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Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

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FARM EXPERIENCE WITH THE TRACTOR

By

ARNOLD P. YERKES, Scientific Assistant,
and H. H. MOWRY, Assistant Agriculturist, Office of Farm Management

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INTRODUCTION.

Modern agriculture requires an enormous amount of power to perform the annual farm operations, and there is a continuous, potential demand for any device that will afford cheaper and more convenient power on the farm. This situation has stimulated the production of many types of mechanical substitutes for the farm horse.

Although mechanical power outfits for farm operations have been used in large and increasing numbers for several years, there have been very few reliable data available to the public on the performance of these outfits under ordinary service conditions. Much of the information which has been offered has originated from sources which would indicate that the presentation of the subject would be a biased one or has been furnished by men who were obtaining good, perhaps

NOTE.—This bulletin is intended to make available to farmers who contemplate buying a tractor the experience of many other farmers who have already used one; it is suitable for distribution west of the Mississippi River.

exceptional, results from their outfits. At the same time, men who have not succeeded are not usually inclined or afforded an opportunity to make their experiences generally known. It is necessary to consider carefully the results obtained by all users, whether they have succeeded or failed, in order to obtain correct information as to the present status of the farm tractor. The data in this bulletin are based upon the experience of a large number of users in both classes. It is important for everyone interested that a reliable and impartial survey be made available. The relative efficiency of various makes of tractors is not considered in this bulletin. It is obvious, however, that this factor of the efficiency of some particular machine may be a most important one to the individual farmer.

DESIGNATION OF TRACTORS.

Owing to the numerous terms used to designate tractors in various sections, it may be well to state that in this bulletin the term "gas tractor" is used to designate those machines which derive their power from an internal-combustion engine burning a vaporized fuel (regardless of the kind of oil burned), which are designed for pulling implements and for doing stationary work. When the term "gasoline tractor" occurs it denotes an outfit of the kind just mentioned in which gasoline is regularly used for fuel. Similarly, the term "kerosene tractor" is used to denote a "gas tractor" in which kerosene is the ordinary fuel. By a "steam tractor" is meant an outfit deriving its power from steam generated in a boiler, heated by means of a fire of coal, wood, straw, or similar fuel.

The smaller machines, designed especially for cultivation, plowing, etc., commonly known as "autoplows" and "autocultivators," in which the tillage implement and power plant are combined in one unit, have not been considered in this bulletin, as these do not properly come under the title of tractors. While there are numerous types of these small self-propelled plows and cultivators intended particularly for use on small farms, few of them have been in actual service long enough and in sufficient numbers to demonstrate their ability to perform the work for which they are intended.

Nor should the data or remarks contained herein be considered as applying to the various types of small tractors designed to pull two or three plow bottoms and selling at a comparatively low figure, large numbers of which have been placed on the market during the past few months. These small, low-priced outfits represent the latest phase of the development of the farm tractor and may fairly be considered as belonging to a different class than those under discussion in this bulletin. While they give promise of proving an economical source of power for a great deal of the field and stationary work on

the average farm, they have not been in actual use under service conditions for a sufficient length of time to demonstrate their utility conclusively.

STEAM AND GAS TRACTORS.

The self-propelled steam thrashing engine was the prototype of the modern steam tractor, the latter differing from the former mainly in the size of the drivewheels and transmission gears. In other words, the steam tractor, generally speaking, was an outfit designed primarily for stationary use, but it was gradually adapted to the heavier work of hauling implements and to other work requiring power. A number of years were required for its development, but it finally proved its value on the large areas of prairie opened up for settlement in the West.

At its best, however, it had several serious disadvantages. It burned bulky fuels, of which it could carry only a limited supply and which required considerable time and labor in conveyance. It consumed a large amount of water, which in a dry country was frequently a serious handicap. It was heavy and cumbersome and required a man of considerable ability to operate it properly. It ordinarily employed a crew of three to five men and of two to four horses. A delay of half an hour or more was often experienced in getting up steam pressure sufficient to commence work, and considerable fuel was consumed in keeping up steam during stops. In many cases the fire would be maintained all night in order to have the engine ready for work the next morning.

These objectionable features were practically overcome by the gas tractor. It burned a fuel of less bulk and attained a higher thermal efficiency, so that it could easily carry sufficient fuel for a half day's run, and in many cases for much longer. One 2-horse load of fuel would keep the engine in operation for several days. It used comparatively little water, and, if desired, a low-priced oil could be substituted for water in the cooling system. It weighed less per unit of power than the steam tractor, was shorter, and could therefore turn in less space. While it demanded a thoroughly competent operator in order to secure the best results, he could easily attend to the entire operation of the engine and would frequently find time to operate the plows as well, although the crew usually consisted of two men and occasionally of three men and two horses. The motor could be started in a moment's time, and no fuel need be consumed when the outfit was idle.

After the steam tractor had been used for plowing for several years, an insistent demand developed for a plowing outfit without the disadvantages of the steam tractor. The early gas tractors were built largely to meet this demand. The gas tractor has therefore

been developed primarily as a plowing engine, with belt work a secondary consideration. Although it was actually superior to the steam tractor in the ways mentioned, it was nearly a decade before it developed sufficiently to prove this superiority and became a real competitor with the steam tractor. Most of its growth has occurred during the past 11 years, and in considering the rapidity with which it has been made it might at first appear that it must have been due to its superiority over both the horse and steam tractor as prime movers for the farm. As to its superiority over the steam tractor there is no doubt. The sales of steam tractors for farm work other than thrashing fell off as those of the gas tractor increased, and the steam tractor is seldom found to-day except in sections where suitable fuel is cheap and convenient, thus giving it an advantage over the gas tractor. The decline in the number of steam tractors used for farm work is shown by the age distribution of those reported:

One year old, 37; 2 years old, 65; 3 years old, 65; 4 years old, 88; 5 years old, 76; 6 years old, 33; 7 years old, 25; 8 years old, 24.

THE GAS TRACTOR AND THE HORSE.

While the gas tractor has almost completely replaced the steam tractor, as has been stated, neither the steam nor gas tractor has affected the sale or use of farm horses to any great extent. (See Tables XXII and XXIII.)

A careful study of the subject shows clearly that the rapid growth of the gas tractor was not due to its superiority over the horse, but to the fact that large tracts of unbroken prairie land were being opened up in the West and that sufficient horses were not available to break the ground and bring it under cultivation. Gas tractors could be, and were, manufactured in a much shorter time than it would have taken to raise the necessary horses for this work. But as this new country developed, horses were rapidly imported, colts were raised, and more and more of the farm work was performed with horses. Quite frequently the tractor which had broken the prairie and brought it under cultivation was entirely replaced by them.

A similar condition existed recently in Kansas. An epidemic diminished the number of farm horses in that State by thousands, and the number remaining was insufficient to perform the field work. Immediately hundreds of traction engines were shipped into the State to meet the power requirements. Whether these machines will retain the ground thus opened to them remains to be seen. Under similar conditions in other States they have not done so, indicating that they are either not as satisfactory as horses for farm work or are more expensive.

The failure of the gas tractor to maintain its position as the principal prime mover in those sections where it was first introduced was

apparently not anticipated by those interested in its production. On account of its failure to maintain this position the heavy demand for gas tractors in those sections was only temporary, and an oversupply of tractors was placed upon the market, resulting in depression in the industry. Similar overproduction due to lack of foresight has occurred in other lines of farm equipment, one of the best examples being the oversupply of grain harvesters during the period of rapid multiplication of the improved models.

Generally speaking, the farm tractor has thus far merely supplemented the work of the farm horse and relieved him of the heavier work; it has not actually replaced horses to any considerable extent.

TRACTOR RATINGS.

When internal-combustion tractors were first introduced, there was considerable confusion among engine users as to their ratings, owing to the fact that several methods were used in computing and designating their horsepower. There are still several formulas used in computing the power developed by the motor, but the terms by which the power is denoted have become more uniform and more generally understood. The terms "brake" or "belt" horsepower are used to denote the total amount of power which the engine will develop and transmit to a belt for stationary work, such as thrashing. This amount of power may be computed or ascertained by actual measurement with a proper apparatus.

The "drawbar" horsepower is the belt horsepower minus the amount of power required to propel the weight of the tractor. Most tractors require approximately 50 per cent of the total power developed by the engine to move its own weight, leaving the remainder available for pulling other implements. The amount of power which is actually exerted on the drawbar varies, of course, with the weight and construction of the tractor, and may be either computed or measured with a dynamometer. The tractor ratings are ordinarily expressed by writing the brake horsepower after the drawbar horsepower; thus, "30–60" would indicate a tractor having a pull of 30 horsepower on the drawbar and developing 60 for stationary work.

The term "horsepower" denotes an amount of power equivalent to that developed by a 1,500-pound horse moving at the rate of $2\frac{1}{2}$ miles per hour and exerting a pull equal to one-tenth of his own weight, or 150 pounds. This represents a power output capable of raising a weight of 33,000 pounds to a height of one foot in one minute, and these figures are commonly used in computing the power developed by an engine. A pull equal to one-tenth of his weight is considered a normal load for a horse. As most farm horses weigh less than 1,500 pounds, it is apparent that they do not ordinarily furnish a

full horsepower. A 1,200-pound horse moving at the rate of 2½ miles per hour and exerting a pull of 120 pounds (one-tenth of his weight) would develop only four-fifths of a horsepower. Thus, an engine delivering 20 horsepower at the drawbar would be exerting a stronger pull than 20 horses (averaging less than 1,500 pounds in weight) normally do hour after hour. It should be borne in mind, however, that the engine is capable of delivering at the drawbar in an emergency but a fraction in excess of its rating of 20 horsepower, while 20 average horses are able for a short time to pull several times their normal load; that is, the engine might be overloaded to deliver 25 horsepower, while the 20 horses can be so urged as to deliver 30, 40, 60, or more horsepower for very short periods of time.

SOURCE OF DATA.

In obtaining the data on which this bulletin is based, several hundred owners in sections where tractors are most widely used were personally visited, and conditions were observed and interviews had with farmers using tractors as well as with those who did not use them. At the same time the opinions of business men with regard to the use of tractors by farmers in their vicinity were secured and brief histories of the experience of users were recorded.

A letter was addressed to all bankers located in the farming sections of the United States lying west of the Mississippi River, requesting their opinions as to the effect of the tractor on the farming industry in their vicinity, the desirability of the tractor as an investment for a farmer, their practice regarding the loan of money for the purchase of a tractor, and related questions. (See Table II.)

A letter was addressed to more than 13,000 tractor owners, inclosing a list of questions to be answered, the replies to which were tabulated and are shown in the following pages. The distribution of these tractor users by States is shown in Table I. Replies were received from about 40 per cent of the men addressed, but many of the reports were discarded because tractors had not been used for a sufficient length of time to enable their owners to form an opinion as to their merits. However, more than 2,000 men who had operated their outfits for one or more seasons furnished detailed reports.

TABLE I.—*Distribution of tractors in States west of the Mississippi River, showing the approximate number of owners reported by bankers.*

State.	Tractor owners.	State.	Tractor owners.	State.	Tractor owners.
North Dakota	3,200	Texas	650	Arkansas	80
South Dakota	2,100	Missouri	345	Arizona	20
Kansas	1,205	Oklahoma	335	New Mexico	15
Iowa	1,200	Colorado	265	Nevada	5
Minnesota	1,060	Wyoming	130	Utah	5
Montana	950	Oregon	125		
Nebraska	730	Idaho	105	Total	13,327
California	700	Washington	102		

OBSERVATIONS OF BUSINESS MEN.

Most of the inquiries to business men were addressed to bankers. It is believed that bankers have a more intimate knowledge of the financial standing of the farmers of their community than most other classes of business men and are also more likely to furnish an unbiased and unprejudiced opinion, based on their knowledge of the financial success of the men who are farming with horses and those who are using tractors. The prosperity of the bankers of a community depends largely upon the prosperity of their patrons, and they naturally keep well informed on all factors influencing the welfare of the community. It appears from many of the answers that the writers had been carefully observing the effect of farm tractors for several years, and their conclusions were based on actual knowledge of the general prosperity of the men who farmed with horses and those who used tractors.

The replies received from all classes of business men showed that where tractors had been used to any great extent or for a considerable length of time the business interests have become prejudiced against them and believe they have had an injurious effect on the farming community and general prosperity of the country. Hundreds of facts and arguments were furnished in support of these opinions, which were not in a form permitting tabulation. The principal reason advanced seems to be the fact that a great many men who have purchased tractors have failed to make them pay, and a large percentage, having bought expensive outfits on time, lost their entire property through foreclosure proceedings and judgments on notes.

It is unfair, however, to ascribe all of these failures to the inefficiency of the tractor; as faulty operation had its share. A very important contributing cause has been the poor business management and judgment of the farmer in incurring an obligation nearly or quite equal to the entire value of his property with no means of meeting it except the production of a good crop or the possible performance of a large amount of lucrative custom work. While a good crop might save him from bankruptcy, he would be more properly termed "lucky" than a good manager. The failure of a crop the first year after the purchase of the tractor has often been sufficient to ruin the owner, while serious breaks or other accidents have frequently accomplished the same result.

Without referring further to the reasons for their opinions, most of the business men consulted do not consider the tractor a good investment for the average farmer. The opinions of bankers as to the effect the tractors have had on the farming industry and their desirability as an investment for the average farmer are shown in Table II. In this table the States are arranged according to the number of

tractor owners known to the bankers, but this is probably the order in which they would appear if they were arranged according to natural conditions most favorable to the tractors and possibly also as to the length of time during which such machines have been used in these States, respectively.

TABLE II.—*Bankers' opinions regarding the tractor.*

States (arranged according to number of tractor owners known to bankers).	Answers of bankers to questions indicated below.			
	Has traction farming had a favorable or unfavorable effect upon the farming industry in your vicinity?		Do you consider a traction engine a good investment for the average farmer in your neighborhood?	
	Unfavorable.	Favorable.	No.	Yes.
North Dakota	343	57	422	20
South Dakota	124	58	225	48
Kansas	83	87	172	26
Iowa	17	59	65	17
Minnesota	57	53	144	11
Montana	87	26	116	8
Nebraska	22	35	61	10
California	4	90	43	34
Texas	23	51	61	23
Missouri	18	16	28	3
Oklahoma	18	23	49	5
Colorado	16	17	33	3
Wyoming	6	12	17	4
Oregon	5	11	12	2
Idaho	5	5	11	4
Washington	7	4	11	2
Arkansas	2	5	5	4
Utah	5	4	11	1
Total	842	613	1,486	225

Each of the bankers whose answers are included in this tabulation knew at least three users of tractors, while most of them knew a much greater number, the average being about 10. It will be observed from this table that while 842 bankers believe the tractor has had an unfavorable effect on the farming industry and 613 state the effect to be favorable, the number of bankers who are of the opinion that the tractor is a good investment for a farmer is only 225, while 1,486 think that it is not. Bankers realize that the tractor has been a benefit to the community in helping to break and open up to cultivation large tracts of virgin land, but they also realize that the risk of this enterprise, as well as much of the expense, has been borne by the individual farmer. Nearly 87 per cent of business men who have had an opportunity to observe the results of tractor farming consider that a tractor is a poor investment for a farmer.

OPINIONS OF TRACTOR OWNERS.

The opinions of the men who have used tractors corroborate the views of the bankers. In reply to the question, "Do you consider a traction engine a good investment financially for a farmer in your

vicinity?" there were 876 who answered "no" and 891 who answered "yes." Of those answering this question, 748 had used their tractor for only one season. The answers of the men who had used the tractor through two or more seasons show 592 negative and 427 affirmative replies. Practically all of the men from whom replies were received were using tractors at the end of 1913, and those who had previously tried them but had discontinued their use are not, therefore, included. It may safely be assumed that nearly all of the latter class would answer the above question in the negative, which would more than double the number of men answering "no," as there are hundreds of men who have discontinued the use of the tractor after a trial. Accurate figures on this point are difficult to secure, owing to duplication among the past users of tractors reported, but a conservative estimate obtained by using the number reported by bankers located in widely separated sections of Montana indicates that more than 400 men have discontinued the use of the tractor for farm work in that State. The answers of present owners of tractors to the above questions are shown in Table III.

TABLE III.—*Answers of tractor owners to the question, "Do you consider the traction engine a good investment financially for a farmer in your vicinity?"*

State.	First season.		Second season.		Third season.		Fourth season.	
	Yes.	No.	Yes.	No.	Yes.	No.	Yes.	No.
North Dakota	108	106	73	154	25	86	15	32
South Dakota	39	28	28	22	16	19	15	14
Kansas	56	22	26	22	9	9	5	5
Minnesota	24	27	37	35	13	12	3	7
Montana	26	26	23	38	7	12	2	12
Iowa	52	17	14	13	9	6	3	3
Colorado	42	4	15	9	11	2	2	.....
Nebraska	22	13	11	14	4	1	.....	3
Texas	25	13	4	8	1	3	.....	.....
Missouri	15	5	3	3	1	1	2	.....
Other States	55	23	16	19	9	4	3	4
Total	464	284	250	337	105	155	50	80
Per cent	62.0	38.0	42.6	57.4	40.4	59.6	38.5	61.5

Table III shows that the percentage of men who believe that the tractor is a poor investment increases with each season's use, until, after four years, 61.5 per cent of the owners are of this opinion. If the opinions of those who have discontinued the use of the tractor could have been included, this percentage would doubtless be increased to 85, thus approximating the judgment of the bankers. For example, 65 per cent of all present tractor owners in Montana have had more than one season's experience, and 65 per cent of these answer the inquiry in the negative. If 65 per cent of the 950 users reported for Montana in Table I, or 617, be taken as the number in that State having more than one year's experience, then 65 per cent of the

latter number, or 400, represents the number of present users who report unfavorably after one season of experience. If to this be added the 400 who have discontinued the use of the tractor in Montana, there appear to be 800 out of 1,017 who hold unfavorable opinions, or about 80 per cent.

In analyzing the reports of users it early became apparent that opinions and estimates furnished by men who had used a tractor for only one season could not be accepted as representing average results, as their answers invariably gave more favorable averages than did those from men who had had experiences of two or more seasons. This is partly due in all probability to the fact that their machines were of better quality than those of previous years, but the differences between the averages are far greater than those existing between the tractors sold early in 1913 and those sold one year previous. The principal reason for these favorable answers is doubtless a natural enthusiasm resulting from the acquisition of new and interesting machines, of which great achievements are expected, but which have not been used for a sufficient time to demonstrate their actual value. The experience gained by the end of the second season, with the novelty gone, the outfit showing the effect of wear and not running so satisfactorily as when new, and the probability of more or less repairing having been necessary, makes the owner better qualified to express an opinion as to the tractor's actual value.

The tractor's efficiency decreases with use, on account of wear. The reports show, however, that it is during the first year of its use, when it should be rendering its maximum amount of service and giving a minimum amount of trouble, that the largest percentage of men change their opinions of the tractor from favorable to unfavorable. It is a reasonable supposition that every purchaser of a tractor believes he is making a good investment at the time of purchase. The data show that after one season's use only 62 per cent retain this opinion, so that it would seem that the results were such as to cause 38 per cent to change their opinion on this point after one year. After two seasons' use more than 57 per cent of present tractor users believe the tractor is a poor investment, and with longer experience this percentage increases.

REPORTS OF SATISFIED AND DISSATISFIED OWNERS.

In order to ascertain whether the owners who expresssed favorable opinions regarding the tractor were actually obtaining better results than those holding opposite views, tabulations were made of the data furnished by these two classes of men, and the averages obtained are shown in Tables IV to VIII, inclusive.

The data compiled from reports of tractor owners shown in Tables IV to VIII are separately given for North Dakota and for all other

States west of the Mississippi River.[1] This separation was made for the following reasons: Sufficient replies were received from owners in North Dakota to give reliable averages. The conditions under which tractors are used in North Dakota are very similar throughout the State, being generally favorable to the tractor on account of the large, level farms, where the types of farming followed are well adapted to the use of mechanical power. Gas tractors have been used in considerable numbers in North Dakota for a greater length of time than in the other States.

SERVICE RENDERED BY TRACTOR.

Table IV shows the average amount of service rendered annually per tractor, together with estimates as to the average life of farm tractors. The figures showing days used per year include custom work of all kinds, as well as stationary work on the home farm. It will be noticed that the number of days the tractor is used per year grows slightly less, as a rule, from year to year, and at the same time the hours lost per day increase.

In connection with the estimated life of the tractor it may be noted that for the group of States the averages are higher for the men who have used the tractor but one season, while in North Dakota they are slightly lower. This is probably partly due to the fact that in making the estimate the men were asked to judge by "observations and experience." In North Dakota many men who had used a tractor for only one year could make a fair estimate of the average life of a tractor from observations of outfits which had been used in their neighborhood, while in other States they have not been so widely used and the estimates are made to a greater extent from personal experience only. There are also other reasons, which will appear in connection with subsequent tables.

Only 24 reports from North Dakota were received from men who had used their tractors more than four years, and about the same number came from the other territory. The age distribution of the tractors reported from North Dakota was as follows:

One year old, 278; 2 years old, 283; 3 years old, 131; 4 years old, 55; 5 years old, 15; 6 years old, 5; 7 years old, 2; 8 years old, 2.

It is known that the number of 4-year-old tractors reported is a very small percentage of the number of tractors actually sold four years ago, much smaller than the percentage reported for the 1 and 2 year old tractors. This would apparently indicate that many of the tractors sold four years ago are no longer in use, and, together with the decrease in the number reported for the third year, might be

[1] The data in the upper half of Tables IV, V, VI, VII, and VIII are all based on the same group of farms, and by combining these parts of tables the complete tabulation for the group may easily be obtained. The same is true of the lower half of these tables.

considered as evidence that the estimated life of the tractor, as furnished by the tractor owners reporting, is too high.

TABLE IV.—*Service rendered annually by tractors on farms in North Dakota and other States west of the Mississippi River, showing the length of life as estimated by the owners.*

[Arranged according to the opinions of owners as to the tractor's desirability as an investment.]

IN THE STATE OF NORTH DAKOTA.

Result of investment as reported by owners.	Average annual use.	Hours in field per day.		Estimated average life of tractor.	Number averaged.	Farms where night work was reported.	
		Spent.	Lost.			Percentage of all tractors.	Average number of nights operated per year.
Men having one season's experience:	*Days.*			*Years.*			
Profitable	87.1	12.5	1.2	8.5	108	14.6	31.8
Unprofitable	69.2	12.4	2.1	5.0	106	13.7	12.9
Men having two seasons' experience:							
Profitable	97.3	13.1	1.4	8.8	73	23.1	26.9
Unprofitable	76.6	12.9	2.7	4.9	154	10.7	16.0
Men having three seasons' experience:							
Profitable	85.2	12.8	1.5	8.8	25	30.0	17.3
Unprofitable	75.6	12.8	2.7	5.4	86	12.9	11.7
Men having four seasons' experience:							
Profitable	92.5	12.6	1.6	8.7	15	10.0	60.0
Unprofitable	73.4	12.0	2.8	5.9	32	8.0	22.5

IN ALL STATES WEST OF THE MISSISSIPPI RIVER EXCEPT NORTH DAKOTA.

Men having one season's experience:							
Profitable	105.8	11.4	1.3	10.2	356	21.3	26.5
Unprofitable	77.9	11.5	2.2	6.4	178	16.5	13.7
Men having two seasons' experience:							
Profitable	102.1	11.7	1.4	9.7	177	28.6	34.7
Unprofitable	73.9	11.8	2.2	3.0	183	16.0	22.2
Men having three seasons' experience:							
Profitable	98.9	11.6	1.4	9.9	80	16.9	38.9
Unprofitable	73.0	11.6	2.5	5.7	69	5.2	18.3
Men having four seasons' experience:							
Profitable	93.5	11.6	1.6	9.3	35	10.7	22.0
Unprofitable	65.2	11.4	2.6	5.9	48	7.1	38.3

To judge by the estimates, the average life of a tractor in North Dakota is approximately only 6 years, while the average estimated life in other States is about 8 years. It is believed, however, that in the case of estimates on the life of tractors for States other than North Dakota, some allowance must be made for the fact, already mentioned, that most of these estimates are based entirely on the owner's personal experience, which the figures show has been a short one for 80 per cent of the men reporting, whereas for North Dakota the figures are to a great extent based on observation of neighboring tractors as well.

However, the life of a tractor can not be properly expressed in years alone. The tractor is a machine; and, like all machines, its life depends on the amount of work it does and on the care taken of it. This life can be shortened by lack of proper care and by abuse in operation. The number of years a tractor will be available for work on a farm, therefore, depends only partly on the hours it will be required to work each year. But if the machine is given proper care, both when idle and when in use, the amount of work done per year will be the principal factor in determining its length of useful life. Table IV shows that during the working life of a tractor in ordinary farm service the amount of service obtained covers from 3,600 to 11,000 working hours, including both traction and stationary work. From these figures it is apparent that a tractor might be worn out in less than two years if operated day and night continuously, while, on the other hand, if used only intermittently its life may be extended over a number of years, with proper protection from deteriorating influences when not in use. It might seem at first thought that a tractor could be made to last indefinitely by replacing worn-out parts with new ones, but there comes a time when the cost of such replacements becomes prohibitive and it is more economical to discard the old tractor and purchase a new one. The tractor's life is, then, the length of time it can be used before the repairs become so expensive as to make its further use uneconomical.

While Table III showed the number of owners who believe the tractor to be a profitable investment, there were two related questions submitted to the owners which are not shown in the tabulations. These were "All things considered, is the tractor more satisfactory than horses?" and "Is it cheaper?" The answers received to these questions agree in many cases with those shown in Table III, but it is interesting to note that among the men who believed the tractor to be a good investment the number reporting the tractor to be cheaper than horses is greater than the number stating that it is more satisfactory than horses. On the other hand, among the men believing that the tractor is an unprofitable investment, the number stating that it is not cheaper than horses is less than the number stating that it is not as satisfactory.

This would seem to indicate that among the successful owners the tractor's economy has been a greater factor than its general utility, while among the unsuccessful owners the expense has been a more important consideration than its unsatisfactory operation.

FUELS USED.

Table V shows the number of engines in each group which burn gasoline, kerosene, and motor spirits, respectively. From this table it will be seen that the percentage of kerosene tractors is slightly

greater in each group where the owners believe the tractor is profitable than in the groups where the owners state that the tractor is unprofitable. While this difference is in no case greater than 13 per cent, it is invariably present, which indicates that it has probably had some influence on the opinions of the owners. A further comparison of gasoline and kerosene tractors will be found in Table IX.

TABLE V.—*Tractors using different fuels on farms in North Dakota and other States west of the Mississippi River.*

[Arranged according to the opinions of owners as to the tractor's desirability as an investment.]

IN THE STATE OF NORTH DAKOTA.

Result of investment as reported by owners.	Gasoline.		Kerosene.		Motor spirits.		Fuel not reported.
	Number using.	Percentage of number reported.	Number using.	Percentage of number reported.	Number using.	Percentage of number reported.	
First season:							
Profitable	37	48.7	33	43.4	6	7.9	32
Unprofitable	50	63.3	27	34.2	2	2.5	27
Second season:							
Profitable	30	49.2	29	47.5	2	3.3	12
Unprofitable	77	62.6	45	36.6	1	.8	31
Third season:							
Profitable	14	60.9	8	34.8	1	4.3	2
Unprofitable	41	64.1	21	32.8	2	3.1	22
Fourth season:							
Profitable	6	46.2	7	53.8	0	.....	2
Unprofitable	16	59.3	11	40.7	0	.....	5
IN ALL STATES WEST OF THE MISSISSIPPI RIVER EXCEPT NORTH DAKOTA.							
First season:							
Profitable	117	46.2	133	52.6	3	1.2	49
Unprofitable	78	53.4	65	44.5	3	2.1	25
Second season:							
Profitable	70	52.2	60	44.8	4	3.0	26
Unprofitable	86	59.3	59	40.7	0	.....	29
Third season:							
Profitable	34	60.7	20	35.7	2	3.6	12
Unprofitable	39	72.2	15	27.8	0	.....	13
Fourth season:							
Profitable	14	51.9	13	48.1	0	.....	5
Unprofitable	19	52.8	17	47.2	0	.....	12

AMOUNT OF MOTIVE POWER PER FARM.

In Table VI are comparisons of the amount and value of motive power maintained by the two classes of tractor users which are being considered, together with the value of special equipment purchased for use with the tractor and the average size of farms for each group.

Little difference is shown in the average sizes of tractors, in their cost, or in the value of special equipment for the tractor. But the men who find the tractor profitable, although they show a greater average acreage, do not keep so many horses as those who reported unfavorably. A comparison of results obtained on different sizes of farms is shown in Table XIX.

TABLE VI.—*Comparison of the average amount and value of motive power maintained by tractor users on farms in North Dakota and other States west of the Mississippi River.*

[Arranged according to the opinions of owners as to the tractor's desirability as an investment.]

IN THE STATE OF NORTH DAKOTA.

Result of investment as reported by owners.	Drawbar horse-power of tractors.	Cost of tractors.	Value of special equipment for tractors.	Horses kept.		Size of farms (acres).
				Present number.	Value.	
First season:						
Profitable	22.9	$2,474	$617	8.9	$1,526	785
Unprofitable	23.2	2,467	650	11.1	1,849	763
Second season:						
Profitable	24.7	2,621	753	10.4	1,831	924
Unprofitable	24.3	2,548	720	13.8	2,241	870
Third season:						
Profitable	23.0	2,572	670	10.3	1,724	783
Unprofitable	24.6	2,604	725	10.4	1,689	719
Fourth season:						
Profitable	23.2	2,247	706	11.6	1,896	896
Unprofitable	21.4	2,430	725	13.7	2,203	846

IN ALL STATES WEST OF THE MISSISSIPPI RIVER EXCEPT NORTH DAKOTA.

First season:						
Profitable	21.9	$2,348	$496	8.8	$1,405	666
Unprofitable	23.7	2,330	528	10.1	1,565	548
Second season:						
Profitable	22.9	2,426	574	8.7	1,398	682
Unprofitable	22.8	2,454	613	10.1	1,595	664
Third season:						
Profitable	22.8	2,549	601	13.8	2,010	847
Unprofitable	21.8	2,478	620	10.5	1,607	759
Fourth season:						
Profitable	19.3	2,252	529	11.5	1,794	714
Unprofitable	22.1	2,322	688	10.8	1,671	614

CUSTOM WORK.

Table VII shows the number of owners in each of the two classes that are being compared who use their tractors for custom work. From these it will be seen that the percentage of men who do custom work, as well as the percentage of men who state that custom work is profitable, is larger among the owners who find the tractor profitable than among the second class of owners. The difference in the prices received is not very marked nor very regular and apparently bears little relation to the percentage of men reporting custom work unprofitable. For a comparison of averages from men who state that custom work is profitable and from those who find it unprofitable, see Table XX.

TABLE VII.—*Custom work done by tractor owners on farms in North Dakota and other States west of the Mississippi River.*

[Arranged according to the opinions of owners as to the tractor's desirability as an investment.]

IN THE STATE OF NORTH DAKOTA.

Result of investment as reported by owners.	Number reporting.	Doing custom work.		Finding custom work profitable.	
		Number.	Per cent.	Number.	Per cent.
Men having one season's experience:					
Profitable	104	76	73.1	64	87.7
Unprofitable	103	56	54.4	21	43.7
Men having two seasons' experience:					
Profitable	72	59	81.9	48	87.3
Unprofitable	149	95	63.8	22	27.8
Men having three seasons' experience:					
Profitable	25	21	84.0	19	95.0
Unprofitable	85	52	61.2	13	27.7
Men having four seasons' experience:					
Profitable	15	10	66.7	8	88.9
Unprofitable	32	25	78.1	9	39.1

IN ALL STATES WEST OF THE MISSISSIPPI RIVER EXCEPT NORTH DAKOTA.

Men having one season's experience:					
Profitable	341	237	69.5	199	88.8
Unprofitable	172	120	69.8	60	54.5
Men having two seasons' experience:					
Profitable	170	130	76.5	102	87.9
Unprofitable	177	115	65.0	43	41.0
Men having three seasons' experience:					
Profitable	78	59	75.6	50	89.3
Unprofitable	67	46	68.7	14	34.1
Men having four seasons' experience:					
Profitable	34	29	85.3	22	81.5
Unprofitable	48	28	58.3	13	50.0

In Table VIII is a comparison of the annual repairs reported by the two classes of owners under consideration, together with the total repairs. In this connection it should be noted that a number of the men who reported the total amount of repairs for their tractors did not report the repairs by years. The total repairs, therefore, do not agree exactly with the sum of the annual repairs.

Considering Tables IV to VIII as a whole, it is seen that the greatest differences existing between the averages for the two classes of owners represented are those between the estimated life of the tractor in years, the average amount of time lost per day, and the repairs. These items show that decidedly better results are being obtained by the men who state that the tractor is a profitable investment, as they lost considerably less time per day on account of engine trouble, had much lower repair charges, and, in their opinion, they will obtain approximately one more year's service from their tractors than the men who believe the tractor is unprofitable.

TABLE VIII.—*Annual repairs for tractors on farms in North Dakota and other States west of the Mississippi River.*

[Arranged according to the opinions of owners as to the tractor's desirability as an investment.]

IN THE STATE OF NORTH DAKOTA.

Result of investment as reported by owners.	First year.		Second year.		Third year.		Fourth year.		Average total repairs.[1]	
	Amount.	Per centage of value.	Amount.	Per centage of value.	Amount.	Per centage of value.	Amount.	Per centage of value.	Amount.	Per centage of value.
Men having had one season's experience:										
Profitable	$26.33	1.1	.....	.....	.....	.....	.....	.....	$26.33	1.1
Unprofitable	72.54	2.9	.....	.....	.....	.....	.....	.....	72.54	2.9
Men having had two seasons' experience:										
Profitable	21.29	.8	$64.00	2.4	.....	.....	.....	.....	96.68	3.7
Unprofitable	69.53	2.7	144.55	5.7	.....	.....	.....	.....	229.49	9.0
Men having had three seasons' experience:										
Profitable	32.70	1.3	87.39	3.4	$91.83	3.6	.....	.....	198.35	7.7
Unprofitable	81.56	3.1	125.62	4.8	175.35	6.7	.....	.....	359.22	13.8
Men having had four seasons' experience:										
Profitable	16.36	.7	52.23	2.3	85.06	3.8	$71.41	3.1	230.05	10.2
Unprofitable	39.73	1.6	63.29	2.6	91.12	3.8	94.58	3.9	442.52	18.2

IN ALL STATES WEST OF THE MISSISSIPPI RIVER EXCEPT NORTH DAKOTA.

Men having had one season's experience:										
Profitable	$36.44	1.6	.....	.....	.....	.....	.....	.....	$36.44	1.6
Unprofitable	75.29	3.2	.....	.....	.....	.....	.....	.....	75.29	3.2
Men having had two seasons' experience:										
Profitable	27.43	1.1	$65.95	2.7	.....	.....	.....	.....	101.24	4.2
Unprofitable	60.40	2.5	122.41	4.9	.....	.....	.....	.....	195.41	8.0
Men having had three seasons' experience:										
Profitable	36.46	1.4	77.03	3.0	$71.50	2.8	.....	.....	196.99	7.7
Unprofitable	52.59	2.1	118.81	4.8	137.48	5.5	.....	.....	325.67	13.1
Men having had four seasons' experience:										
Profitable	18.70	.8	43.00	1.9	57.66	2.7	$83.87	3.7	290.57	12.9
Unprofitable	43.48	1.9	93.12	4.0	122.50	5.3	151.87	6.5	424.84	18.3

[1] Many owners reported the total repairs, but did not give them by years. This column is the average of all reports of total repairs, and therefore does not agree exactly with the sum of the annual repairs.

It will also be noticed that the successful owners use their tractor more days annually than do the unsuccessful owners, which would naturally be expected in view of the smaller number of horses kept by the former class of men.

The causes underlying the difference in results obtained are many and various. While much of the difference can be traced to the owner or operator, other important factors are involved, and some of these will be shown in the tables that follow.

GASOLINE AND KEROSENE TRACTORS.

In view of the fact that the groups of owners who gave favorable reports regarding the tractor invariably showed a larger percentage of kerosene tractors than did the groups reporting unfavorably, it was thought desirable to make a comparison of these two types of tractors, in order to ascertain what difference, if any, existed between them. Table IX shows this comparison.

This table was prepared entirely from figures furnished by tractor owners located in North Dakota who had used their tractors for two seasons. This was done for the reason that it was not considered advisable to give too much weight to the reports furnished by men who had used their tractors but one season and were therefore not fully qualified to express reliable opinions. Nor was it considered fair to the tractor to include reports from men who had purchased tractors three or more seasons ago, and who were therefore basing their opinions largely on less efficient models than those now on the market. While the tractors which have been in use for two seasons are not quite so efficient as those sold during 1913, the difference is not so great as exists between the earlier models and those which have been used two seasons.

TABLE IX.—*Comparison of gasoline and kerosene tractors on farms in North Dakota, prepared from reports of owners with two seasons' experience.*

Item of comparison.	Data from owners of tractors.	
	Gasoline.	Kerosene.
Number of tractors reported	127	94
Owners stating that tractor is a good investment.....per cent..	28	39
Life of tractor (estimated).....years..	5.9	6.9
Annually used.....days..	82	88
Average time spent in the field per day.....hours..	13	13
Time lost per day for repairs, etc.....do....	2.2	1.9
Average drawbar rating of tractors.....horsepower..	24.6	23.0
Average size of farms.....acres..	841	866
Number of horses kept:		
Before purchase of tractor	15.8	17.8
After purchase of tractor	11.6	12.3
Average number of horses displaced	4.2	5.5
Owners who do custom work.....per cent..	69	74
Owners doing custom work who find it profitable.....do....	47	67
Average cost of tractor.....dollars..	2,573.00	2,469.00
Average cost of repairs required:		
First season.....do....	61.00	33.00
Second season.....do....	123.00	81.00
Average value of special equipment purchased.....do....	692.00	734.00
Price received per acre for plowing.....do....	1.87	1.88
Price received per acre for breaking.....do....	3.54	3.56

It is believed that the comparison made in Table IX is the fairest and most reliable which it is possible to make, and a similar method has been used in preparing several of the tables that follow.

From the comparison made, it will be seen that the figures are slightly in favor of the kerosene tractor in almost every case, the

most important differences being in the estimated life and the cost of repairs required annually; but the percentage of replies, days used annually, hours lost, horses replaced, and percentage finding custom work profitable, all of which are favorable to the kerosene tractor, are worthy of note.

While this table shows that the amount of equipment per tractor is greater for the kerosene than for the gasoline tractors, the difference being $42, this figure is really favorable to the kerosene tractor, as it is shown in Table X that the kerosene tractor pulls a greater cross section of plows, etc., than does a gasoline tractor of equal rating. It will, therefore, require a larger gang to provide a full load, and consequently the cost of the equipment is slightly higher.

Table X presents a comparison of the operating factors for gasoline and kerosene tractors of 15 and 30 horsepower, drawbar rating. These figures were furnished by men in North Dakota with only one year's experience and are therefore probably slightly more favorable to the tractor than would be the case if the owners were men of longer experience. The reason for using figures furnished by men with only one season's experience is the fact that among the reports for tractors which had been used for two seasons there were very few for gasoline and kerosene tractors of exactly the same ratings for which complete information had been furnished. While the number of these machines among the 1-year-old tractors is not large, it is believed to be sufficient to insure a fairly reliable comparison.

TABLE X.—*Comparison of results obtained on farms in North Dakota with gasoline and kerosene tractors during their first season's use.*

Item of comparison.	Drawbar ratings of tractors.			
	15 horsepower.		30 horsepower.	
	Gasoline.	Kerosene.	Gasoline.	Kerosene.
Number of tractors reported	28	24	41	27
Plowed per hour.....acres..	1.4	1.5	2.1	2.3
Depth plowed.....inches..	5.9	6.2	6.1	6.3
Width of plow.....do....	77.1	80.6	110.8	123.3
Width of harrow drawn at same time as plows...do....	98.1	102.9	96.3	107.7
Distance traveled per hour.....miles..	2.1	2.1	2.3	2.2
Fuel used per day.....gallons..	33.0	44.0	57.9	66.5
Cost of fuel used per day.....dollars..	6.41	5.50	10.26	8.78
Cylinder oil used per day.....gallons..	2.5	3.3	4.1	4.6
Cost of cylinder oil used per day.....dollars..	.91	1.29	1.69	1.84

Table X shows that the acres plowed per hour, the depth plowed, width of plow, and width of harrow are all greater for the kerosene than for the gasoline tractor. The amount of fuel consumed is greater for the kerosene tractor, but the cost is less, on account of the lower price per gallon. Both the amount and value of the lubricating oil used are greater for the kerosene tractor, however.

FUEL SUPPLY.

The showing made by the kerosene tractors in comparison with those burning gasoline is of special interest in view of the comparatively recent introduction and development of the kerosene tractor. A few years ago the supply of gasoline could not be increased rapidly enough with the distilling systems then in use to meet the requirements of the thousands of gasoline engines of all kinds being manufactured. As a consequence, the price of gasoline gradually increased.

The engine manufacturers, therefore, fearing that the rise in the price of gasoline would hurt the sale of their product, devoted their efforts to developing an engine which would burn the heavier and cheaper oils. At the same time the oil refiners bent their efforts toward developing a process which would produce a larger quantity of the lighter fuels from the crude oils. Both have apparently accomplished their purpose. Engines are now on the market which apparently handle the heavier fuels with even better results in some respects than are obtained from the engines burning gasoline, while the oil refiners can now vary the quality of petroleum products at will.

On account of a misunderstanding which seems to be quite general as to the present status of the fuel resources of this country, a short discussion of the subject will be of interest.

There seems to be a rather prevalent opinion that the supply of fuel oil is rapidly nearing exhaustion, that the percentage of the lighter fuels, especially gasoline, which can be obtained from the crude oil, is growing less, and that the price of gasoline will therefore soon increase to such an extent as to prohibit its use in farm engines. Statements to this effect are quite common and frequently appear in print. While appearances may have indicated such a condition a few years ago, recent developments in the petroleum industry prove that such statements have no foundation in fact at the present time.

In the opinion of Dr. David T. Day, of the United States Geological Survey, the known oil supply of this country will in all probability be sufficient for the next 100 years. Dr. Day has been in charge of the petroleum investigations of the Geological Survey for a number of years and is qualified to speak with authority on this subject. As to the percentage of gasoline that can be obtained from the crude oils, Dr. Day, in a recent address before the Franklin Institute, spoke as follows:

> This consideration naturally suggests the vital question of an adequate gasoline supply. Even if we produce 25,000,000 barrels of gasoline in the next year this would probably be too little for a year or two of further automobile progress.

The means for meeting the demand are in sight. * * * In the first place, recent developments in knowledge of the resources of the United States make it probable that there will be no great decline in oil production in the future; therefore no decline in gasoline supply is likely. As to the necessary increase, this will come from synthetic gasoline obtained from petroleum itself.

Several years ago I found that if these oils are distilled under pressure the yield of gasoline is still greater, and that the unpleasant odor, due to deficiency in hydrogen in the composition of the oils, can be remedied by actually combining hydrogen with the oil in the still under the influence of a catalytic agent. Recently the demand for any kind of gasoline has waived the requirement of good odor, and other processes are producing much synthetic gasoline.

By such means, low-grade residues have been made to yield from 20 to perhaps 70 per cent of their weight in material which will serve as gasoline.

The "low-grade residues" of which Dr. Day speaks in the last paragraph quoted are the oils from which the regular amount of gasoline has been distilled under the old processes. Under the new process probably 75 per cent of nearly all of the crude oils may be converted into gasoline.

It is therefore safe to assume that the price of gasoline will not advance in the next few years because of scarcity, for sufficient gasoline can be readily produced to meet all requirements. In other words, the oil-refining industry has reached a stage where the quantity of any petroleum product may be increased or diminished at will, to meet the requirements of the trade; that is, if the demand for gasoline increases and that for kerosene decreases, part of the raw product which in the past has been distilled into kerosene will be converted into gasoline instead.

The heavier oils possess more heat units per gallon, but practically the same per pound as the lighter ones. The more heat units a given quantity of fuel contains, the more power it should develop; therefore, if the heavier products could be as readily burned as the lighter ones they should command a higher price per gallon. The heavier fuels present difficulties in starting the engine when cold, however, usually requiring it to be run for a short time on a lighter fuel until it becomes hot enough to handle the heavier one satisfactorily. Recent improvements in design promise to overcome this objection.

FUEL CONSUMPTION.

The consumption of fuel per hour by tractors of different ratings is shown in Table XI. According to these figures, the amount of fuel consumed per hour varies from about $3\frac{1}{5}$ gallons for the 20-horsepower tractor to $5\frac{3}{4}$ gallons for the 30-horsepower outfit during the first year. For the 2-year-old tractors the range is from $3\frac{1}{7}$ to about $6\frac{1}{3}$ gallons per hour. In five out of the seven groups the amount is greater for the second year than for the first, which would seem natural, as after wear has commenced in the motor the fuel consumption will not be so economical.

While the figures in Table XI would appear to indicate that the consumption of fuel per drawbar horsepower is considerably greater for the small tractors than for the large ones, Table XIV shows that the small tractors are usually loaded more nearly to their full capacity than the large ones, and the consumption of fuel per unit of work done is slightly less for the 12 and 15 horsepower tractors than for those of 30 horsepower.

TABLE XI.—*Average consumption of fuel per hour by different sizes of engines and per drawbar horsepower hour on farms in North Dakota.*

Fuel consumption per hour.	Drawbar rating of engine (horsepower).						
	12	15	20	22	25	30	40
First year:							
Per engine.....gallons..	3.264	3.462	3.211	5.419	4.725	5.761	5.684
Per drawbar horsepower.....do....	.272	.231	.161	.246	.189	.192	.142
Second year:							
Per engine.....do....	3.854	4.177	3.140	5.885	5.858	5.675	6.367
Per drawbar horsepower.....do....	.321	.278	.157	.268	.234	.189	.159

There appears to be considerable irregularity in the figures shown, but this is not really the case, as the reasons for the varying consumption for the different sizes are as follows: The 15, 22, and 30 horsepower groups all contain a larger percentage of kerosene tractors than the 12, 20, 25, and 40 horsepower groups, and, as has already been shown, the kerosene tractors consume a greater quantity of fuel than the gasoline tractors. There are also more kerosene tractors in the 12-horsepower group than in the 20, and several of the outfits included in the 20 and 25 horsepower groups are apparently overrated, to judge both by their fuel consumption and by the amount of work done, as shown in other tables.

The fuel cost per unit of work varies, of course, with the price per gallon. The prices for the different fuels vary considerably in different States. The averages of those reported are shown in Table XII. The general averages per gallon for the four fuels commonly used were as follows: Distillate, 8.17 cents; kerosene, 10.08 cents; motor spirits, 15.86 cents; gasoline, 18.94 cents. The distillate and motor spirits are not extensively used, as the table shows.

TABLE XII.—*Average prices for fuels, per gallon, as reported by farm tractor owners.*

State.	Gasoline.	Kerosene.	Motor spirits.	Distillate.
	Cents.	*Cents.*	*Cents.*	*Cents.*
Montana	22.99	15.37	.....	.....
North Dakota	19.51	11.79	16.53	.....
South Dakota	18.47	9.86	14.39	.....
Nebraska	18.06	9.44	.....	.....
Minnesota	17.72	9.31	.....	.....
California	17.50	.....	.....	8.29
Texas	17.50	9.90	.....	6.25
Missouri	17.00	7.90	.....	.....
Kansas	16.23	7.78	.....	.....
Average	18.94	10.08	15.86	8.17

LUBRICATING OIL.

The quantity of lubricating oil required is another question of considerable importance in connection with the operation of a tractor. The average consumption per hour for tractors of different ratings is shown in Table XIII. The increase in the amount of oil consumed shows closer relation to the increase in the horsepower of the tractor than did the fuel, although there are some irregularities, most of which are explained by the remarks in connection with Table XI. The price per gallon for lubricating oil not only varies in different sections, but varies according to quality. The prices paid per gallon range from 25 to 60 cents, the average price being about 40 cents.

TABLE XIII.—*Average consumption of cylinder oil per hour for different sizes of farm engines and per drawbar horsepower hour.*

Cylinder-oil consumption per hour.	Drawbar rating of engine (horsepower).						
	12	15	20	22	25	30	40
First year:							
Per engine.....gallons..	0.168	0.267	0.291	0.302	0.325	0.401	0.424
Per drawbar horsepower.....do....	.014	.0178	.0145	.0137	.013	.0134	.0106
Second year:							
Per engine.....do....	.280	.282	.276	.408	.302	.338	.477
Per drawbar horsepower.....do....	.0233	.0188	.0138	.0185	.012	.0112	.0119

The figures shown include all lubricating oil used, whether for cylinders or other purposes, but do not include the cost of greases. This is a comparatively small item, and it is difficult to obtain figures for it.

CROSS SECTION OF PLOWS DRAWN AND AREA PLOWED BY TRACTORS.

The cross section of plows drawn by tractors of different ratings is given in Table XIV, showing that the area of the cross section of plows drawn by the different sizes of tractors bears a close relation to the quantity of fuel used. In this table it will also be seen that the 20 and 25 horsepower outfits do not pull plows commensurate with their ratings, to judge by the loads drawn by the other tractors. Attention is invited to the remarks made in connection with Table XI regarding the rating of tractors in the 20 and 25 horsepower classes and the percentage of gasoline and kerosene tractors in the remainder (p. 22). The area of the cross section of plows drawn by the tractors which have been used two seasons is generally less than the area the first season. There are several possible explanations of this, but the most probable one is believed to be that before the end of the second season many owners have learned that it does not pay to overload a tractor.

Table XIV also shows the average number of acres plowed per hour by tractors of different ratings on farms in North Dakota. These

figures show a close relation to the cross section of the plows, as given in the upper half of the same table. The irregularities already noted in the case of the 20 and 25 horsepower tractors also occur. In five out of the seven classes of tractors there is shown a slight decrease in the amount of work done per hour by the tractors which have been used two seasons.

TABLE XIV.—*Average area of the cross section of plows drawn and area plowed per hour in North Dakota by different sizes of farm engines.*

Plows and plowing.	Drawbar rating of engine (horsepower).						
	12	15	20	22	25	30	40
Area of cross section of plows drawn:							
First year—							
Per engine.....square inch..	447.21	474.86	474.69	716.86	625.37	726.68	908.92
Per drawbar horsepower.....do....	37.27	31.66	23.73	32.58	25.01	24.22	22.72
Second year—							
Per engine.....do....	464.62	459.43	455.81	662.72	665.03	736.03	748.68
Per drawbar horsepower.....do....	38.72	30.60	22.79	30.12	26.60	24.53	18.71
Area plowed per hour:							
For 1-year-old tractors—							
Per engine.....acres..	1.248	1.410	1.405	1.946	1.637	2.175	2.374
Per drawbar horsepower.....do....	.104	.094	.070	.088	.065	.073	.059
For 2-year-old tractors—							
Per engine.....do....	1.386	1.350	1.327	1.753	1.926	2.028	2.165
Per drawbar horsepower.....do....	.116	.090	.066	.080	.077	.068	.054

While these averages are in harmony with the other figures regarding the operating factors, attention is invited to the fact that an average amount of work for a tractor in North Dakota may be either a great deal more or a great deal less than for some other section where conditions are different. There are so many factors which influence the amount of work which can be accomplished with a tractor that average figures are of use only in the section from which they were obtained or under conditions almost identical. The figures for North Dakota represent, for the most part, extremely favorable conditions for tractor plowing.

BREAKING.

The conditions which obtain in breaking sod, are even more various and produce wider variations in the amount of work done than those which are found in plowing.

The number of reports on breaking received from any one section was too small to merit publication of the averages obtained from them. In North Dakota, where the sod is broken with comparative ease and where there is little brush to interfere, the average acreage broken per hour varied from about eight-tenths of an acre for the 12-horsepower tractors to 1½ acres for the 30 and 40 horsepower tractors.

Many men report the same acreage per day in breaking as for plowing, as the breaking is not done so deep as plowing and the tractor wheels find a better grip. In most cases, however, the acreage broken per day is only about two-thirds of that plowed.

COMBINATION WORK.

The percentage of tractor owners who reported combination work with their tractor, i. e., performing two or more operations at one time, such as plowing and harrowing, was much smaller than might have been expected. The figures in connection therewith for the States of North Dakota, South Dakota, Iowa, and California are shown in Table XV. From this it would seem that combination work is practiced considerably less in the semiarid regions than in the more humid sections, although the total number of owners who attempt other operations than plowing and harrowing at the same time is very limited.

There are several reasons for this lack of combination work. Usually there is not much excess power available for other implements if the plow is the full width of the tractor, and, too, additional implements require more attention and this frequently causes more delays, a stop for one implement meaning a stop for the entire outfit.

TABLE XV.—*Use of farm tractors for combination work in the States of North Dakota, South Dakota, Iowa, and California.*

Number reported.	State.	Using plows only.		Using plows and harrows.		Using plows, harrows, and drills.	
		Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
	Men having one season's experience:						
266	North Dakota	155	58.3	106	39.8	5	1.9
82	South Dakota	47	57.3	35	42.7	0	.....
82	Iowa	19	23.2	63	76.8	0	.....
44	California	10	22.7	34	77.3	0	.....
	Men having two seasons' experience:						
262	North Dakota	140	53.4	118	45.1	4	1.5
59	South Dakota	30	50.9	29	49.1	0	.....
34	Iowa	4	11.8	29	85.3	1	2.9
27	California	6	22.2	20	74.1	1	3.7
	Men having three seasons' experience:						
124	North Dakota	68	54.8	52	42.0	4	3.2
39	South Dakota	19	48.7	18	46.2	2	5.1
17	Iowa	4	23.5	13	76.5	0	.....
15	California	2	13.3	12	80.0	1	6.7
	Men having four seasons' experience:						
55	North Dakota	22	40.0	32	58.2	1	1.8
38	South Dakota	19	50.0	18	47.4	1	2.6
9	Iowa	5	55.6	4	44.4	0	.....
0	California	0	.....	0	.....	0	.....

But the principal reason is probably the fact that it is difficult to have the implements follow each other in proper alignment, especially on curves and at corners, which causes poor work to be done. This is especially true in drilling, and most farmers prefer to do this work with horses in order to have it done properly. The harrowing is not so important, as ground missed by it does not so materially affect the crop and does not show after the crop has grown. There is a distinct advantage in the case of many soils in having the harrowing done promptly, yet it appears, considering the four States as a whole, that only about 52 per cent of tractor owners pull harrows with the plows.

DEPTH OF PLOWING.

In order to ascertain whether plowing is usually deeper when done by tractor than when done by horses, Tables XVI and XVII were prepared. Table XVI shows the average depths of tractor plowing in nine States for the number of seasons for which reliable averages could be obtained. While the variations seem to be slight, they are greater than would appear at first glance. Each depth shown represents an average of a large number of reports, most of which are, of course, close to the final average; therefore, in order to increase or diminish the final average even one-tenth of an inch requires a general increase or decrease in the individual reports.

TABLE XVI.—*Average depth of tractor plowing on farms in various States.*

State.	Average depths reported (inches).				State.	Average depths reported (inches).			
	First season.	Second season.	Third season.	Fourth season.		First season.	Second season.	Third season.	Fourth season.
North Dakota	6.18	5.88	6.14	6.11	Iowa	6.35	6.42	.....	.....
South Dakota	6.47	6.44	6.57	6.58	California	6.85	6.77	.....	.....
Kansas	6.30	6.47	6.50	.....	Nebraska	6.71	6.02	.....	.....
Minnesota	6.21	5.87	5.55	.....	Texas	6.19	.....	.....	.....
Montana	6.19	6.17	6.09	.....					

The distribution of the individual reports for all States west of the Mississippi River is shown in Table XVII. The concentration of the reports on the 5, 6, and 7 inch depths will be seen. The reports for the second season show a decided decrease in the percentage reporting 7 inches or more, with a corresponding increase for 6 inches or less. In the third and fourth seasons there appears to be a gradual return to the greater depths, but in connection therewith it must be borne in mind that the men who have used tractors for three or four seasons have been the most efficient operators; in fact, they are the survival of the fittest, for the first two seasons serve to eliminate many of the inefficient operators, as well as many of the defective outfits.

TABLE XVII.—*Percentage of tractor plowing done at various depths on farms in all States west of the Mississippi River.*

Depth of plowing.	First season.	Second season.	Third season.	Fourth and subsequent seasons.	Depth of plowing.	First season.	Second season.	Third season.	Fourth and subsequent seasons.
4 inches	3.84	4.94	5.17	5.94	8 inches	11.54	7.84	11.72	8.22
5 inches	16.85	23.51	20.34	14.61	9 inches	2.72	1.60	3.45	.91
6 inches	37.22	41.66	36.55	41.10	10 inches	2.04	.....	.....	5.94
7 inches	24.32	18.72	20.34	21.46					

While no averages showing the depth of plowing done by horses which are entirely comparable with those shown in Tables XVI and XVII are available, a comparison of these averages with such averages as were available for horse plowing indicates that the difference in depth of plowing, if any exists, is rather in favor of the horse.

The reason for so little deep plowing with the tractor is very evident upon a slight examination into the matter. Most tractors are incapable of pulling a plow cutting the full width of the tractor and turning more than a 6-inch furrow under ordinary conditions. Therefore, if deeper plowing is to be done the gang must be decreased in width, i. e., one or more plow bottoms must be raised, when the gang will no longer cut out the full width of the tractor's track, which will probably result in the tractor's wheels passing over the same ground twice, causing excessive packing of the soil.

But the greatest difficulty is that the gang plow which is not as wide as the tractor must be hitched to one side of the longitudinal center of the machine, in order to permit the drivewheels to travel on the unplowed land. Such a hitch not only makes the tractor difficult to steer, but exerts a twisting strain on the tractor's frame, which is conducive to short life and heavy repair charges. If such a plow is hitched to the center of the tractor, one drivewheel must travel on the plowed land in order to bring the plow close enough to the land side, thus requiring more power to propel the tractor and making steering difficult.

Most tractor owners, therefore, prefer to use a gang plow wide enough to permit its being attached to the center of the tractor frame and at the same time allow the drivewheels to travel on the unplowed land, regulating the depth of the plow by the amount of power available.

PACKING SOIL BY TRACTORS.

With the early steam tractors the packing of the soil by the tractor's wheels often caused serious injury to the crop.

This feature of the early tractor was much advertised and caused considerable prejudice in the minds of many farmers against all tractors, both gas and steam.

While some gas tractors, under certain conditions, have injured the crop by packing the soil, this is not ordinarily the case. The answers of 135 tractor owners who were personally interrogated on this point have been compiled. These men were located in various States in the Northwest. In answer to the question "Does the packing of the soil by tractor wheels injure the crop?" only 9 men state that the packing of the soil is injurious, while 101 say that it is not, 22 of this number declaring it to be beneficial. Of the 135 owners answering, 25 replied: "If the soil is wet, yes; if dry, no."

It may be safely stated that on most soils, when they are in fit condition to be worked satisfactorily with horses, the modern gas tractor will cause no injurious packing. The slippage of the tractor's wheels in soft ground will probably be a more serious matter than the packing.

COMPARISON OF DIFFERENT SIZES OF TRACTORS.

Table XVIII was prepared in order to ascertain what influence the size of the tractor has on the results obtained with it. In this table the tractors working in the State of North Dakota have been shown separately from those in other States, and only figures furnished by men having two seasons' experience have been shown, for reasons already given.

In tabulating the data by sizes of tractors it was found advisable to group them to a certain extent, in order to have a sufficient number in each class to give reliable averages. They were accordingly arranged in five classes, as follows: (*a*) 8 to 14 horsepower, (*b*) 15 to 19 horsepower, (*c*) 20 to 25 horsepower, (*d*) 26 to 30 horsepower, and (*e*) 40 horsepower and over.

These classes were arbitrarily arranged so as to place a considerable number in each group and at the same time to keep the most common sizes in separate classes. The average rating of the tractors in each group is shown in the table. Thus, the 8 to 14 horsepower class includes three common sizes: 8, 10, and 12, although there is not a very large number of any of these sizes. The 15 to 19 horsepower class consists almost entirely of 15 horsepower tractors. The 20 to 25 horsepower class includes three common sizes: 20, 22, and 25, but, like the first class, none of these sizes has a very large number. The 26 to 30 horsepower class contains 30-horsepower tractors almost exclusively. No machines with drawbar ratings between 30 and 40 horsepower were reported, and the tractors in the fifth class are mostly 40-horsepower outfits, as very few larger sizes were reported.

From this tabulation it would appear that the 15-horsepower tractors have a longer life than those of other sizes. The length of life seems to decrease slightly with the increase in size of tractors over 15 horsepower, while for the smaller sizes it is a little less than for the 15-horsepower tractors. The larger sizes of tractors lose more time per day than those of 15 horsepower or less, the loss increasing with the size of the tractor. The amount of special equipment required increases with the size of the tractor until the 30-horsepower size is reached. The amount of special equipment for the 40-horsepower tractor is less than for those of 30 horsepower. Previous tables have shown that the amount of work done by the 40-horsepower tractor, as well as the load drawn, is not commensurate with its rating, but no reason is known why the value of its equipment should be less than for the 30-horsepower tractor.

TABLE XVIII.—*Comparison of tractors of different sizes, which have been used for two seasons on farms in North Dakota and other States west of the Mississippi River.*

IN THE STATE OF NORTH DAKOTA.

Item of comparison.	Drawbar rating of engine (horsepower).				
	Less than 15.	15 to 19.	20 to 25.	26 to 30.	40 and over.
Number of tractors reported	20	34	105	99	21
Average drawbar rating of engines.....horsepower..	11.6	15.0	21.2	30.0	40.7
Cost of engine.....dollars..	2,010.16	1,928.92	2,360.41	2,902.05	3,153.25
Cost of special equipment.....do....	457.08	557.36	714.72	836.56	826.95
Life of tractor (estimated).....years..	6.2	7.0	6.4	6.6	5.0
Used per year.....days..	57.1	88.3	85.1	85.9	61.1
Time spent in the field per day.....hours..	12.4	13.4	12.9	13.0	12.7
Time lost in the field per day.....do....	2.7	2.3	2.1	2.0	2.4
Average size of farms.....acres..	622.2	613.9	792.6	995.2	1,156.0
Horses now kept:					
Number.....	10.4	9.2	11.3	13.6	17.3
Value.....dollars..	1,834.72	1,381.78	1,883.80	2,259.54	2,706.57
Fuel used in engines:					
Gasoline.....per cent..	66.7	20.6	67.5	49.4	92.9
Kerosene.....do....	33.3	79.4	28.9	45.6	7.1
Motor spirits.....do....	0	0	3.6	5.0	0
Cost of repairs required:					
First season.....dollars..	30.64	33.58	44.63	52.67	105.59
Second season.....do....	75.85	84.71	103.10	122.25	102.32
Owners stating that tractor is a good investment.....per cent..	13.3	39.1	30.8	38.0	18.7
Reporting night work.....do....	0	18.2	17.1	16.9	5.6
Average nights used by men reporting night work.....	.....	22.0	16.4	22.7	6.0
Owners doing custom work.....per cent..	70.6	75.8	65.4	73.7	61.9
Men doing custom work who find it profitable, per cent.....	40.0	70.8	48.2	63.9	38.5

IN ALL STATES WEST OF THE MISSISSIPPI RIVER EXCEPT NORTH DAKOTA.

Number of tractors reported.....	60	73	153	107	41
Average drawbar rating of engines.....horsepower	10.8	15.1	21.7	30.0	40.4
Cost of engine.....dollars..	1,654	1,820	2,356	2,876	3,616
Cost of special equipment.....do....	281.35	461.05	600.61	763.56	719.23
Life of tractor (estimated).....years..	8.9	9.1	8.1	7.2	6.8
Used per year.....days..	75.4	88.9	83.6	86.3	122.9
Time spent in the field per day.....hours..	11.1	11.6	12.2	11.7	11.5
Time lost in the field per day.....do....	1.5	1.5	1.8	1.8	1.9
Average size of farms.....acres..	397	563	576	875	1,246
Horses now kept:					
Number.....	7.9	9.9	8.9	10.8	13.5
Value.....dollars..	1,147.02	1,540.54	1,420.10	1,758.42	2,242.50
Fuel used in engines:					
Gasoline.....per cent..	69.8	12.3	58.4	57.3	88.2
Kerosene.....do....	30.2	86.2	40.0	41.7	5.9
Motor spirits.....do....	0	1.5	1.6	1.0	5.9
Cost of repairs required:					
First season.....dollars..	23.36	13.92	35.54	41.34	97.54
Second season.....do....	40.01	33.05	93.25	75.88	207.68
Owners stating that tractor is a good investment.....per cent..	47.0	64.8	43.9	43.9	62.5
Reporting night work.....do....	6.5	17.5	19.0	17.2	45.5
Average nights used by men reporting night work....	8.3	20.7	28.2	36.8	54.1
Owners doing custom work.....per cent..	56.1	72.9	74.1	75.7	80.0
Men doing custom work who find it profitable, per cent.....	75.0	78.3	66.3	54.3	67.9

It will be noticed that the 15-horsepower tractors have the lowest repair charges, those for the 40-horsepower tractors being more than seven times as great as for the 15-horsepower outfits. A larger percentage of owners of 15-horsepower tractors than of any other size report that the tractor is a good investment. The next largest percentage of favorable reports is from the 40-horsepower class, while the percentage of favorable reports from the intermediate classes is considerably below those for the 15 and 40 horsepower groups.

These facts, together with others shown in the tables, seem to indicate that the 15-horsepower tractor is giving better average results than any other size. It will be seen that the 15-horsepower tractors also give more favorable operating figures than any other size of tractor.

While the figures for the different sizes of tractors in Table XVIII show other variations, it is believed most of them are due to causes other than the size of tractor. For example, the number of horses kept, the percentage of night work done, and the percentage of custom work done, increase with the size of the tractor, but this increase is probably due largely to the fact that the larger tractors are usually found on the large farms, as will be noticed by the average sizes of the farms shown in the table.

SIZE OF FARM.

In North Dakota, tractors are seldom found on farms of less than 320 acres, the average size of the farm on which tractors are used in that State being between 700 and 800 acres. In other States, particularly in Iowa, tractors are frequently found on farms as small as 160 acres. As will be seen from Table XIX, however, a very large percentage of tractor owners do custom work with the tractor, indicating that the home farm does not furnish sufficient work to keep the tractor busy during the entire working periods. It will also be noticed that the farms of less than 480 acres show a greater percentage of owners doing custom work than do those of larger size.

Table XIX was prepared in order to ascertain what effect the size of the farm had upon the results obtained from the tractor. The figures used in its preparation are those furnished by tractor owners in North Dakota who have used their outfits for two seasons. A similar table for other States was not made because of the many types of farming which would be represented, as it was believed the many and varying factors involved would vitiate the results obtained. In North Dakota, however, as has already been stated, the conditions are very similar throughout the State, and the averages in the table are believed to show the relation of the size of the farm to the results obtained, as far as it is possible to do so.

In this connection, attention is invited to the fact that there is a close relation between the size of the tractor and the size of the farm, the larger tractors usually being found on the large farms. In both the tabulation by size of farm and by size of tractor, therefore, it is impossible to determine to just what extent each of these factors influences the result.

From the table it would appear that slightly better results are being obtained on the larger farms. It will be noticed that the percentage of owners reporting that the tractor is a good investment is greatest

for the farms of more than 640 acres, although it will also be observed that these men show a rather high percentage of kerosene tractors, which may be partly responsible for this, as well as other favorable averages for the larger farms.

While the estimated life of the tractor is slightly higher for the small farms, it should be borne in mind that these farms for the most part have comparatively small tractors, especially the 15-horsepower size, and this tractor shows a high average life in Table XVIII.

There is no appreciable difference in the number of days used per year, which would indicate that the smaller farms not only have a greater percentage of owners who do custom work, but that the amount of custom work per farm is also greater.

TABLE XIX.—*Relation of the size of the farm to the results obtained with tractors.*

Item of comparison.	Size of farms (acres).				
	161 to 320.	321 to 480.	481 to 640.	641 to 1,000.	1,001 to 2,000.
Number of farms reported	25	33	58	83	55
Average size of farms...acres..	300.2	424.2	583.2	846.4	1,411.5
Owners stating that tractor is a good investment, per cent	10.0	30.8	22.2	39.7	40.0
Drawbar rating of engine...horsepower..	20.0	22.5	22.8	25.0	27.4
Cost of engine...dollars..	2,286.19	2,497.72	2,416.49	2,579.45	2,730.56
Cost of special equipments...do....	624.98	641.18	635.04	766.59	799.37
Cost of repairs required:					
First season...do....	30.89	20.47	50.49	58.01	59.62
Second season...do....	106.74	82.28	90.01	82.84	177.04
Horses now kept:					
Number	5.7	6.9	9.0	11.6	19.2
Value...dollars..	957.73	1,135.88	1,427.59	2,004.75	3,100.57
Life of tractor (estimated)...years..	7.3	7.1	6.0	6.3	6.6
Used per year...days..	80.8	78.3	79.1	86.8	77.1
Time spent in the field per day...hours..	13.2	12.3	12.9	13.3	12.7
Time lost in the field per day...do....	2.4	2.1	2.0	2.3	2.2
Fuel used in engines:					
Gasoline...per cent..	47.8	71.9	58.7	49.2	44.2
Kerosene...do....	47.8	25.0	39.1	45.9	55.8
Motor spirits...do....	4.4	3.1	2.2	4.9	0
Reporting night work...per cent..	15.8	14.3	14.0	11.9	19.6
Average nights used by men reporting night work...	13.0	12.8	13.0	14.1	33.2
Owners doing custom work...per cent..	79.2	84.8	64.9	78.5	46.4
Men doing custom work who find it profitable, per cent	56.2	48.1	36.7	67.9	61.9

The percentage of owners who use their tractor at night is greatest for the farms of 1,000 to 2,000 acres, and these men likewise use their tractors for the greatest number of nights per year. From this fact it would appear that only on the larger farms is there sufficient work to utilize the full capacity of the tractor during the busy season, and even on these large farms more than 46 per cent of the owners do custom work.

As would be expected, the cost of the tractor increases with the size of the farm, owing, of course, to the increase in the size of the outfit. The repair charges and value of special equipment likewise increase with the size of the farm for the same reason. But while the cost of special equipment undoubtedly bears a close relation to the size of the

tractor, the investment cost per acre is of great importance. Table XIX shows that on the smaller farms of approximately 300 acres the cost per acre for mechanical power is about $7.60, while on the larger farms, averaging about 1,400 acres, the cost per acre is less than $2. Similarly, while the small farms show an investment of about $2 per acre for special equipment, the large farms have only one-fourth this amount.

In this connection, the value of work horses per acre should also be noted. For the 300-acre farms the cost for work stock is about $3 per acre, while for the 1,400-acre farms it is only $2 per acre.

Especial attention is invited to the difference in the ratio of the investment cost per acre for the two kinds of power. For mechanical power the investment per acre for the small farms is more than 3½ times as great as for the large farms, while for animal power it is only 1½ times as great.

The reason for this difference is probably the fact that a stable of horses, consisting of a number of individual units, can be regulated in size to meet actual requirements, the price per unit being practically uniform no matter in what number purchased. On the other hand, the tractor is a complete unit and must be of sufficient power to fulfill the maximum demands which may be made upon it, while the cost per horsepower is greater in the small sizes than in the large ones. In other words, the owner of a 600-acre farm who purchases a 30-horsepower tractor will have a lower investment per acre for power than the owner of a 300-acre farm who purchases a 15-horsepower tractor, because the 15-horsepower tractor costs more per horsepower than the 30-horsepower outfit; while the owner of a 600-acre farm who purchases one work horse for each 30 acres of land, or 20 horses, will have the same investment charge per acre as the owner of a 300-acre farm who purchases one work horse for each 30 acres of land, or 10 horses, the cost per horse being nearly the same, no matter in what number purchased.

From Table XIX it will be seen that the total investment per acre for power on the 300-acre farms is about $10, while for the 1,400-acre farms it is only $4 per acre, although the 300-acre farms have a unit of power for every 12 acres, while the 1,400-acre farms have one unit for every 32 acres. It is evident, therefore, that either the 300-acre farms have more power per acre than is necessary and economical or that the 1,400-acre farms have an inadequate amount of power.

From a careful study of the data shown, in conjunction with other information available, it is believed that the large farms have a normal acreage per unit of power and that farms of the grain type which have a smaller acreage per horsepower are overequipped and therefore less economically equipped. The owner of a 300-acre farm who has an invested capital of $10 per acre for power and one unit of power for

every 12 acres can not hope to produce crops as cheaply as his neighbor with a 1,400-acre farm who has an invested capital of only $4 per acre and who tills 32 acres with each unit of power.

It is not surprising, therefore, that the owners of farms containing 640 acres or less do considerably more custom work than those with larger farms, as the excess power must produce some income in order to justify its maintenance.

In this connection, it should also be noted that the repairs per acre are considerably less for the large farms than for the small ones, which naturally follows, in view of the difference in equipment. It is probable that the repairs bear a closer relation to the size of the engine than to the size of the farm, in view of the slight difference in the number of days used.

USE OF TRACTORS AT NIGHT.

The number of men who used their tractors at night was found to be surprisingly small (about 11 per cent in North Dakota and 14 per cent in other States) and in most cases the number of nights used per year was comparatively insignificant. While the tractor is theoretically capable of working night and day, it appears that night work is seldom done.

The explanation of this probably lies in the fact that in normal years there is little need for operating at night, unless it be during harvest, when it may be desirable to rush the work as much as possible in order to prevent loss from storms. However, tractors are not extensively used for harvesting except in those sections where it is practicable to use a combined harvester. Another reason for the small amount of night work is the necessity of having two operating crews for the outfit. This is obviously impractical in most cases.

In order to ascertain whether any loss of efficiency occurs when operating at night, a number of tractor owners who had operated at night were asked for estimates as to the percentage of efficiency compared with work done in the daytime. The average of these estimates was 93.3 per cent.

This slight loss in efficiency appears to be due almost entirely to inability to watch the operation of the outfit as well as it can be done during the day and the additional time required to make any adjustments which may be necessary.

Among some 70 men who were interrogated regarding night work the opinion was almost unanimous that the motor developed more power at night than during the day, some estimating the increase to be as much as 20 per cent.[1]

[1] This information was voluntary, the men having been asked simply for an estimate as to the efficiency of the tractor at night. They offered their observations as to the increase of power at night as a phenomenon which they could not explain. In view of the varying opinions of gas-engine experts on this point, the unanimous observation of tractor operators that such an increase does occur is of interest.

CUSTOM WORK.

In order to ascertain what difference, if any, existed between the figures furnished by men who did custom work with their tractors and found it profitable and those who did custom work but did not make it pay, Table XX was prepared. From this it would appear that the principal factors which operate to make custom work unprofitable are the time lost by the engine and repair charges, which are, of course, closely related, as making repairs and replacing parts take considerable time. It will also be noticed that the men who say that custom work does not pay show slightly less investment in equipment in each case, although not sufficiently less to draw any definite conclusions therefrom.

Little difference exists in the prices received per acre for custom work by the men who report it profitable and those who find it unprofitable, which would seem to indicate that this factor had little influence on the result. This, together with the fact that nearly 50 per cent of the tractor owners who have tried custom work state that it is unprofitable, would seem to justify the assumption that the prices received for custom work, namely, about $2 per acre for plowing and $3.70 per acre for breaking, are very close to the actual average cost of performing this work, assuming that the cost for fuel, oil, interest charges, etc., were the same for each class of owners, which would probably be the case.

TABLE XX.—*Comparison of figures furnished by farm tractor owners in North Dakota who had done custom work.*

[Columns headed "Yes" include figures from men who stated that custom work was profitable; those headed "No" include figures from men who stated that custom work was unprofitable.]

Item of comparison.	First season.		Second season.		Third season.		Fourth season.	
	Yes.	No.	Yes.	No.	Yes.	No.	Yes.	No.
Number answering	118	40	92	72	44	38	20	15
Average drawbar rating of tractor.....horsepower..	23.8	23.2	24.5	24.5	24.3	25.1	22.6	22.9
Average price of tractor, dollars	2,525.36	2,460.85	2,563.70	2,557.19	2,615.68	2,694.41	2,376.32	2,431.00
Average time lost in the field, hours	1.4	1.9	1.5	2.4	1.9	2.8	1.7	2.9
Average cost of repairs, dollars	33.60	68.09	88.03	249.87	197.35	411.00	227.49	681.74
Average value of equipment, dollars	648.23	636.78	733.16	721.70	761.34	748.64	756.50	745.73
Average size of farm....acres..	730.2	796.0	804.9	708.4	692.8	806.2	682.3	820.0
Average price per acre received for plowing.....dollars..	1.97	1.80	1.91	1.91	2.03	2.21	2.03	2.08
Average price per acre received for breaking.....dollars..	3.66	3.48	3.68	3.46	3.71	3.71	3.81	3.68

In this connection it should be noted that very few farmers in figuring the cost of performing work of this character take into consideration interest and depreciation charges, which previous tables have shown to be very heavy for the average tractor.

REPAIRS.

The cost of repairs has always been an item of considerable importance in connection with the farm tractor. Not only have the repairs been expensive, but the time lost in obtaining new parts and inserting them has been a serious matter.

This feature has frequently been pointed out as one of the greatest disadvantages of the tractor and one which practically precludes its use on the average farm.

It is only fair to the tractor, however, to state that a very large percentage of the repairs are made necessary through inefficient operation. The statement that any man can operate a gas tractor efficiently after only a few minutes' instruction is so far from the truth that it would seem that its falsity should be apparent to even the uninitiated. Yet this erroneous idea has been responsible for hundreds of failures and an enormous amount of repair charges, the effect of which has been detrimental to the tractor industry. If every man who used a tractor during the years of its development had been thoroughly competent to operate it, the history of the farm tractor would be very different.

While the average farmer's familiarity with many machines and their operation should make him an apt pupil in the study of the gas tractor, it is in no sense a complete education therein. There are many tractor owners at the present time who, while operating their tractor with a certain degree of satisfaction, are unfamiliar with many details of its mechanism; in fact, it is the exception to find a tractor owner who fully understands one of the most important parts of the tractor—the ignition system.

It is this ignorance regarding details, some of them apparently trifling, which all too frequently causes expensive delays. An internal-combustion engine is extremely simple in its operation, but it is simple only to one who understands it fully. No one but an experienced operator can obtain the best results with a farm tractor, and the necessity for an owner carefully studying the principles of the internal-combustion engine and the operation of his own tractor before undertaking to operate the outfit can not be overemphasized. The lack of such preparation is clearly shown in the cost of repairs to tractors during their first season's use. As has been stated, although in nearly every case all repairs required the first season which are not caused by the operator are furnished free, it was found that the repairs for which owners are required to pay during the first season average about 2 per cent of the first cost of the tractor.

While previous tables have shown the amount of repairs for various groups of tractors, it was thought a table showing the general average repairs for tractors might be of value. It would be mani-

festly unfair to the modern tractor to consider repairs on outfits placed on the market several years ago, while the repairs required during the first season on tractors of one, two, and three years of age do not vary to any great extent, and Table XXI was prepared to show the repairs on tractors up to three years of age. The repairs required on tractors located in North Dakota and California have been shown separately, while the remaining States west of the Mississippi River are grouped.

It will be noticed that the repairs for tractors in California are much heavier than for the other States. This is due mainly to the difference in the types of tractors most generally used, a large percentage being of the track-laying type. These are usually more expensive outfits, as will be seen from the table.

These figures show that during the first season, when all repairs not caused by the operator are ordinarily furnished free, the average tractor owner spends for repairs an amount varying from 1.7 to 4 per cent of the tractor's cost.

TABLE XXI.—*Tractor repair charges per year, with percentage of first cost, on farms west of the Mississippi River.*

Range of inquiry.	Average price of tractor.	First season.		Second season.		Third season.	
		Average repairs.	Percentage of cost.	Average repairs.	Percentage of cost.	Average repairs.	Percentage of cost.
For 1-year-old engines:							
North Dakota	$2,465	$44.86	1.8				
California	3,181	127.18	4.0				
Other States	2,279	38.94	1.7				
For 2-year-old engines:							
North Dakota	2,542	49.37	1.9	$107.15	4.2		
California	3,620	142.37	3.9	306.68	8.5		
Other States	2,361	34.66	1.5	72.89	3.1		
For 3-year-old engines:							
North Dakota	2,590	62.17	2.4	108.44	4.2	$138.39	5.3
California	3,604	150.13	4.2	186.50	5.2	220.50	6.1
Other States	2,430	43.62	1.8	104.09	4.3	98.24	4.0

During the second season the repair charges show a variation between 3.1 per cent and 8.5 per cent of the tractor's cost, while for the tractors which have been used three seasons the percentage is more favorable, varying from 4 to 6.1 per cent.

From this it would appear that a prospective purchaser of a tractor should expect during the three seasons' use repair charges of at least 10 per cent of the first cost.

The repair charges given throughout this bulletin include only the cost of the new parts. The cost of installing these parts is often considerable, but it is sometimes done by the tractor owner and sometimes by hired machinists. It is therefore difficult to ascertain the value of the labor expended in making the repairs.

DISPLACEMENT OF HORSES BY TRACTORS.

It is difficult to determine to just what extent the tractor has influenced the use of horses on the farm, on account of the other influencing factors in the shape of automobiles, motorcycles, auto-trucks, and binder engines, all of which are doing work formerly done by horses. In spite of all these competitors the farm horse has increased considerably in numbers and value during the past few years.

The United States Census report shows that in 1900 there were 11,513,649 horses and mules on farms located in States west of the Mississippi River, while the Bureau of Statistics of the United States Department of Agriculture states that on January 1, 1914, they numbered 14,287,000, a numerical gain of 2,773,351, or 24.1 per cent in 14 years.

During the same period the increase in the valuation of these animals was much greater, viz, from $493,454,902 to $1,427,074,000, or 189.2 per cent; but here again there were numerous influencing factors, the principal ones probably being a heavy export demand and the breeding of horses of a far better quality.

The gains mentioned occurred while the number of gas tractors was increasing from less than 100 to perhaps 13,000.

A comparison of the increase in the number of farm horses and of tilled acres in the States west of the Mississippi River would be desirable, but accurate figures on the increase in tilled acres are not available, and, furthermore, improvements in farm implements and in the management of farms have tended to increase the acreage tilled per horse.

A study of the conditions existing on farms where tractors have been introduced is of especial interest in this connection. The result of such a study is shown in Table XXII.

The data contained in this table were obtained by personally visiting the tractor owners. The records for the farms represented were selected without reference to the number of horses displaced, the only point which was considered in selecting them being to ascertain whether the information furnished was complete. Therefore, the fact that of the number thus selected 39 belonged in the group where horses were displaced by the tractor and 43 in the group where no horses were displaced by the tractor would seem to be a rather reliable indication that in about 50 per cent of the cases the tractor does not actually displace horses on farms where it is introduced.

These farms average approximately 900 acres in size and should therefore provide a large amount of work for the power employed, whatever its kind. They are mostly of the grain type, exceptionally well adapted for the use of a tractor. The average age of the tractors

is less than two years, which shows that for the most part they are very modern outfits. The tractor did not entirely displace the horses on any farm.

TABLE XXII.—*Displacement of horses by tractors on farms.*

Item of comparison.	Farms on which horses were—		All farms.
	Displaced.	Not displaced.	
Number of farms	39	43	82
Average size of farm.....acres..	924	875	896
Average area tilled per farm.....do....	844	661	748
Average number of horses per farm:			
Before purchase of tractor	25.3	13.2	18.9
After purchase of tractor	8.8	13.2	11.1
Average number of horses displaced per farm	16.5	.....	7.8
Value of horses displaced per farm.....dollars..	3,115.86	.....	1,423.89
Average value per horse.....do....	188.84	176.10	182.55
Average drawbar rating per farm.....horsepower..	26.1	24.3	25.1
Average cost of tractor.....dollars..	2,635.00	2,775.00	2,702.00
Total present rating per farm.....horsepower..	34.9	37.5	36.2
Average area tilled per drawbar horsepower of tractor.....acres..	32.3	27.2	29.8
Average area tilled per horse:			
Before purchase of tractor.....do....	33.4	50.0	39.5
After purchase of tractor.....do....	95.9	50.0	67.3
Average area tilled per total horsepower after purchase of tractor...do....	24.2	17.7	20.5
Average age of tractors.....years..	1.8	1.9	1.9
Average use of tractor per year.....days..	94.5	120.2	101.6
Cost of maintaining a horse per year (estimated).....dollars..	84.09	105.56	96.81
Average price of fuel per gallon.....do....	.147	.185	.167
Average price of oil per gallon.....do....	.423	.388	.405

While the value of special equipment which would be required with the tractor is not shown here, from previous tables it is evident that the value of such equipment would not be less than $700 per farm; therefore, on more than 50 per cent of the included farms the purchase of the tractor increased the invested capital approximately $3,500 and on the remainder the horses displaced would lack about $300 of equaling the value of the tractor and its necessary equipment.

On the farms where horses were displaced, the tilled acreage per horse before the purchase of a tractor was 33.5, which is believed to be about the normal area. Although the acreage per drawbar horsepower of the tractor on these farms was only 32.3, yet an average of 8.7 horses per farm was retained, making the tilled acreage per unit of power 24.2 acres. On the other hand, the tilled acreage per horse on the farms where horses were not displaced was 50 acres, and the tilled acreage per drawbar horsepower of the tractor purchased was 27.2 acres, or an average of 17.7 tilled acres per unit of total horsepower. The tilled acreage per total horsepower for both of these groups would appear to be too small for the most economical operation.

In Table XXIII are shown some further data relative to the displacement of horses by tractors. This table was prepared from figures furnished by tractor owners in North Dakota who had used their tractors for two seasons.

TABLE XXIII.—*Displacement of horses on farms in North Dakota where tractors have been used for two seasons.*

Item of comparison.	Farms on which no horses were displaced.	Farms on which horses were displaced—drawbar rating of engine (horsepower).		
		20 or less.	21 to 29.	30 or over.
Number of farms reported	82	40	16	29
Average number of horses used:				
Before purchase of tractor	16.6	13.8	15.9	20.7
After purchase of tractor	16.6	8.4	9.2	12.1
Horses displaced:				
Average number		5.4	6.7	8.6
Average value ..dollars..		891.56	1,202.92	1,489.35
Average cost of tractor ..do..	2,543	2,020	2,665	3,000
Average drawbar rating of tractor ..horsepower..	24.1	18.1	22.9	31.2
Value of special tractor equipment ..dollars..	720	556	743	803
Cost of repairs required:				
First season ..do..	43.34	46.36	37.00	80.49
Second season ..do..	115.64	83.33	43.29	125.25
Owners stating that tractor is a good investment ..per cent..	10.3	37.5	53.3	52.4
Life of tractor (estimated) ..years..	5.4	6.2	7.4	7.3
Used per year ..days..	60.3	98.0	106.5	90.0
Time spent in the field per day ..hours..	12.7	13.3	13.0	13.2
Time lost in the field per day ..do..	2.7	1.9	2.4	1.9
Fuel used in engines:				
Gasoline ..per cent..	57.6	69.4	28.6	47.6
Kerosene ..do..	39.4	27.8	64.3	47.6
Motor spirits ..do..	3.0	2.8	7.1	4.8
Average size of farm ..acres..	940	662	779	1,024
Owners doing custom work ..per cent..	52.4	78.9	75.0	85.2
Men doing custom work who find it profitable ..do..	37.8	51.9	60.0	72.2
Reporting night work ..do..	9.4	26.7	18.2	18.2
Average nights used by men reporting night work	31.5	25.4	17.5	17.3

While the percentage of farms on which horses were displaced is greater than for Table XXII, this is explained by the fact that many tractor owners in filling out the form on which the information was furnished gave only the number of horses used after the purchase of the tractor, the space for the number previously kept being left blank. It is very probable that many of these were intended to indicate that the number was the same, but in the absence of positive information on this point the data were not tabulated.

On these farms the number of horses displaced is considerably less per farm than for those shown in Table XXII. In no case is the value of the horses displaced equal to 50 per cent of the first cost of the tractor.

There appears to be little difference in the results obtained by the two classes of owners. The most significant variations seem to be found in the percentage of owners who report that the tractor is a good investment, the percentage doing custom work, and the percentage doing night work. In these three cases the men who did not lay off horses after purchasing the tractor show much lower percentages than those who report that horses were displaced by the tractor.

CONDITIONS ESSENTIAL TO SUCCESS WITH THE TRACTOR.

The fact that some men have found the tractor a profitable investment is proof that under certain conditions it can be used successfully for farm work.

The physical condition of the land determines largely the degree of success which can be obtained with a tractor. The ideal conditions are large, level fields, free from obstructions, such as trees, stumps, rocks, holes, and ditches, with a soil firm enough to furnish a solid footing for the drive wheels, yet not sufficiently hard to make an excessive draft on the plows.

But the most important qualification is efficient management and operation. This has been touched upon, but can not be overemphasized. For the operator to be able to start and stop the motor and to steer the outfit skillfully is not enough. He must understand his tractor thoroughly, and not only be able to locate quickly any trouble which occurs and remedy the same promptly, but he must be capable of avoiding a great many of the troubles commonly experienced with tractors, by frequent inspection of the bearings, ignition system, etc., thus keeping them in first-class condition at all times.

Not only in the actual operation of the tractor does the efficient tractioneer contribute to the success of the outfit, but by carefully studying the work to be done and planning it so as to allow the tractor to work to the greatest advantage at all times. If the land is rolling he will so lay out his work that the tractor will ascend on the easiest grades and descend on the steepest. If the farm is laid out in square or irregular fields he will replan it so as to have the fields as long as possible, thus lessening the number of turns which will be required. He will fill in holes and ditches where practicable and remove obstructions in order to facilitate the tractor's work. He will recognize the fact that work can not be done with a tractor in exactly the same manner as with horses, and to attempt to do so is not only unfair to the tractor but is inviting failure. In many cases a change in crop rotation will be of great advantage. Where a tractor is used the crops raised should be such as can be planted and harvested with the tractor, thus reducing the number of horses which must be kept.

The necessity of having tractor owners properly trained for the operation of their outfits has been recognized by most manufacturers, and several have established schools for their customers where they can be instructed by experts in the care and operation of the tractor. The tractor salesmen have also realized that in selling outfits to men who are incompetent to operate them they are not only injuring their own interests, but those of the tractor trade in general.

A number of agricultural colleges have added courses in tractioneering, and there are several privately conducted tractor schools. It is believed that most farmers who contemplate purchasing a tractor would find it well worth while to take a short course in tractioneering

at some one of these schools. It will be time and money well spent. The knowledge gained will be of great assistance in selecting a tractor, as well as in operating it. The time and money which the course requires will be saved in many cases during the first two seasons.

Another important factor in determining the success or failure of a tractor is the amount of capital invested in it. The average farmer can not afford to increase his power investment to any great extent. In purchasing a tractor he should not, therefore, spend as much for it as he can realize on the horses it will displace, for the reason that the working life of a tractor is only about half that of a horse, while there are many operations for which the tractor can not be used. The first cost of a tractor should on that account be correspondingly less. It is unsafe to rely on an increase of crops from better work with the tractor, as in most cases this is not realized.

It is significant that many farmers who have bought second-hand tractors at low prices have been very successful with them. It is also significant that the sales of the larger and more expensive outfits have fallen off, while those of the smaller and comparatively cheap ones have largely increased. While there have been numerous influences which combined to produce this result, there is a sound economic reason for it. The average farmer is not only conservative, but he realizes that he can not afford to increase his investment in power too much. While the cost of fuel and oil per unit of power is less than the cost of feed for horses, the overhead charges, due to interest on investment, depreciation, repairs, etc., more than offset this on the expensive outfits, except under conditions unusually favorable to the use of the tractor.

By reducing the first cost the interest and depreciation charges are correspondingly reduced, and it is to be supposed that the cost of repair parts will be proportionate to the first cost. It is apparent that the price of tractors has been too high in the past to permit the average farmer to use them successfully. The indications at present point to a general reduction in the price of these outfits and an increased sale as the price is lowered.

With a decrease in the price of farm tractors and an increase in their mechanical efficiency, simplicity, and durability, all of which seem to be assured, together with more efficient operation by men who have been properly trained for their work, it is safe to predict that the tractor will soon become an important factor in reducing the cost of crop production on the average farm.

SUMMARY.

While the data included in this bulletin represent the experience of a large number of users of gas tractors, it must be borne in mind that they are a record of a machine in the process of development

and not the record of a completed and perfected outfit. Furthermore, most of these tractors have been operated by men who were not properly trained and equipped to handle them efficiently, and during the first few years of the development of the gas tractor the machines placed on the market were mainly large outfits, which were necessarily expensive, and failure meant a heavy financial loss.

It is generally recognized that the gas tractor was of great value in rapidly breaking up large areas of prairie sod in the West at a time when horses were not available, but after the sod was broken they proved an unprofitable investment for the individual farmer in a large percentage of cases. A few owners have found the tractor a very profitable investment, doing its work more satisfactorily and much cheaper than could be done with horses, while a great many discontinued its use after a trial.

The percentage of owners reporting favorably regarding the tractor decreases with the length of time they have used their outfit, due partly to the fact that the older machines were not as good as the later ones, but mainly to a better realization of the tractor's value in their work.

As would be expected, owners who report unfavorably regarding the tractor obtain poorer average results than those who state that the tractor is a good investment. The repair charges reported by both classes of owners indicate that this is due to a considerable extent to less efficient operation by the owners reporting unfavorably.

The average life of a tractor as estimated by owners in North Dakota is about six years, while the average life as estimated by owners in States other than North Dakota is about eight years. To judge by the small percentage of reports received for tractors three or more years old, it would appear that a large number of outfits three, four, and five years old are no longer in use, indicating that the average life is even less than six years.

The plowing done with tractors has been little, if any, deeper than that done with horses.

Combination work is not practiced to a great extent and usually is limited to harrows or drags after the gang plow.

The percentage of tractors which are operated at night is comparatively small, varying from 11 to 14 per cent, although the tractor's efficiency at night is very good.

No injurious packing of the soil is caused by the tractor's wheels if the soil is in proper condition to be worked.

The item of repairs has been one of considerable importance in connection with the use of farm tractors, but the data indicate that a large percentage of such repairs have been caused by inefficient operation.

The necessity for the operator of a gas tractor being thoroughly trained for his work, if a tractor is to prove a success, is obvious. Failure to comply with this requirement has been the cause of many failures.

The tractors which have been operated by kerosene show, as a whole, slightly better average results than those operated by gasoline, indicating that the heavier fuels can be burned at least as satisfactorily as the lighter ones. The amount of kerosene used per unit of work, however, is usually slightly more than for gasoline, which would appear to indicate that the combustion of the kerosene is generally not as perfect as that of the gasoline. This is partly due to the fact that many owners are burning kerosene in tractors equipped with ordinary gasoline carburetors.

The necessity of a tractor being equipped to operate on either heavy or light fuels is not so great as it was a few years ago. Modern processes of refining make it possible to convert approximately 75 per cent of any crude oil into gasoline or heavier fuels, as desired, and it is stated by an excellent authority that the supply of crude oil available is ample for several generations. Therefore, the question of fuel supply need give the tractor owner no concern.

The data apparently show that the tractors with drawbar ratings of 15 horsepower are giving slightly better results than either the larger or smaller sizes.

The tractor has not, as a rule, displaced its equivalent in work horses, as regards either power or value. Its purchase, therefore, usually increased the investment in power, as well as in certain kinds of equipment. The necessity for a large acreage, if the invested capital per acre is to be kept within a safe limit, is very apparent, although in many farming communities a tractor may prove profitable on a small acreage, provided the owner can obtain some lucrative custom work for the tractor when it is not required on the home farm. A great deal of the custom work which has been done with tractors has proved unprofitable to the tractor owner, however.

The modern gas tractor of 10 or more horsepower has thus far, within its limited area of use, proved to be an auxiliary of the farm horse rather than a substitute. When properly handled, it is often of great value in permitting one or two men to perform a large amount of work within a limited length of time. With further development, a lower first cost, and in the hands of a conservative class of farmers who have been carefully trained in their operation, tractors will undoubtedly continue to grow in number and efficiency, extending their field of work into new territory. The heavy demands for power to break new land are practically over, and the growth of the tractor will hereafter be due more to its merit than in the past.

The present trend of the tractor industry points to the development of cheaper and smaller outfits, designed to pull only from two to four plow bottoms.

The studies here presented merely aim to set forth in a broad way tractor conditions as now found on the farm. A study of these data should be made by every farmer contemplating the purchase of a tractor.

Up to the present time the tractor appears to have made for itself no important place in the agricultural economy of this country. In a few limited localities in the West where conditions especially favor its use large tractors are used by some men with apparent profit. The general situation, however, indicates that the large tractor is not to be a factor in increasing farming by extensive methods and on a large scale, for a few years at least. Instead, there are indications that the tractor of the future must make possible more intensive agriculture on farms of moderate size, though the large outfits will probably continue to be used on some of the exceptionally large farms in the West.

It is worthy of note that some of the successful users of tractors were able to reduce the number of their farm horses. This fact suggests that there may be a field for farm reorganization to make possible the economical utilization of the tractor. Such development depends upon the production of a smaller and cheaper outfit, costing considerably less per unit of drawbar power than its equivalent in horses, thus offsetting the difference in their working life. It must be nimble, simple, and absolutely certain in operation when properly handled. Given such an outfit, the average farmer can afford to reorganize his farm work so as to discard one or more teams, and by utilizing the tractor for heavy field work and for driving machinery be able to reduce the cost of crop production.

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