Fig. 1 Modern medium weight tractor, embodying automobile design principles

Fig. 2 Distinctive light tractor design using wide driving drum

Modern Agricultural Tractor Designs

By Victor W. Pagé, M. S. A. E.

THE general application of mechanical power to the farmer's work has increased the productiveness of the fields and has greatly enlarged the scope of the farmer's activities. It has been estimated that in one farm task alone, plowing, more energy or power is expended than in the combined manufacturing establishments of the world for a similar period.

The first plowing engine was built in 1858 and utilized steam power. It was capable of drawing eight plows through prairie sod at the rate of 3 miles per hour. The first tractor propelled by an internal combustion engine was placed on the market about 23 years ago, but it was a very clumsy and inefficient mechanism when compared to the more highly refined steam tractor of that period. The development of the practical internal combustion motor and the reduction in its weight and increase in power output made possible by the growth of the automobile industry had its influence on improving the gasoline engine for tractors. The introduction of the practical internal combustion traction engine was of even more importance to the farmer than the invention of the reaper and binder or the threshing machine. It supplied agriculturists with a power that could be applied to good advantage to work that called for the expenditure of much energy. It also supplied a convenient and easily portable power plant that could be used economically for driving many of the machines necessary to carry on farming operations profitably.

Space is not available to go into the comparative merits of animal and mechanical power or to outline the reason why horses, mules and other draft animals are destined to give way to the gas tractor on even very small farms. Some of the lighter tractors which are now available can be made to do any work that the animal can and at the same time are suitable for much work where horses cannot be used at all. A farmer cannot afford to feed and house all the year round the number of horses necessary to do the work of a 50 horsepower gas tractor if the conditions are such that the machine may be used to advantage.

Before describing the improvements in light tractor design it may be well to sum up briefly the requirements of the ideal, all-purpose tractor:

First, it should be universally adaptable so that it can do all kinds of belt or drawbar work. It should be just as well adapted for running farm machines requiring power as it is for hauling plows, harrows or loaded wagons.

Second, the ratio between power and weight and the arrangement of components are important things to consider. If the tractor is too light it will not have the required traction effort between the drive wheels and the ground, and considerable useful power will be dissipated in slippage. On the other hand, if the machine weighs

too much it will pack the soil and will not be practical for use on soft ground. It is evident that more power will be required to move a heavy weight over the ground than a tractor of less mass, and the power needed is especially noticeable when climbing hills. Authorities familiar with tractor design seem to agree that the

Fig. 3 The "steel mule" tractor is attached to implements just as animals are, and is controlled from the seat of the trailing vehicle

weight distribution should be such that the greater part of the total weight should come over the traction members.

Third, as much contact area between the traction members and the ground should be provided in order to avoid loss of power through slipping and packing of the soil due to concentration of much weight on a limited bearing area.

Fourth, the tractor should have change-speed gearing which will provide at least two forward speeds and

Sixth, the tractor should be designed with special reference to the work it is to do and should be constructed of sufficiently good materials so that the weight may be kept within reasonable limits and combine strength with lightness. The tractor should be easy to start and the various controlling functions such as gear shifting, clutch operation and steering should be simplified and control levers so proportioned as to be handled without requiring great muscular exertion. It is evident that the simple tractor will be easier to understand, maintain, and repair. In fact, the simpler designs will be more easily operated by the average farm hand. The construction should be so arranged that automatic steering can be secured when doing certain classes of work, such as plowing, so that the engineer or operator may utilize part of the time in handling the plow shares.

Quite a number of the tractors of modern design answer nearly all of the above requirements. The mechanism is simple and the relation of the parts is good from both theoretical and practical consideration. In most of the machines of to-day useful lessons have been drawn from current automobile practice. It is a safe statement that the tractors which more nearly incorporate the ideal requirements enumerated are those which follow the rules of practice established by automobile builders. In essential elements the automobile and gas tractor are similar, though, of course, the parts and detail arrangement must be modified for the heavier and slower machines. One of the marked tendencies in tractor design is to use multiple-cylinder power plants.

When the gasoline tractor was first evolved a large horizontal single cylinder stationary engine was mounted on the supporting frame or chassis that was the same as those used on steam tractors. At the present time multiple cylinder engines are used because these have less vibration and the general arrangement of the chassis parts have been altered to some extent. In the steam tractor the drive gearing was generally exposed and was composed of a gear train of heavy cast iron gears with practically no finish. At the present

Fig. 4 Medium weight three-wheel tractor of modern design, pulling three-bottom gang plow

time not only the gearing but other parts of the transmission system, such as the clutch, are encased and protected from grit and dirt. Cut alloy steel gears running in oil and operated in practically the same way as change speed gearing on automobiles have replaced the heavier forms used on the early machines. Pressed steel and standard structural forms such as channels and I-beams are replacing the cumbersome cast frames of the early tractor. Whereas the earlier machines used plain bearings at all parts, the modern tractors use ball and roller bearings which not only have longer life than the plain babbit type, but which offer a material saving in power, as well as reducing the repair expense by

Fifth, it is desirable that the engine be capable of operating on the cheaper liquid fuels such as kerosene, distillate and others of the more plentiful products of petroleum. The rapidly increasing cost of gasoline makes it imperative to use other fuels and as the tractor engines, for the most part, are heavy-duty constant-speed types, no difficulty should be experienced in using kerosene.

keeping the parts in the proper relation longer. While it would take at least half a day for an experienced man to pour a babbitt bearing and fit it properly, the anti-friction bearings, which are interchangeable, can be easily removed and replaced by new ones in much less time.

Considerable interest is being displayed in the three-wheel constructions. In fact most of the light tractors that are being offered this year are of the type having a single traction member and two steering wheels. The type shown at Fig. 1 is one of recent construction and may be considered fairly representative of this class. The front wheels are 36 inches in diameter with a 6-inch face, while the main drive wheel is 62 inches in diameter with a 24-inch face. The engine is a four-cylinder, four-cycle motor, capable of delivering 25 horse-power belt pull and 15 horse-power drawbar pull at approximately 900 revolutions. The cooling system includes a flat tube radiator through which water is circulated by a $6\frac{1}{2}$ -inch centrifugal pump. Ignition is by magneto. The transmission provides two speeds ahead and one reverse. The low speed is $1\frac{1}{4}$ miles per hour—the high speed, $2\frac{1}{2}$ miles per hour. Larger sprockets are furnished which may be easily fitted and which will give higher speed.

This tractor will pull two gang plows or two disk harrows. It is capable of hauling two binders or two drills and will trail three to five grain wagons. It will pull two manure spreaders or an eight-foot road grader. It has sufficient belt power to operate a 32-inch separator, a silage cutter, corn shredder, corn sheller, circular saw, feed grinder, water pump, hay baler or grain elevator. The machine is easily controlled as it is handled very much as an automobile. Especial attention is directed to the thorough inclosure of all gearing in dust-proof, oil-tight cases.

The machine shown at Fig. 2 is practically a three-wheel type, though the drive is through an extremely wide traction member or drum. This not only provides good traction, but carries the weight on a great area. It is said that this tractor can turn in a 22-foot circle and that the machine can be maneuvered equally as well on plowed land as on hard ground. One advantage of the three-wheel forms described is that the mechanism is simplified owing to the elimination of the differential. The power plant is a four-cylinder, four-cycle auto type engine. Owing to the compactness of the machine it is specially adapted for orchard cultivation. In all features except the wide drive drum this tractor follows conventional practice.

The tractor shown at Fig. 3 is distinctive in construction inasmuch as it is a practical motor-driven machine that can be hitched to any horse-drawn implement and operated from the seat of the vehicle the tractor is drawing, just as though it was being drawn by horses. This is an advantage because it can be used in connection with the horse-drawn implements already in the farmer's possession. The tractor is controlled by means of three wheels and a lever on the end of a long column which consists of three lengths of tubing, one inside of the other. This control column is connected with the tractor through a universal joint and can be swung at will to any position desired. The middle wheel is the steering, the small wheel in front of the steering wheel operates the clutch and the remaining wheel actuates the gear-shifting apparatus. The carburetor control which is used to regulate the engine speed is in the form of a lever projecting in front of the clutch control wheel. The motor gives 30 horse-power on the belt. It is a four-cylinder, four-cycle heavy duty type following approved automobile practice.

The distinctive feature is the traction member or "crawler," as it is called, which consists of an endless chain apron of metal plates, each link of which is a single piece of metal connected to the adjoining piece by means of a connecting pin having a large bearing surface. Either malleable iron or vanadium steel links may be furnished. The endless chain is driven by a manganese steel gear located at the rear of the traction tread member, while the center part is supported by two flanged idler wheels which prevent the tread from slipping sideways and at the same time guide it properly. The advantages of the track-laying type of drive, where the machine is to be used in soft ground, are now well recognized, as the weight of the machine is distributed over so large a surface that it will not sink even

into soft ground. The ground pressure is lighter than that of a man. The area to support the weight is so large that a horse would need shoes having an area of 1 square foot each attached to its four feet to enable it to tread as lightly on the ground. The turning radius is $8\frac{3}{4}$ feet so the machine will turn in an 18-foot circle. The width of the front tread is adjustable from 3 feet, $9\frac{1}{4}$ inches to 6 feet, $9\frac{3}{4}$ inches, which allows of cultivating rows 30 to 48 inches wide.

The type of light tractor shown at Fig. 4 is equipped with a double cylinder engine of the two-cycle type which is attached to the frame by a three-point suspension. The cylinders are of $5\frac{1}{2}$ -inch bore and 7-inch stroke, and the engine is rated as 22 brake horse-power in belt and 15 drawbar horse-power. Heavy duty ball bearings are used at all points except the engine and rear axle bearings. This engine has been designed to use kerosene or other low grade fuels after an initial start is obtained on gasoline. Oil is used for cooling the engine, this providing a non-freezing medium that will not deposit scale in the radiator or rust the metal parts. A tractor of this kind can do the work of eight big, strong horses. It can be used for all forms of belt

seat on the trailing vehicle. A special wheeled trailer is provided to carry the driver when operating machines that have no seat and for driving the tractor from place to place without transporting the implements.

Very little change has been made in the design of the standard type medium and heavy weight tractors which are represented by the form shown at Fig. 6 and which have been used for nearly a decade. These are invariably of the four-wheel pattern and are intended for use on large farms. The smaller machines described, which are more economical to operate, are, of course, able to do any of the work that would be necessary on the small farm. The latter type of machine has been the one most needed, but it is only within the past two or three years that any serious attempt has been made to produce tractors for the use of the agriculturist farming a small acreage. These sell at prices ranging from \$400 to \$1,000, and so they cater to a large demand.

The Current Supplement

THE use of the automobile in military operations has been attracting much attention, for it has been very apparent that this motive power is absolutely indispensable in any modern army. The paper on *Automobiles in The Great War*, in the current issue of the SCIENTIFIC AMERICAN SUPPLEMENT for July 29th, No. 2117, contains matter of the greatest interest to everyone, as it reviews in a most competent way the types of vehicles used by the Allies, and considers the various technical features in view of actual experience in war work. *British Methods of Handling Coal* describes the machinery used in England for handling coal in bulk at the shipping docks, and affords an interesting comparison with American methods, which were described in the SUPPLEMENT some time ago. The article is profusely illustrated. *Shadow Pictures by Parallel Rays* tells of a method for producing negatives without a lens, that is useful for many purposes. It is accompanied by several interesting illustrations. *The U. S. Government Libraries at Washington* gives much useful information in regard to the great collections of printed matter at the National Capital, which are of inestimable value to the public. The paper on *Modern Views of the Sun* is concluded in this issue. *Bird Houses* gives many useful hints on the construction and care of these shelters for our feathered friends, and it is illustrated by a number of practical diagrams. *The Determination of the Resistance of Ships* reviews recent investigations bearing on the question of designing suitable power for different classes of vessels. Other articles of value in this issue are *X-Rays and the Theory of Radiation*; *The Relation Between the Cutting Efficiencies of Tool Steels and Their Brinell or Scleroscope Hardness*; *The Process of Case Hardening and Feeding the Firing Line*.

China's Density of Population

ABOUT 95 per cent of the population of China is confined to one third of the area of the country, with a density of 200 to the square mile. Five per cent of the population inhabits 65 per cent of the area, with a density of 10 to the square mile. Lack of transportation facilities and the absence of adequate means of protection account for the sparseness of settlement in the outlying dependencies. About 40 per cent of China's population is in the provinces south of the Yangtse River, with a density of 230 to the square mile. This territory has twice the area of the original 13 states of the American Union and four times the population.

There are no wheeled vehicles in use south of the Yangtse except of the Canton and Yunnan Railways. There are therefore no roads in this section. Rice is cultivated throughout this area, and transportation is over paths rather than roads or by boats or water ways. In this section the water buffalo and oxen are the only animals used on the farms, and goods are carried on the backs of men rather than on pack animals or wheeled vehicles, except where the few miles of railways are in operation.

Rice is often spoken of as the staple article of food for the whole of the Chinese people, yet tens of millions of people in China have never seen or tasted rice. Vast areas of the country north cannot grow rice.

In the outlying dependencies, constituting 65 per cent of the total area of China, the density of population is less than that of our Middle West of the United States.

Fig. 5 Light motor cultivator that is also adapted for attachment to other farm implements. Has drawbar pull equal to a team of horses

Fig. 6 Typical example of medium weight tractor that has not been changed in construction for some time because it is well adapted to the work for which it was designed

work and will pull all types of horse-drawn implements. It has a capacity for drawing three 14-inch plows under average conditions. It is a very simple machine and easily operated as it steers just like an automobile when not following a furrow and is self-steering when plowing. The machine weighs 6,000 pounds.

The motor cultivator shown at Fig. 5 is a form of tractor, though, of course, it is not adapted for heavy work. It is designed so that it can be hitched up to a mowing machine, hay rake or harrow just as well as to the cultivator attachment. The power plant is a two-cylinder, V-type motor, of $3\frac{1}{2}$ -inch bore and 5-inch stroke. The transmission is through worm gearing, housed in a dust-proof oil retaining case. The gearing is supported by ball bearings. The tractor attachment is supported by the two driving wheels which are 40 inches in diameter and 5 inches face. Cleats are provided on the wheels to obtain greater traction. The machine weighs but 1,000 pounds and is easily handled by the 12 brake horse-power motor which has a drawbar pull about equal to an ordinary team of horses. The machine may be driven at any speed desired up to 4 miles per hour and is easily guided from the driver's