of the pressure in the cylinder. Apply the test to each cylinder in turn and any difference in the compression-holding power of the different cylinders will be noticeable.

Q. When the usual adjustment of the clearance does not correct a loose and noisy valve action, what is apt to be the cause of the trouble?

A. The pin of the cam roller has probably worn so that there is considerable lost motion between the roller and the pin on which it turns. The only remedy is to replace the roller and pin or maybe the tappet complete. Any lost motion at this point permits the roller to move upward the distance represented by the wear before the tappet itself can lift. While the play at any one point may be very small, when it is increased by an equivalent amount at two or three other points, the total is sufficient to reduce the effective valve opening considerably, with a corresponding decrease in the power. When new parts are not readily obtainable, this condition may be remedied by boring out the holes of the cam roller and the rocker lever and fitting them with bushings.

Q. When grinding valves, is it necessary to continue the operation until the entire valve and seat have taken on a polish?

A. No; the operation may be considered complete when both the valve and the seat are smooth all around and completely free from any sign of pitting. A polished surface may give a little closer fit, but the difference is not enough to compensate for the time necessary to produce it. The grinding operation should always be finished by the use of the fine grinding compound.

Q. In case a motor has been allowed to run until the valve seats have become very badly pitted, is it necessary to cut these down by grinding alone?

A. No; a valve-seat reaming tool should be employed for cutting away the metal until the pitting has almost disappeared, and the remainder of the operation should then be carried out by grinding in the usual manner. No more metal than necessary should be removed with the reamer as cutting too deep will simply shorten the life of the cylinder casting. Valves are made in two standard tapers, 45 degrees and 60 degrees, and care must be taken to see that the angle of the reamer blades corresponds to that of the valve seat before beginning to cut.

Q. Is there any way of testing the tightness of the valves before putting them back into the motor?

A. When the valves are in cages, they may be tested by pouring some gasoline into the cage and noting whether it leaks past the valve or not.

Q. Does a rapid loss of compression under such a test always definitely indicate that the valves are at fault?

A. No; the piston rings may be worn or the lubrication may be poor, so that there is not a good compression seal in the cylinder. To definitely ascertain the trouble, take out the spark plugs and pour an ounce or two of heavy cylinder oil into each cylinder. Turn the motor over fifteen to twenty times with the plugs out to work this oil down on the pistons, replace the spark plugs and repeat the test as first described. Failure to hold compression will then mean poorly seating valves almost invariably, since, with a fresh oil seal, even loose piston rings will hold compression when the motor is being turned over by hand. The necessity for putting in this oil indicates that the oil in the crankcase or the circulating system needs renewing. This test for loss of compression should be carried out with the motor cold.

Q. What is the best method of grinding the valves?

A. With a valve-in-head type of motor, take the valve cages over to the bench so that there is no risk of getting any of the grinding compound into the cylinders. Use nothing but the specially prepared grinding compound designed for this purpose; ordinary emery and oil should never be employed as it will score the valve and its seat. When a special valve grinder is not at hand, a screw driver bit in an ordinary brace makes the best grinding tool. Smear some of the compound on the valve, drop it on its seat and turn it first one way and then the other, making about a quarter turn in each direction without exerting much pressure. When the compound has been squeezed out, put in more and continue the operation, repeating this for fifteen to twenty minutes. Wash the valve and seat off with kerosene and examine to see if all signs of pitting have been removed and the valve has a bright uniform band around its entire circumference. The presence of any breaks in this ring indicates low spots and calls for further grinding. Never turn the valve completely around when grinding, making only a quarter turn, since the complete turn will score the seat. Be careful to flush off every trace of the grinding compound with kerosene when through to prevent any trace of it getting into the cylinder. Otherwise, the engine will be ruined. Where the valves cannot be taken away from the motor for grinding, the greatest care must be exercised to prevent any of the compound from getting into the cylinders or down into the valve guides.

Q. Why is it necessary to grind the valves at such short intervals?

A. The exhaust valves in particular are subjected to exceedingly high temperatures that pit the metal face of the valve. Once this pitting starts, it proceeds rapidly and if the valves are allowed to run too long without grinding, these pits in the valve face will be so deep that new valves will be necessary. They will also be deep in the valve seat with the result that a correspondingly longer time is required to grind them out. By grinding at the proper intervals, only fifteen to twenty minutes will be required for each valve, whereas if they are allowed to run too long, it may take an hour or more to get each valve and its seat into proper condition again. The motor will also run very much better and deliver more power if the valves are kept in good condition.

Q. What is the cause of a valve leaking very badly at times?

A. Hard particles of carbon from the cylinder may lodge in the pitted face of the seat or valve and prevent if from closing tightly. Even though the valve be held off its seat only a few thousandths of an inch, it cannot hold any compression.

Q. What is the cause of a valve binding so that it will not operate?

A. Worn valve guides will sometimes permit sufficient side play to cause the valve stem to become bent. Lack of lubrication and an accumulation of dirt and carbon in the valve guide will cause the valve stem to expand to a point where it binds hard and fast in the guide.

Q. What causes a valve head to warp so that the valve must be replaced?

A. It may be caused by overheating of the motor due to partial failure of the cooling system, such as may be caused by a slipping fan belt, trouble with the circulating pump, shortage of water in the system, or the clogging of some of the pipes or the radiator. An accumulation of sediment or scale in the jackets or the radiator may have the same effect.

Q. Do valve springs ever need replacement?

A. In the course of a season's use, the temper may be drawn sufficiently to make the valve action sluggish, particularly in a motor that runs very hot, but ordinarily the valve springs do not often need replacement.

Q. Is it ever necessary to check the valve timing of the engine?

A. It is never necessary except in reassembling the engine after it has been taken down. Since the camshafts are made with the cams integral, no relative movement of the cams is possible and it is only necessary to time one cylinder. Most engines have reference points by which the valve timing may be checked when reassembling the engine.

PISTONS

Q. What attention do the pistons require?

A. The piston rings will wear to such a degree that the pistons no longer hold the compression and there is a substantial falling off in the power.

Q. How often should it be necessary to replace the piston rings?

A. This will depend entirely upon the care that is taken to keep dirt out of the lubricating oil and to prevent its entrance to the motor through the carburetor. If the oil is handled carelessly, containers being allowed to stand uncovered and a film of dust settling on them, or if the carburetor is not provided with an air cleaner, a great deal of grit will find its way into the motor and will grind the piston rings down rapidly and also the bearings.

Q. How may the pistons be tested for tightness?

A. The valves being in good condition, preferably recently ground, the test may be made as previously described for testing the valves; or, with the handhole plates off the crankcase, have an assistant turn the motor over slowly and note whether there is any sound of air blowing down past the pistons into the crankcase. Put a few ounces of fresh oil into each cylinder through the spark plug openings, replace the plugs, and repeat the test. Loss of compression may be due entirely to poor lubrication. Drain the crankcase, wash out with kerosene, and replenish the oil supply; and test in the same manner.

Q. Is wear of the piston rings the only cause for loss of compression, aside from pitted valves?

A. An accumulation of carbon under the piston rings may be holding the piston ring joints apart or the latter may have all worked into line so that the pressure is escaping through them. If, with good tight valves, there is still a loss of compression after putting fresh oil into the cylinders, it is an indication that the piston rings need attention.

Q. Does the compression fail in all the cylinders equally, or is one of the cylinders likely to be worse than the rest?

A. The wear is likely to be uneven, so that one or two of the cylinders will be found very much worse than the rest. Sometimes only one cylinder will fail to hold compression. Test in the same manner as described for the valves, pulling the crank up very slowly to note the resistance offered by each piston in turn as it comes up on the compression stroke. It may be found much easier to move one of the pistons than the others. When this is the case, it will be necessary to fit new rings on that piston.

Q. How are new piston rings fitted?

A. Oversize piston rings are supplied for this purpose. They are slightly larger (a few thousandths of an inch) than those originally supplied with the motor in order to compensate for the wear of the cylinder. Take the old rings off by inserting thin strips of steel (old table-knife blades or discarded hack saws are excellent for the purpose) at three or four points around the piston and under the ring. Scrape and wash out all carbon and gummed oil in the slots. Do not use a file for this purpose. First try the new rings by fitting them in the cylinder, which operation will show how much will have to be taken off to allow them to enter the bore. They must be small enough to insert an inch or two into the cylinder, since it is turned somewhat larger for a short distance at the end. If the rings are too large, take a few cuts with a fine file across the faces of the joint, being careful to keep the surfaces square and parallel. Very little must be taken off each time and the ring tried in the cylinder again. The job must be carried out with painstaking care as unless it is properly done the new rings will be no better than the old ones. When they have been properly fitted, use the same strips to place them on the piston, care being taken not to spring the rings out of round in putting them on.

Q. When fitting rings in the cylinder as a preliminary to putting them on the piston, should the break come together for a good fit?

A. No; allowance must be made for the lengthwise expansion of the ring due to the high temperature, and this allowance must be greater for the top ring than for the lower ones as it becomes hotter. Depending upon the diameter of the cylinder, it is customary to allow $\frac{20}{1000}$ to $\frac{30}{1000}$ inch between the ends of the topmost ring and $\frac{10}{1000}$ to $\frac{15}{1000}$ inch for the other two. Bearing shims are often stamped with the thickness in thousandths of an inch and may be used as a gage. Unless this allowance is made, the expansion of the ring will cause it to bind against the cylinder wall and may cause scoring.

Q. Must the piston ring be a tight fit in the piston slot?

A. Allowance for expansion must also be made here. After scraping the piston slots free of carbon and washing them out with kerosene so that they are perfectly clean, insert the ring and see that it turns freely in the slot. A piece of coated catalog paper has a thickness of $\frac{4}{1000}$ to $\frac{5}{1000}$ inch and it should be possible to insert a piece of this paper between the ring and the slot. If the rings are too tight they will bind on the piston and cause damage as mentioned above. Unless they can be moved freely in the slots, they will have to be made smaller by taking metal off the bottom edge of the ring. Smear some valve grinding compound on a flat metal plate or a smooth piece of hardwood plank and rotate the ring in this under pressure with the hand. Be sure to wash off all traces of the grinding compound before trying on the piston again.

Q. Do the pistons themselves ever have to be replaced?

A. The same condition that causes rapid wear of the piston rings, that is, dirt in the lubricating oil, will also cause equally rapid wear of the pistons. When this wear amounts to $\frac{15}{1000}$ to $\frac{20}{1000}$ inch, the piston will rock on the piston pin in the cylinder and produce a distinctive noise, known as *piston slap*, which cannot be traced to any other cause. At first, it is likely to be attributed to a loose bearing, and as it increases it will greatly resemble a bearing knock. When one piston reaches this stage, it is better to replace all of them with oversize pistons. The cylinders should be examined carefully for scoring and tested to see if they have worn out of round as it may be necessary to rebore them or to replace the cylinder casting to make a good job of it.

Q. Can the pistons be tested for looseness without taking the motor down when a knock cannot be traced to any other cause?

A. The amount of wear that will cause considerable piston slapping is so small that it would be difficult to detect it without having the cylinder and piston on a bench where the fit can be examined closely. The average driver would never attribute the loud knocking caused by a loose piston to the apparently slight amount of play that is revealed when the piston is examined.

Q. What causes besides dirt in the lubricating oil will bring about rapid wear of the pistons or scoring of the cylinders?

A. Other causes are the use of a poor grade of oil, using the same oil too long, or any other condition that results in inefficient lubrication, such as overheating due to partial failure of the cooling system. Unless there is a good oil film between the piston and the cylinder, the metal comes into actual contact and scoring follows. Too thin an oil will be burned away by the heat of the explosion as fast as the film is formed on the cylinder, while too heavy an oil may not reach the upper end of the cylinder bore owing to failure to pass the piston rings. Worn piston rings will permit particles of carbon from the combustion chamber to work between the piston and the cylinder wall. Partial failure of the lubrication system, such as the clogging of an oil lead in a force-feed system, the clogging of the screen or of the pump in a circulating system, or an insufficient supply of oil in a splash system, will result in scoring.

Cylinder scoring may be due to the piston ring binding owing to failure to allow for expansion in fitting or to the piston sticking owing to an accumulation of carbon under it. The wrist pin may become loose and move endways so that it scrapes against the cylinder wall; or in assembling the piston and connecting rod, the wrist pin may be so placed that it presses the piston unevenly against one side of the cylinder. Carelessness in valve grinding that results in some of the compound getting into the cylinder will cause serious scoring sooner than almost anything else.

CARBURETOR

Q. What attention does the carburetor need?

A. It should be drained at frequent intervals to remove the accumulation of sediment. Care should be taken to prevent dirt from getting into the fuel, and the latter should be strained as it is poured into the tank. In making needle-valve adjustments, the needle must never be screwed down hard on its seat, since this is likely to turn a shoulder on it so that proper adjustments cannot be made with it.

Q. When the carburetor floods, what is the usual cause of the trouble?

A. The usual cause is dirt lodging under the needle valve in the float chamber. Where a hollow copper float is used, it may have sprung a leak, causing it to sink.

Q. How should the carburetor be adjusted to give the maximum power with the most economical fuel consumption?

A. Definite instructions covering every make of carburetor cannot be given, but the same principles can be applied to all. With the motor running, cut down the fuel supply gradually until the motor begins to run irregularly or to miss. The fuel mixture is thus made leaner, and in some cases the motor will back fire through the carburetor when the mixture becomes too lean. When the point of adjustment has been found at which the motor is not getting sufficient fuel, turn back slightly until just enough fuel is being supplied to permit it to idle regularly. This is termed the low-speed adjustment and some carburetors have no other, that is, only the fuel supply can be regulated. Others have a high-speed adjustment as well; this controls the air supply and takes the form of an adjustable auxiliary air valve. Speed the motor up and release the tension of the auxiliary air valve spring until the point is reached where too much air is being admitted and the mixture again becomes too lean. Then turn back slowly until as much air is being admitted as is possible without causing irregular operation.

Q. Does the working of any other part of the motor influence the carburetor adjustment?

A. Unless all other parts of the motor are in good working condition, it will be found impossible to make a satisfactory carburetor adjustment. Valves in need of grinding, excessive clearance between valve tappets and stems or rocker arms, worn piston rings or pistons, and worn valve guides will all influence the adjustment of the carburetor. Air drawn in through worn valve guides, a leaky intake manifold, or a leak at the throttle valve of the carburetor will weaken the mixture and make it too lean, so that the motor loses power and overheats. With the motor running, take a squirt can and put some gasoline on the intake manifold gaskets and around the valve stems and note whether it is drawn in or not. New gaskets will remedy trouble of this nature at the manifold. Whenever the manifold has to be taken down, it is always better to replace the gaskets, since it is difficult to make used gaskets tight.

Q. The float valve and needle adjustment being in good condition, what is the cause of the trouble when a regular flow of fuel cannot be obtained at the nozzle in the mixing chamber?

A. The supply line may be partially clogged or the vent hole in the top of the carburetor may be stopped up. This is a small opening designed to admit air in order that there may be atmospheric pressure on the fuel in the float chamber. If this clogs up, a partial vacuum is formed. In a gravity system the air vent on the tank may have become stopped up and the fuel will not flow to the carburetor owing to the lack of atmospheric pressure on top of the supply. In a pressure or a vacuum tank supply system the trouble may be with the pump, or with loose joints, or with the tank itself.

Q. When difficulty is experienced in making a satisfactory low-speed adjustment, what is likely to be the cause?

A. The needle valve may have been forced down on its seat so that a burr or ring has been formed on the needle. The latter should be taken out and repointed.

Q. Is an air cleaner indispensable in connection with a tractor carburetor?

A. It will save its cost and the time required to attend to it many times over. Without it, pistons, rings, and bearings will grind out very rapidly, and trouble will be experienced with accumulations of carbon, more than half of which will be nothing more nor less than dirt drawn in through the carburetor.

Q. What attention does the air cleaner require?

A. Frequent cleaning is the only attention needed. When the cleaner is of the dry-air type, the engine should always be shut down before emptying it. If it is a washer type, see that it is constantly supplied with plenty of water. Clean out either type twice a day or oftener, if necessary, rather than wait until it is full. Analyses of carbon accumulations taken from automobile cylinders have shown them to consist of 65 per cent, or more, of road dirt.

Q. How can an over-rich mixture be detected?

A. Note the color of the exhaust from the muffler. The presence of black smoke indicates that too much fuel is being fed; blue smoke, too much lubricating oil; and grayish-white smoke, poor combustion of kerosene usually due to an excess of water. An over-rich mixture, particularly when kerosene is being used, will cut the lubricating oil from the cylinder walls and cause scoring unless remedied.

Q. What is the object of feeding water with the fuel?

A. To assist in keeping the temperature of the engine down to the proper point for satisfactory working. The steam generated rapidly absorbs a great deal of the heat and has the further advantage of preventing the formation of carbon in the cylinders. It also causes better combustion, particularly in the case of kerosene.

Q. Should water be fed with the fuel regardless of the grade of oil employed?

A. Little or no water is necessary when using gasoline, but the majority of motors will not operate satisfactorily on kerosene without it.

Q. Is there any danger of feeding too much water, particularly when the motor is running very hot and appears to need it?

A. Excess water fed with the fuel is liable to lower the temperature to the point at which kerosene recondenses to a liquid; in such a case considerable of it works its way past the pistons and down into the crankcase. This destroys the film of lubricant on the cylinder walls and is liable to cause damage, not alone to the cylinders themselves but likewise to the bearings; thinning the oil in the crankcase destroys its lubricating qualities. If the motor appears to be getting too hot, the trouble should be remedied by locating the fault in the cooling or the lubricating system and not by attempting to overcome it by increasing the amount of water fed.

Q. What indication is there of excessive water in the fuel?

A. A grayish white smoke will appear at the exhaust indicating that the kerosene is not being completely burned in the cylinders. Cut down the water supply very gradually until the smoke disappears, the motor being kept running at a good speed, since if run too slowly on kerosene the combustion of the latter will not be complete owing to the drop in temperature.

Q. Are all tractor motors provided with hand-controlled apparatus for feeding water?

A. No; some carburetors are designed to feed water automatically as it is needed, while in others the use of a wet air cleaner is depended upon to supply the proper amount of water required.

Q. Where hand control is provided, should the water be fed as long as the engine is running?

A. It is better to shut it off five minutes or so before the motor is to be stopped, and the fuel should be switched from kerosene to gasoline at the same time, as this will leave the motor in better condition and facilitate restarting.

Q. What precautions should be taken with the water supplied for this purpose?

A. Clean rain water should be used, and it is well to strain it through two or three thicknesses of cloth to prevent the entrance of any dirt.

COOLING SYSTEM

Q. When the engine overheats despite the fact that the cooling system is working properly, what is the cause of the trouble?

A. It may be due either to an over-rich or an over-lean mixture. In either case combustion is slow instead of taking the form of the explosion required to produce the maximum power. The mixture continues to burn throughout the stroke and in the exhaust passages and muffler. Flame issuing from the exhaust is an indication of this condition. The ignition may be retarded too far and bring about the same condition.

Q. What are some of the causes of failure of the cooling system?

A. Among the causes are the following: insufficient water supply; fan belt slipping; pump running too slow when driven by a belt; insufficient lubrication; leaks in radiator or at pump packing permitting water to escape or air to enter; and clogging of radiator, circulating pipes, or water jackets with an accumulation of sediment. The cooling system should be drained at frequent intervals and flushed out with clean water. An accumulation of carbon in the cylinders will also cause the engine to overheat and if allowed to become very bad, will cause preignition, which imposes very heavy stresses on all moving parts of the engine.

Q. When hard water has to be used in the cooling system and scale forms, how can this be removed?

A. A strong soda solution made by adding several pounds of common washing soda to enough boiling water to fill the system should be used for a day or so in place of ordinary water. The system should then be drained and flushed out. The use of rain water will prevent the formation of scale. Particles of iron rust in the water when the system is flushed should not be confused with scale; these will always be found, even if the system is drained every day.

Q. Do the flexible-hose connections ever cause any trouble?

A. The inner plies of the hose sometimes become detached owing to the high temperature of the cooling water and either partially or wholly clog the passage. The passage is liable to become wholly clogged with the pump type of circulation owing to the much smaller diameter of the hose used. To guard against trouble of this nature, use nothing but the hose connections supplied by the manufacturers as replacements since this hose is specially made to withstand hot water. Ordinary hose will disintegrate rapidly when employed for this purpose and should never be so used except to tide over an emergency, being replaced with a new connection as soon as possible.

Q. Is partial or total failure of the cooling system the only cause of overheating?

A. No; there are numerous other causes of overheating. The motor may be run with the ignition retarded; the lubrication may not be efficient; or carbon may have accumulated in the combustion chambers, as pointed out in a previous answer.

Q. How can carbon be prevented from accumulating in the motor?

A. After the motor has been shut down for the day and is very hot, take out the spark plugs, turn the motor over by hand until all the pistons are at approximately the same height, and pour into each cylinder about an ounce of kerosene, letting it stand this way over night. Do not use more than this amount of kerosene (a tablespoon will hold about an ounce) on the theory that if a little does good, more will do better, since more kerosene will cut the lubricating film off the cylinder walls and thin the oil in the crankcase.

Q. How can the fan belt be kept in good condition?

A. Make adjustments only when the motor is hot and do not put any more tension on the belt than is necessary to prevent slipping. A belt that is set up too tightly will wear very quickly besides imposing undue stresses on the pulley bearings. Keep the leather soft by applying neatsfoot oil from time to time.

Q. How often should the radiator and cooling system be drained?

A. Two or three times a season are sufficient in summer if clean rain water is being used and it is strained before being put into the radiator. In winter it will be found better practice to drain the entire system every night rather than to depend upon an anti-freezing solution, since the latter lowers the boiling point of the water to such an extent that it is likely to boil away. In any case, if alcohol is used in the anti-freezing solution, it is likely to boil out of the water, so that the latter cannot be left in over night with safety. Some tractors are cooled by oil, and in cold weather it is necessary to thin this oil with kerosene before it will circulate freely.

Q. When it is discovered that a considerable quantity of the water has boiled away and the motor is very hot, is it good practice to fill up with cold water immediately?

A. This should not be done, particularly in winter, as the fresh supply is likely to be very cold and the sudden contraction would impose severe stresses on the radiator joints, starting leaks.

Q. What attention does the pump of a circulating system require?

A. See that the glands are kept tight. The appearance of a drop of water at the gland indicates the beginning of a slow leak. Give the gland nut a partial turn to tighten it; if water still appears, it will be necessary to repack the stuffing box. Use oil-soaked cotton wick or graphite packing.

HORSEPOWER RATINGS

Q. Why are tractors rated as 10–20, 16–30, etc., always giving two horsepower ratings?

A. Tractors are designed to be used for belt as well as for field work. In doing the latter, the tractor must use a substantial percentage of its power to move itself. The lower rating accordingly expresses the amount of power available for plowing. When standing, as in performing belt work, the only losses are caused by whatever transmission gearing is interposed between the engine and the belt pulley, so that almost the entire output of the power plant is available for driving other machinery.

Q. What constitutes an overload, and why do all manufacturers warn the tractor user so strongly against subjecting the machine to overloads?

A. Considerable confusion exists as to the meaning of the term horsepower. For a few minutes, as in pulling out of a hole, a heavy draft horse is capable of exerting 600 to 800 pounds drawbar pull, which is the equivalent of more than 1 hp., but the same horse cannot exert much more than an average of 100 pounds drawbar pull at a speed of three miles an hour in hauling a load all day. The fact that a tractor having a field rating of 16 hp. may be pulled out of a bad place by three heavy horses does not indicate that the team is capable of doing as much work as the machine. The animals can only exert this much power for a very short period. The tractor will generate an amount of power at the drawbar equivalent to fourteen or fifteen horses at the usual plowing speed and will keep it up all day. A load such as twelve horses could haul all day would represent the practical working maximum for such a machine. A heavier load than this, apart from emergencies which call for all the power the machine can produce for only a very short period, would represent an overload for that tractor. In other words, the tractor should not be steadily subjected to a load amounting to more than 75 per cent of its capacity. Manufacturers warn tractor owners against overloading their machines because tractors will wear out very quickly under the excessive strain and will not give satisfactory service during the machine's greatly reduced useful life. Regardless of the plow rating of the tractor, as for instance, three-plow or four-plow, the number of plows used should depend upon the nature of the soil. When the latter is very heavy, or the plowing has to be done on an up grade, fewer plows should be used. More and better work will be done by not subjecting the tractor to any greater load than it can pull without exerting more than 75 per cent of its power.

ENGINE TROUBLES

FAILURE TO START

Q. What are some of the commoner causes of failure to start?

A. Over 95 per cent of all failures to start are due to either lack of fuel or lack of the spark to ignite it. Part of the remaining 5 per cent are due to the failure of the two to come together at the right time, while the rest may be put down to faults having no connection with either the carburetor or the magneto.

Q. Does lack of fuel in this connection mean an empty tank and nothing more?

A. While a great deal of energy has been expended to no good purpose in trying to start an engine that was connected to an empty gasoline tank, lack of fuel implies a great deal more than that. It does not do much good to have a full tank unless the fuel is actually getting into the cylinders every time the engine turns over. There may be a stoppage between the tank and the carburetor or between the latter and the cylinders. A plugged air vent either at the tank or at the carburetor will prevent the liquid fuel from reaching the carburetor nozzle. A stopped-up carburetor nozzle will not vaporize any fuel, while a broken throttle connection which leaves the throttle closed will not permit any spray from an open nozzle to reach the motor, or at least not enough to render starting easy. Air leaks at the carburetor, the manifold, or the valve stems will weaken the mixture considerably.

Q. Is it not as hard to start with too much fuel as with too little?

A. Flooding the cylinders makes starting very difficult, and when this has occurred, the only remedy is to shut off the supply entirely and crank the motor for a few minutes to clean out the cylinders. Priming too freely is a bad practice, since the liquid gasoline cuts the lubricating oil from the cylinder walls and destroys the compression to such an extent that in an old engine it is next to impossible to start even though the fuel and the spark come together in the right place at the right time. This is one of the unspecified causes responsible for part of the 5 per cent of the failures to start mentioned previously. There will be a weak explosion every time a cylinder should fire, but not enough power will be produced to cause the engine to take up its cycle and run.

Q. When the cylinders have been flooded by over-priming with gasoline, what should be done?

A. Close the throttle and open the air valve or choker, so that no gasoline is drawn through the carburetor. Take out the spark plugs and put 2 or 3 ounces of heavy cylinder oil into each cylinder. Replace the plugs and turn the motor over for two or three minutes with the ignition off.

Q. Has the position of the throttle lever any effect on the fuel supply at starting?

A. Some engines can only be started readily with the throttle at a certain position, usually not more than one-third open and sometimes considerably less. On a cold morning opening the throttle too far is liable to allow too much gasoline in liquid form to find its way into the cylinders, so that the effect is the same as that of over-priming or flooding.

Q. How should an engine be primed?

A. Gasoline should be carried in a squirt can for this purpose and not more than a teaspoonful should be squirted into each cylinder through the pet cocks. If the engine does not start after priming two or three times, look for some other cause of fuel or ignition failure. If the engine starts and only turns over a few times and then stops, the cause is likely to be lack of fuel as indicated by the fact that it ran on what was injected into the cylinders. In priming the float in the carburetor is also depressed by means of a button or lever provided for the purpose. This floods the carburetor and causes the gasoline to overflow through the nozzle into the mixing chamber. The moment any gasoline leaks out of the carburetor, the float should be released, since otherwise the cylinders will be flooded. Never prime the carburetor just as the engine is starting, as this will produce an over-rich mixture and probably cause a pop back which may ignite the gasoline in the carburetor.

Q. Is water in the gasoline a frequent cause of failure to start?

A. It may not be a very frequent cause, but the occurrence of any water in the gasoline will make it difficult to start the motor. Being heavier than gasoline the water sinks to the bottom of the tank and there may be enough of it to partly fill the carburetor. The remedy is to drain the carburetor, taking out a half-pint or so.

Q. What effect does the use of kerosene as fuel have on the starting of the motor?

A. It has no effect, if the matter is properly handled. At least five minutes before the engine is to be stopped the kerosene should always be shut off and the engine allowed to run on gasoline so that all traces of kerosene will be cleaned out of the cylinders and the manifold. If this has not been done, it will take considerable cranking to start the engine, and it may also be necessary to inject 2 or 3 ounces of fresh oil into each cylinder to renew the compression seal since the kerosene condenses in the cylinders as soon as they get cold and then runs down past the pistons into the crankcase.

Q. Will an adjustment of the mixture make starting any easier?

A. The actual adjustment of the carburetor itself should never be disturbed for starting purposes, as, if this is done, either the carburetor will seldom be properly adjusted for efficient running or a great deal of time will be spent unnecessarily in making adjustments. Moreover the carburetor parts will soon wear badly and make efficient adjustment impossible. Most carburetors are provided with a *choker* which, when closed, causes all the air to be drawn past the nozzle, thus increasing the suction and giving a rich mixture. This should be closed for starting and opened the moment the motor gets under way. Ordinarily the running mixture is too lean to make starting easy.

Q. What are the commoner causes of failure to start through ignition trouble?

A. Among the causes are the following: a ground or short-circuit in the wiring; points of plugs burned too far apart; moisture on the distributor of the magneto; failure of the contact points in the breaker box of the magneto to separate when the cam strikes the hinged lever; impulse starter of magneto stuck or spring broken; putting plug cables on wrong plugs when a change has been made just before attempting to start; badly sooted plugs; spark lever advanced too far; and loose connections, particularly where a separate coil is used with the magneto.

Q. What simple test can be made to determine whether the spark is occurring in each cylinder at the proper time?

A. Take out the plugs, leaving the cables attached to them, and lay the plugs on the cylinder head. Then turn the motor over slowly and note whether or not the sparks occur at the plugs in the proper sequence. Note whether there is a strong blast of air from one of the spark plug holes each time the motor is turned over; if not, pour an ounce or two of fresh oil into each cylinder. The failure to start may be due to lack of compression.

Q. If, when the spark plugs are thus placed, no spark occurs at them, where should the trouble be sought?

A. Take off the cover of the contact breaker of the magneto; have an assistant turn the motor over slowly, and note whether the points of the contact breaker separate twice per revolution (four-cylinder motor). If they do separate, note whether the faces of the contact points are clean and square. If they are blackened or pitted, clean and true them up with a very fine file or a strip of fine sandpaper, and then so adjust them that they come together firmly when the cam is horizontal and do not separate more than $\frac{1}{64}$ inch when the cam is vertical. By giving the motor a sharp turn beyond a compression point a spark will be noted between the points; or the impulse starter may be used and the result noted.

Q. Assuming that a spark takes place between the contact points of the magneto, but none occurs at any of the spark plugs, where should the trouble be sought?

A. Open up the distributor of the magneto and wipe it free of any moisture or dirt that may have accumulated on it. Turn the motor over and note whether the distributor brush revolves as it should. Adjust all the spark plug gaps to not more than $\frac{1}{32}$ inch; see that the plugs are properly cleaned and that they are lying on their sides on the cylinder heads, so that only their bodies come in contact with the metal. If they are so placed that the central electrodes are touching, the current will pass through them without causing a spark, since there are then no gaps for it to jump. In case none of these tests produces a spark at the plugs, there is more than likely to be some internal trouble with the magneto, though this is of comparatively rare occurrence.

Q. When the impulse starter fails to operate, what is likely to be the cause of the trouble?

A. Either the mechanism has become gummed up with oil and dirt or the spring has broken. Cleaning out the impulse starter with gasoline and re-oiling will remove the former cause.

Q. When the engine fails to start after having been primed once or twice and cranked several times, in what order should the cause of the trouble be sought?

A. This will depend largely upon weather conditions. In very cold weather it is quite likely that nothing but the low temperature is the cause of difficulty in starting. Results will usually follow continued cranking, as this warms the engine up somewhat and makes it turn over easier, with the result that the first weak explosions may cause it to take up its cycle. In warm weather, if a start does not follow several attempts at cranking, test the ignition first and then the fuel supply, applying the different tests already outlined and in about the order given.

Q. Are there any other points in the ignition system that are likely to be responsible for failure to start?

A. If, when turning over, the motor produces a spark at the contact breaker but none at the plugs, investigate the magneto switch. It may have become broken or its connections may be faulty. See that it is in the right position, since many tractor motors can only be stopped by short-circuiting the magneto by means of the switch. In case the switch is in the *STOP* position, no spark will occur at the plugs. On some tractors the spark-advance lever takes the place of the switch; by fully retarding it the magneto is short-circuited, and the motor cannot be started.

Q. Do the magnets of the magneto lose so much of their strength that no current is produced?

A. In time, the heat and vibration are liable to weaken the magneto, but this is far from being a common source of trouble. If, after making the tests mentioned, no spark is produced, take off the distributor plate of the magneto and rest a screwdriver blade on the gear casing so that its end comes within $\frac{1}{8}$ inch of the collector ring. Turn the motor over, and note whether a spark jumps this gap. A $\frac{1}{8}$-inch spark at this point will indicate that there is no falling off in the power of the magneto. If a spark cannot be produced in this way, there is something wrong with the magneto itself, and it should be sent to the manufacturer for repairs. Ordinarily remagnetization is only necessary if the magneto has been taken apart and the magnets allowed to stand without a "keeper," or piece of soft iron across their ends, or if they have been removed from the magneto and reassembled in the wrong way.

Q. When the contact points have become so badly pitted and burned away that they cannot be properly adjusted after cleaning and trueing up, what should be done?

A. One or both of the contacts should be replaced and adjusted properly. The magneto manufacturer usually supplies a special wrench for this purpose, one end of it serving as a gage for the proper gap between them. The lock nut of the movable point should always be screwed down firmly after the adjustment has been made or it will back off owing to the vibration.

Q. Are there any connections on the magneto which are likely to become short-circuited or grounded?

A. When the wire is brought out through the side of the magneto, the insulation may become so worn that the metal touches the side of the opening, causing a short-circuit. In the inductor types of magneto, such as the Remy and K–W, this is most likely to occur at the grounding screw where the wire is fastened to the side of the magneto. In shuttle-wound types, such as the Eisemann, Kingston, and Bosch, the break may be at the point where the wire is fastened to the armature or where it is fastened to the collector ring.

Q. Can the contact breaker become short-circuited?

A. Metallic dust or filings will be liable to cause this; the remedy is to clean out the inside of the box with gasoline. Whenever an adjustment is made, the contact points must always be redressed so as to come together squarely. For this purpose use only the small file supplied by the manufacturer, and take off just as little of the platinum as possible, since it is worth considerably more than gold.

Q. How can the contact=breaker box be tested for a short=circuit?

A. Remove it from the magneto, place a piece of paper between the points, and then hold the box within $\frac{1}{8}$ inch of the shaft while the magneto is turned over with the other hand. No spark should occur; if it does, it indicates that the insulation of the adjustable contact point is poor and should be replaced. The test should then be repeated with the paper removed so that the points are in contact; a spark should then occur when the armature is turned over, the breaker box being held within $\frac{1}{8}$ inch or less.

Q. Does oil getting on the parts injure the magneto in any way?

A. If allowed to get between the contact points in the breaker box, it will insulate them. On the shuttle-wound types of magneto there is a collector ring and brush, and allowing any oil to get on them will prevent the operation of the magneto altogether. Oil usually carries more or less dirt with it, and if allowed to get on the distributor, it is liable to cause leakage of the high-tension current, so that no spark occurs at the plugs.

Q. How often should the contact points of the magneto need attention?

A. This will depend more or less on the particular type of magneto and the engine, but they should be inspected at least once every thirty days while the tractor is in service steadily and trued up with the sandpaper or special file whenever the slightest irregularity of their surfaces is evident. Taking off a little at frequent intervals will keep the points in much better condition and will save the costly platinum, since once the points start to pit this process proceeds very rapidly. Emery should never be used on the points.

Q. Is excess oil in the motor ever a cause of failure to start?

A. When there is so much oil in the motor that considerable of it finds its way into the combustion chambers, it will collect on the spark plug points and insulate them, if unburned, or short-circuit them, if carbonized. The fact that the motor apparently ran satisfactorily just before being shut down the last time is not conclusive evidence that the spark plugs are in good condition. The magneto generates a high voltage when running at full speed, and the motor will often continue to operate in spite of poor conditions whereas it cannot be started again, once it has become cold, without first remedying the faults.

Q. What is the commonest cause of failure to start a motor equipped with low-tension ignition?

A. Dirty plugs, or ignitors, are probably the most frequent cause. As in the case of the high-tension spark plugs just mentioned, the engine may continue to run with the plugs in poor condition, but once it has been shut down and allowed to become cold, the magneto will not produce a spark at the dirty plugs at the low speed at which the engine is cranked. Whenever an engine with this type of ignition is difficult to start, the first thing to do is to examine the plugs. Give them a thorough cleaning with gasoline and a wire brush, taking out the moving contact to remove any soot that has been forced into the bearing. These plugs may be tested by laying on the cylinder head, contacts up, and snapping the contact with a small piece of wood while an assistant turns the motor over so that the magneto is generating.

Q. What other attention do these plugs require?

A. The contact points burn away rapidly and need frequent dressing up to keep their contact faces from becoming pitted. They should be trued up in the same manner as directed for the magneto breaker-box contact points, and while the material is not so expensive, no more than necessary should be taken off. The operation should be repeated at frequent intervals to keep the plugs in good condition.

Q. How may the low-tension magneto be tested to find out whether it is generating or not?

A. Place a screwdriver blade against the single terminal of the magneto and hold the end against some metal part of the motor while the motor is cranked. Move the tip of the screw-driver over the metal while maintaining contact with the terminal at the other end and sparks will be noted at the tip. A similar test may be made by disconnecting the cable leading from the coil. Rub the metal terminal of this cable over different adjacent parts of the motor so that contact is made and broken while the engine is being cranked, and much larger sparks will be noted.

Q. If, after making tests successfully, no spark is obtainable at the ignitor plug itself, what is the cause of the trouble?

A. The plug is likely to be at fault. Oil that has been used for any time carries in solution a considerable percentage of carbon in a finely divided state. When hot, this oil is thin and is forced into the insulation of the plug, short-circuiting it, though apparently there is nothing wrong with it. The only remedy is to renew the insulation of the plug.

Q. Though a test of the ignitors shows them to be in good working condition, the motor still fails to start and examination shows every other part to be working properly, so that the fault is evidently with the ignition, what is the cause?

A. Either some part of the ignitor tripping mechanism has failed, so that the contacts do not separate, or the timing has become deranged, so that the separation takes place at the wrong moment. In the latter case the spark is occurring in the cylinder, but it is taking place either too soon or too late to fire the charge. Check up the timing of the ignitor mechanism in accordance with the maker's instruction book.

Q. How can the dry cells ordinarily used for starting with low-tension ignition be tested?

A. A pocket ammeter, or so-called battery tester, should be used for this purpose. Hold the tips on the cells only long enough to allow the instrument needle to come to rest, since the ammeter represents a dead short-circuit on the battery and will run it down very quickly. If the reading of the ammeter shows less than 10 amperes, the batteries are of no further use for starting purposes and should be renewed. Any other method of testing will only show whether the battery is actually dead or not, and dry cells may make a fairly large spark through the coil but will give a reading of only 2 to 3 amperes on the instrument and will fail to ignite the charge in the cylinder. Batteries when this low give out very quickly. If the switch has been left on the battery side inadvertently, give the cells ten to fifteen minutes to recuperate and then test again.

Q. What is likely to go wrong with the wiring of a low-tension system?

A. About the only thing that can happen to this wiring is a loose connection at the magneto, at the ground on the motor, at the ignitor connection, or at the switch. The switch itself may become short-circuited and thus prevent any current from reaching the plugs.

Q. Does the tripping mechanism of a low-tension system require frequent attention?

A. The trip-rod mechanism should be inspected from time to time to see that it is working normally, as the vibration is likely to knock it out of adjustment. The springs should be replaced whenever they show any signs of weakening.

RUNNING TROUBLES

Q. What causes the engine to emit smoke?

A. Among the causes are the following: an over-rich mixture caused by faulty adjustment of the carburetor; and flooding of the carburetor due to a leaking metal float or a water-logged cork float. In either of these cases the smoke will be black. Oil getting into the combustion chambers in excess, caused by feeding too much oil or by broken or stuck piston rings, will produce a blue smoke. Feeding an excessive amount of water when burning kerosene or running the engine too cold will produce a white or gray smoke, indicating that the kerosene is not being entirely consumed.

Q. What is the cause of back firing through the carburetor?

A. A slow-burning fuel mixture is being fed, that is, one either too lean or too rich, usually the former, so that there is still flame in the cylinder when the valve opens. At times this will occur to such an extent that the flame issues from the exhaust pipe at the end of the muffler. This is an indication that the mixture is too rich, since it is still burning after being exhausted from the cylinder. One of the valves may not be closing properly;

it may be held off its seat slightly by an accumulation of carbon, or its stem may have become bent, so that the spring cannot close it. When the ignition has been dismantled, reassembling the cables on the wrong plugs so as to alter the firing order will cause a back fire, but in this case the engine cannot be started. An air trap in the fuel line or partial clogging of the latter will also cause this at times.

Q. What are the commoner causes of missing?

A. The most frequent cause is a defective spark plug. Owing to the heat and the vibration the porcelain of a plug will break, but the cracks will be so small that they are invisible. The pressure forces carbon-laden oil into these cracks and the plug becomes short-circuited, though apparently in good order. Test by short-circuiting the plugs in turn with a wooden-handled screwdriver. When short-circuiting a plug causes no perceptible difference in the running of the engine, replace it. Pitted and badly worn contact points in the magneto breaker box will also cause irregular running. (See the directions given under Failure to Start.) Missing may also be caused by the fuel mixture being too rich or too lean, partial stoppage of the fuel line, water in the gasoline, defective insulation or loose connections, carbon dust on the distributor plate of the magneto, or a sticking valve.

Q. In what other ways may spark plugs fail besides the porcelain cracking?

A. Very frequently the electrodes burn too far apart, so that the current is unable to jump the gap, or if it does, the spark is weak and irregular. Plugs become foul through an accumulation of soot in them, and to clean a badly sooted plug out thoroughly, it may be necessary to take it apart. The insulation of a mica plug will fail in time through the hot oil and carbon being driven into it under pressure, and the only remedy is to replace the insulator. Leakage around the gasket sometimes occurs, and when it is not sufficient to cause a hissing noise, it will be indicated by the porcelain of the plug becoming very dirty. Squirt a little oil on the porcelain when the engine is running and bubbles will form at the gasket if the plug is leaking. Cheap plugs are made with iron electrodes, and the latter burn away so fast that it may be necessary to adjust the gap once a day.

Q. What is the cause of preignition?

A. Usually an accumulation of carbon in the combustion chamber. This carbon deposit often takes the form of small cones which become incandescent when the engine is running under full load so that the fresh mixture is ignited the moment it enters the cylinder. When running on kerosene, the piston head may become so hot as to produce the same result. In either case, preignition will be evidenced by a heavy pounding and the engine should be stopped at once as this imposes a very heavy stress on all the moving parts. Increasing the amount of water fed with the fuel will remedy it when it is due to overheated pistons and the use of kerosene. Otherwise, the engine will have to be cleaned out to remove the carbon.

Q. How can the accumulation of carbon be prevented?

A. By using only the grade of oil recommended by the manufacturer of the tractor; cleaning it out and putting in a fresh supply as often as directed; keeping the piston rings in good condition, so that an excessive amount of oil cannot find its way into the combustion chambers; and keeping the carburetor properly adjusted, so that too rich a mixture is not used. Feed the proper amount of water when burning kerosene. In spite of these precautions, more or less carbon will always accumulate in the cylinders. This amount can be kept down to a minimum by pouring a few ounces of kerosene into each cylinder at the end of a day's run when the engine is still very hot and leaving this in the cylinders over night. Before starting up in the morning, the compression seal should be renewed by putting a few ounces of fresh oil into each cylinder.

Q. When the engine fires regularly but the explosions are so weak that very little power is produced, what is the cause of the trouble?

A. Some of the commoner causes are as follows: spark plug points burned too far apart; excessive clearance at the valve stem tappets or rocker arms, so that only a fraction of the fuel required is being admitted; valves in need of grinding; poor compression caused by oil not being renewed at sufficiently short intervals; broken or stuck piston rings; leaks around spark plugs; use of a fuel mixture that is too lean or too rich, so that slow burning results instead of an explosion; a weakened or broken valve spring; clogging of the passages of the muffler with carbon; or any obstruction in the exhaust piping.

Q. What causes the engine to run regularly for a time and then to misfire badly?

A. This may be caused by switching to kerosene before the engine has run long enough on gasoline to become thoroughly warmed up; a valve with a bent stem that operates properly at times and then sticks during a few revolutions; air leaks around the valve stems or in the intake manifold; dirt in the carburetor, so that the nozzle is partly clogged at times and free at others; defective insulation or a loose connection which interrupts the circuit from time to time owing to the vibration of the engine, causing it to change position; water in the gasoline; carbon on the distributor plate of the magneto; or faulty spark plugs which will permit the engine to run regularly when idling but which will fail the moment the load is applied. A spark plug with fine cracks in the porcelain will fail under load owing to the greatly increased pressure in the cylinder, but will often spark regularly when the engine is running without load. A loose connection or weak spot in the insulation is the most puzzling of these causes since it is often the most difficult to find.

Q. What causes the engine to stop suddenly?

A. This is generally due to a failure of the ignition, owing to a break in the circuit caused by a connection dropping off, the switch suddenly opening under the vibration, or some part of the wiring becoming short-circuited. Clogging of the fuel line or of the carburetor nozzle or an empty tank will also result in the engine stopping. Where the stoppage is due to failure of the fuel supply from any cause, the engine will not usually come to as sudden a stop as when the ignition fails. The contacts in the breaker box of the magneto may have stuck together. If the cooling or the lubricating system fails, it will also take more time to bring the engine to a stop and there will be noises that give ample evidence of the cause of the trouble. The engine should be shut off the moment these noises occur for otherwise it will be forcibly stopped by the binding of the pistons, thus putting the engine out of commission.

ENGINE NOISES

Q. How are the different engine noises that signify trouble in the operation of the motor characterized?

A. Experienced motor mechanics give a different term to each one of several distinct classes of noise indicating faulty operation, such as knock, hammer, pound, and slap, and to the ear that is familiar with them each can be distinguished.

Q. What do these different noises signify to the experienced ear?

A. A knock is the first indication of looseness in a bearing, usually a connecting-rod big end, and the sound is generally that of a sharp metallic blow. When it is allowed to develop or when looseness in the crankshaft bearings develops, the sound becomes louder but not so sharp and is more aptly described as hammering, owing to its similarity to the blow of a sledge. Pounding is caused by preignition and by overheating and is so violent as to rack the whole motor very badly. Slap is the result of worn pistons, the skirts or lower ends of which are banged against the cylinder walls every time the motor fires. The noise produced is very similar to that of a knock and is often mistaken for the latter, though an experienced mechanic will seldom go wrong on this. In addition to the noises mentioned, there is another that is readily distinguished by the experienced ear, and that is the clatter caused by a loose valve motion, indicating that an excessive amount of clearance has been allowed to develop between the valve tappets and stems or in the rocker arms. To the inexperienced ear all strange noises will be *knocks* and it may seem to be drawing too fine distinctions to differentiate between knocking, hammering, and pounding, but familiarity with a motor will enable the operator not only to make these distinctions but to know as well what causes the different noises.

Q. Which of these noises calls for immediate attention on the part of the operator to prevent damage to the motor?

A. A very good rule to follow is to shut the motor down the moment any of these noises is heard and correct the trouble, but those that call for immediate attention to prevent serious damage are hammering and pounding. The first indicates a very loose bearing, which may result in a broken crankshaft if allowed to run a moment longer than necessary, while pounding not only imposes exceedingly heavy stresses on every part of the motor but may also be the first sign of failure of either the cooling or the lubricating system. The cause may be nothing more serious than lack of sufficient water when burning kerosene or the fact that the spark lever may be advanced too far.

GOVERNOR

Q. What causes the engine to race when the load is thrown off?

A. The governor needs adjustment, or the connection between it and the throttle has parted.

Q. What attention does the governor ordinarily need?

A. This depends largely upon the type of governor. Some are housed in and the lubrication provided for by filling the housing with oil; such a governor needs very little attention, except to adjust it when it permits the engine to idle too fast. An adjusting screw is provided for this purpose. With the engine running, turn the screw gradually until the engine slows down to a point where it idles satisfactorily. The governor spring weakens in time, and the adjustment is provided to permit of increasing the tension. Apart from this, the only regular attention required by those types which are not automatically lubricated is to oil the bearings at regular intervals and see that the connecting linkage is in good order.

CLUTCH AND TRANSMISSION

Q. What provision is made for taking up wear in the clutch?

A. The friction surface, which is usually asbestos on a wire foundation, should be replaced when worn sufficiently to require it. After considerable service the spring pressure may let up sufficiently to cause unsatisfactory operation of the clutch. An adjustment is provided for increasing the tension of the spring, and this should be tightened just enough to make the clutch hold under load; but it is not good practice to attempt to make up for a badly worn friction facing by increasing the tension of the spring. Replace the facing first. This, of course, does not apply to the type employing metal to metal contact surfaces. Apart from this, the chief attention required is lubrication, which should be carried out in accordance with the manufacturer's instructions, some clutch mechanisms calling for oil as much as two or three times a day.

Q. Is it good practice to let the machine stand with the clutch out of engagement?

A. No; as it only weakens the clutch spring and shortens its life. Whenever the machine is to stand more than a few moments, the gears should be shifted to neutral and the clutch allowed to engage. It is particularly bad practice to let the machine stand over night with the clutch out of engagement.

Q. Are a worn friction facing and a weak spring the only causes of a slipping clutch?

A. Allowing oil or grease to fall on the friction faces of the clutch will cause it to slip badly.

Q. What attention does the transmission require?

A. Maintain the oil level as indicated in the manufacturer's instructions and use only the oil called for by the latter. Drain as often as instructed, and wash out with gasoline or kerosene before refilling. This is usually two to three times a season, though some types may require it oftener. When the case has been cleaned out, inspect the gear teeth carefully for breaks, and see that any chips or foreign matter are removed. By filtering the old oil through several thicknesses of cloth, it may be used for other farm machines which do not require the same high degree of lubrication as the tractor.

Q. Does the differential require any special form of attention?

A. The differential is frequently combined with the transmission, so that it is lubricated by the same supply of oil. Where it is separate from the transmission, the attention required is the same as that just mentioned for the transmission.

HOUSING TRACTOR

Q. Does it pay to build a special shelter for a tractor?

A. It will undoubtedly be found a good investment, since the cost of a building large enough to shelter the tractor and provide a working bench beside it will usually be less than the added depreciation incurred by leaving it exposed to the weather.

Q. When the tractor is put up for the season, what attention should be given it?

A. Before putting the machine away for the winter, the valves should be ground, the bearings adjusted, the valve mechanism and the magneto overhauled, the oil drained from the crankcase and the transmission, and the latter washed out and provided with a fresh supply of oil. Wash the cylinders and pistons by putting a pint or more of gasoline in each cylinder and running the motor for half a minute. Then put a pint of fresh oil in each cylinder and turn the motor over by hand a few times to spread it over the surfaces; otherwise, the cylinders and pistons may rust. Coat all exposed parts with grease and cover the machine with a tarpaulin or old canvas. Make a list of all replacement parts necessary and order them at the time the machine is put away in order that they may be installed during the winter.

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