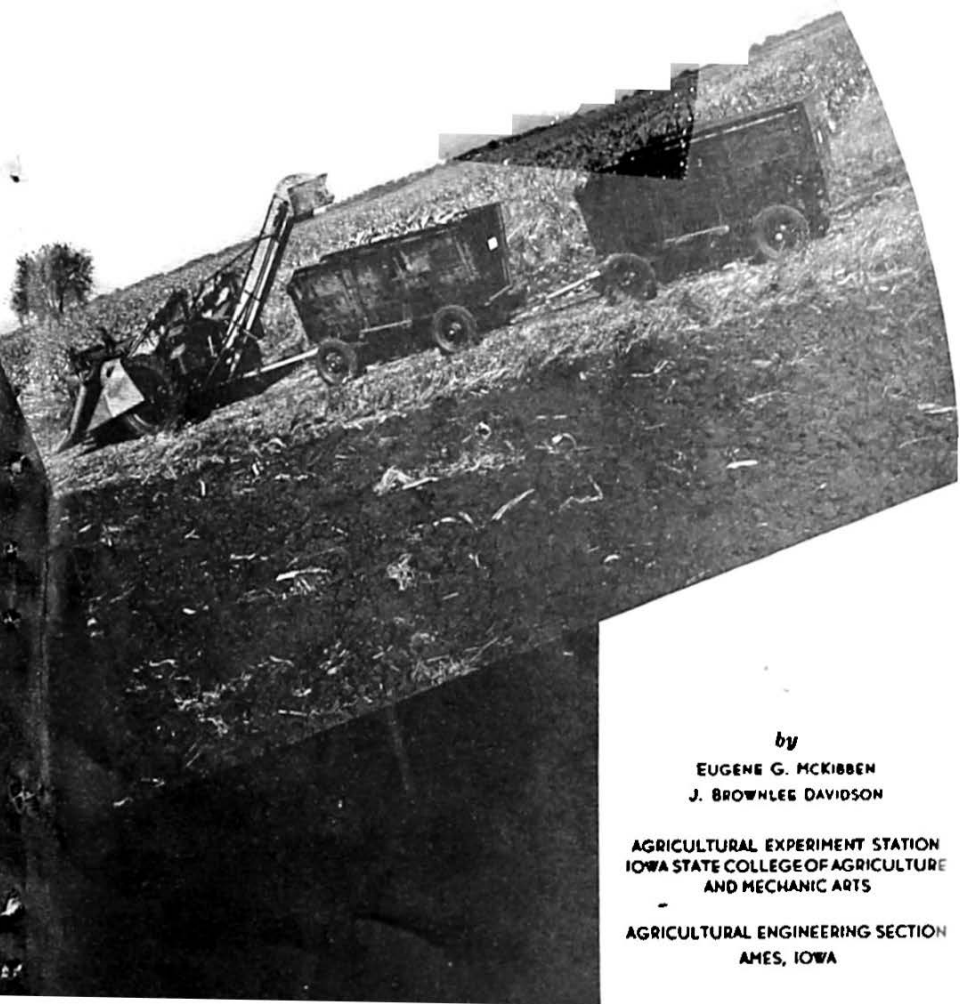


-Life Service and Cost of
Service of Pneumatic Tractor Tires

Life, Service and Cost of Service of Pneumatic Tractor Tires



by

EUGENE G. MCKIBBEN
J. BROWNLEE DAVIDSON

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

AGRICULTURAL ENGINEERING SECTION
AMES, IOWA

CONTENTS

Summary	167
Economic importance	169
Source of information	170
Conditions of use	170
Tire brands and sizes	171
Use of tires	172
Use for hauling	174
Tire wear	174
Cost of maintenance	175
Estimated useful life	176
Saving in fuel	177
Saving in time	179
Use of higher gear	180
Wider machines	180
High lug tread designs	181
Use of water for wheel weights	181
Utility of tractor tires	181
Characteristics of rubber tires compared with steel wheels	182
Annual cost of use of tractor tires	183
Comparison of cost and service	184
Factors favoring effective use	185
Literature cited	186

SUMMARY

The experience of Iowa farm users of 199 sets of pneumatic tractor tires indicates satisfactory durability and field performance. These users, selected as a representative sample, were located in 73 counties and represent the equivalent of 381 years of individual observation.

The use per year reported ranged from 240 to 3000 hours with an average of 984. Hauling constituted, on the average, only about 4 percent of the use of rubber tired tractors. The extent of this type of use varied widely, 0 to 75 percent, and there appeared to be a tendency for it to increase as operators became more experienced with pneumatic equipment.

Considerable variation in the rate of tire wear was reported, and the necessity of avoiding excessive slippage was frequently emphasized. Annual maintenance costs were found to be very low, averaging only 28 cents per set per year, although in individual cases annual costs averaged as high as \$5. The estimated useful life in years varied from 3 to 15 with an average of 7, and the estimated useful hours of use averaged 6,765.

Estimated fuel savings for the same work ranged from 0 to 50 percent with an average of 22 percent. A nearly similar average saving in labor, 23 percent, was reported also, with the range from 5 to 50 percent.

The use of a higher gear for most field operations was reported by 54 percent, and 93 percent used a higher gear for at least one important implement. The use of machines of greater operating width was reported by 40 percent.

The new high lug treads were reported as being generally more satisfactory, particularly for adverse traction conditions. All but three of the 40 users who had tried water as a substitute for cast iron wheel weights were satisfied with the plan.

The cooperators reported the following advantages for pneumatic tractor tires: Reduced fuel and labor requirements; higher speeds; easier operation on hard surface roads; less damage to farm roads, lanes, meadows and pastures; decreased tractor breakage and wear and greater comfort.

The disadvantages experienced were higher first cost, possibility of delay and expense from accidental damage, the expense of also equipping at least part of the drawn equipment with rubber tires, lower maximum drawbar pull under many conditions, excessive bouncing under certain conditions, more objectionable tracks in loose tilled soil and decreased stability for belt work.

The most effective use of a rubber tired tractor requires the highest practicable speed, the widest implement which can be pulled satisfactorily by the engine and tires at this speed and enough wheel weight to provide effective traction.

Pneumatic tires for a two-plow, all-purpose tractor add about \$200 to its cost and represent on the average about one-fifth of the total cost, which is somewhat less than the average increase in capacity reported by users. The probable annual cost of use for such a set of tires is about \$40. This expenditure appears to be well justified, at least where a tractor is used 500 hours or more per year and where the proper adjustments between speed, wheel weight and load can be made.

Over 98 percent, all but three users, were satisfied with the performance of pneumatic tractor tires.

Life, Service and Cost of Service of Pneumatic Tractor Tires¹

BY EUGENE G. MCKIBBEN AND J. BROWNLEE DAVIDSON²

The application of pneumatic tires to the farm tractor is one of the most striking and rapid changes in farm mechanical equipment which has occurred during this century. The first tires designed for farm tractor use in the United States were sold in the fall of 1932 (13). During 1935, less than 3 years later, nearly 20,000 tractors, 14 percent of the wheel tractor production, were equipped with rubber tires at the factory. The next year, 1936, 31 percent of the production was so equipped, and the percentages for 1937 and 1938 were 42 and 64 respectively. During the 4 years, 1935-38, over a quarter of a million of factory equipped rubber tired tractors were purchased by American users (2). Although no reliable figures are available it is probable that rubber tires were installed on about half as many more tractors by dealers and farmers.

ECONOMIC IMPORTANCE

In view of this extensive sale of tractor tires and the fact that they usually add about 20 to 25 percent to the purchase price of a farm tractor, their probable life and maintenance costs are matters of considerable economic importance to Iowa farmers. In order to obtain information on these and related problems a survey of the experience of Iowa users of farm tractors equipped with rubber tires was made during the summer of 1938.

¹ Project 576 of the Iowa Agricultural Experiment Station.

² The authors wish to acknowledge the cooperation of Mr. P. C. Taff, assistant director of the Iowa State College Extension Service and Mr. C. H. Chase, secretary of the Iowa Implement Dealers' Association, Inc., for assistance in contacting users of tractors equipped with pneumatic tires, and the assistance received from other members of the Agricultural Engineering Section of the Iowa Agricultural Experiment Station.

SOURCE OF INFORMATION

The cooperation of users was obtained through county agents and representative implement dealers. Five questionnaires were sent to each county agent and five to a carefully selected implement dealer in each county. Usable returns from 196 farmers covering 199 sets of tires were received. As shown in table 1, 80 percent of these answers were obtained from users contacted through county agents. In this table, as in the other tables which present the results of this survey, the returns are divided into six groups on the basis of the number of months of experience with pneumatic tractor tires, with figures for the total of all returns in the seventh column.

CONDITIONS OF USE

The conditions under which the tires reported were used are given in table 2 and appear to be quite representative of Iowa farming conditions. Seventy-three of the state's 99 counties are represented. A more complete picture of this distribution is given in fig. 1.

The more common types of topography and soil texture are well represented in all groups. The sizes of farms reported are, however, well above the average for the state.

TABLE 1. SOURCE OF CONTACT WITH USERS.

	Months used, inclusive						Total experience
	55-56	43-54	31-42	19-30	7-18	0-6	
1. Total number reported	5	12	34	60	56	32	199
2. Percentage of contacts by:							
a. County agents	100	58	88	82	84	69	80
b. Implement dealers	0	42	12	18	16	31	20

Crop acres per farm ranged from 80 to 1,200 with a mean of 259 acres which is more than twice the mean reported by the 1935 census. This was to be expected because of the greater utility of a tractor, particularly a rubber tired tractor, on larger farms.

On the other hand, the figures in line 5b of table 2 give some evidence of a trend toward the adoption of rubber tired

tractors on smaller farms. This trend will undoubtedly be still more marked in the future because of the recent introduction of smaller, low-cost, one-plow tractors equipped with pneumatic tires.

Table 2 also indicates a preponderance of all-purpose tractors and thus conforms to the present trend of tractor sales in Iowa.

TIRE BRANDS AND SIZES

Although no attempt was made to evaluate the relative performance of different brands or sizes of tires, table 3 is included to indicate the extent of representation obtained in the different groups. This table shows a total of seven brands and nine sizes, practically all the brands and sizes available by 1938.

TABLE 2. CONDITIONS OF USE.

	Months used, inclusive						Total experience
	55-66	43-54	31-42	19-30	7-18	0-6	
1. Total number reported	5	12	34	60	56	32	199
2. Counties represented	5	11	30	46	38	23	73
3. Topography, percent* reporting							
a. Level	20	50	42	33	47	44	41
b. Undulating	60	17	42	40	39	25	37
c. Rolling	20	42	36	50	37	53	43
d. Hilly ^b	0	0	6	7	12	9	7
4. Soil texture, percent* reporting.							
a. Sand	0	0	0	3	0	0	1
b. Sandy loam	20	0	9	10	12	9	10
c. Loam	80	30	47	33	20	28	32
d. Silt loam	20	40	30	24	55	41	37
e. Silt clay loam	0	10	15	17	20	6	15
f. Clay loam	0	10	6	14	6	13	10
g. Clay	0	10	6	7	0	3	4
5. Crop acres in farm ^c							
a. Smallest	270	130	80	80	101	87	80
b. Average	392	315	279	255	247	226	259
c. Largest	553	640	800	1200	680	560	1200
6. Type of tractor—percent.							
a. All-purpose	80	92	91	98	92	88	93
b. Other	20	8	9	2	8	12	7

* The sums of percentages for the different soil topographies and textures exceeds 100, because in many cases the same man reported two or more topographies or textures.

^b Two cooperators reported steep topography.

^c The crop acreage is at best only an indication of the intensiveness of tractor use because of the prevalence of custom work and frequent ownership of two or more tractors.

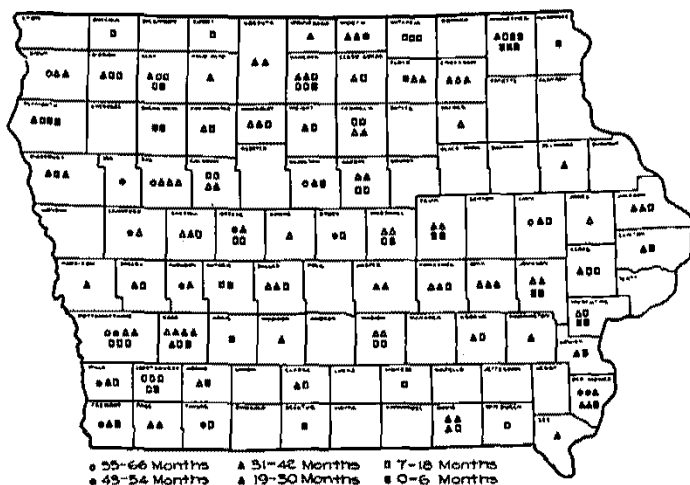


Fig. 1. Distribution of users contacted by survey.

TABLE 3. NUMBER OF TIRE BRANDS AND SIZES.

	Months used, inclusive						Total experience
	55-66	43-54	31-42	19-30	7-18	0-6	
1. Total number reported	5	12	34	60	56	32	199
2. Number of brands reported	2	2	5	5	7	6	7
3. Percent reporting, by sizes							
a. 7.50-36"	0	0	0	0	3	6	2
b. 9.00-36"	20	58	21	22	19	22	23
c. 9.00-40"	0	0	0	0	2	3	1
d. 10.00-36"	0	0	0	2	11	6	5
e. 11.25-24"	60	34	64	41	22	25	37
f. 11.25-28"	0	0	9	27	33	6	20
g. 11.25-36"	0	0	3	5	3	19	6
h. 12.75-28"	20	8	3	3	7	6	5
i. 13.50-28"	0	0	0	0	0	6	1

USE OF TIRES

The intensity of use of rubber tired tractors is indicated by table 4 which shows an average of 984 hours per year with a minimum of 240 and a maximum of 3,000. In terms of hours per month these values are equivalent to 82, 20 and 250 respectively. More complete data which emphasized the wide variation in intensity of use are given in fig. 2.

The values given in the 0-6 months group of table 4 are of particular interest. They indicate the very intensive use of tractors during the spring plowing and planting season.

TABLE 4. USE OF TIRES.

	Months used, inclusive						Total experience
	55-66	43-54	31-42	19-30	7-18	0-6	
1. Average months used	60	48	38	25	14	3	23
2. Hours used per year							
a. Number reporting	4	3	30	49	48	27	166
b. Smallest	540	480	310	240	300	580	240
c. Average	948	984	876	1008	1044	1620 ^a	994 ^c
d. Largest ^b	1400	1600	2450	3000	2200	4800	3000 ^c
3. Percent of use for hauling							
a. Number reporting	6	7	27	51	45	26	161
b. Smallest	0	0	0	0	0	0	0
c. Average	12	7	3.5	6.8	2.7	1.5	4
d. Largest	50	25	20	75	10	10	75

^a The average for this group is high, because it is based only on use during the "spring-rush" season.

^b The figures in this line are high. In every case, however, this is explained by one or more of the following situations: Large farms, custom work or use of the tractor for hauling. The 4800-hour figure has the added explanation that it represents only 3 "spring-rush" months.

^c Does not include those sets used less than 7 months, because in some cases such sets had been used only during the spring-rush season.

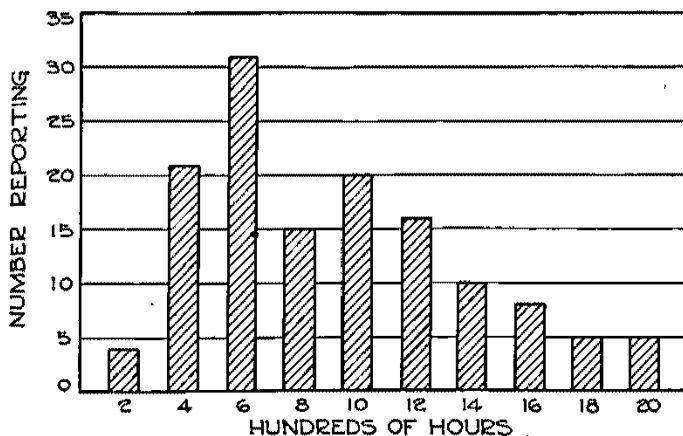


Fig. 2. Hours of use per year. No returns reporting less than 7 months of experience with rubber tires are included; there were four cases reporting figures greater than 2,000.

TABLE 5. TIRE WEAR AND MAINTENANCE COSTS.

	Months used, inclusive						Total experience
	55-66	43-54	31-42	19-30	7-18	0-6	
1. Condition of tire tread							
a. Number reporting	5	11	34	68	52	19	179
b. Percent reporting,							
(1) Design less than ¼ gone	0	9	15	34	69	95	—
(2) Design ¼ gone	80	37	52	54	31	5	—
(3) Design ½ gone	0	27	21	10	0	0	—
(4) Design ¾ gone	20	13	9	2	0	0	—
(5) Smooth	0	9	3	0	0	0	—
2. Total repair costs per set ^a of tires							
a. Number reporting	5	12	34	60	56	32	199
b. Number having no repair costs	4	3	14	37	40	32	123
c. Average	^b	\$ 0.94	\$ 1.61	\$ 0.57	\$ 0.29	0	—
d. High	\$ 3.00	\$ 4.00	\$ 10.00	\$ 8.50	\$ 5.00	0	—
3. Average repair cost per set ^a per year	\$ 0.12	\$ 0.24	\$ 0.54	\$ 0.28	\$ 0.29	0	\$ 0.28

^a Both front and rear tires.

^b Omitted because only one set of this group of tires had maintenance costs.

USE FOR HAULING

The estimated use for hauling is also included in table 4, which shows the very wide range of 0 to 75 percent and the rather low average of 4 percent. The figures in line 3c suggest, however, a tendency for hauling to increase with increased experience in the utilization of rubber tired tractors.

TIRE WEAR

The condition of the traction tire treads as reported by the cooperators is shown in table 5. As was to be expected there is a wide variation. This is caused, in part at least, by variations in soil condition and in intensity of use. In many cases, however, it is probably the result of improper utilization of traction tires. Excessive slippage resulting from too large a drawbar load or from a lack of sufficient wheel weight is

the most important cause of rapid wear. This factor was specifically emphasized in the supplementary statements made by a number of the users. In general, the tread conditions reported seem to justify the figures for estimated useful life listed in table 6.

COST OF MAINTENANCE

The maintenance costs reported by the cooperators are also given in table 5. The average cost per set per year, 28 cents, is remarkably low, which is explained by the fact that 123 users, about 60 percent, had no maintenance costs. On the other hand, the possibility of serious damage from careless handling or even unavoidable accidents must not be overlooked. The high repair costs reported in certain cases were mostly the result of such carelessness; backing the tractor into a sharp projection on some machine or allowing the edge of a misaligned drive belt to wear through an expensive tire.

There were, however, only 24 reports of individual expense items of \$1 or more. Half of these were for inner tube repair and replacement and half for vulcanizing casings.

TABLE 6. ESTIMATED USEFUL LIFE.

	Months used, inclusive						Total experience
	55-66	43-54	31-42	19-30	7-18	0-6	
1. Percent of tires still in use	100	84 ^a	89 ^b	98 ^c	100	100	97
2. Years of future use							
a. Number estimating	5	11	27	54	37	14	—
b. Lowest estimate	1	2	1	2	2	2.5	—
c. Average	5.3	3.8	4.1	5.1	5.3	6.5	—
d. Highest	10	9	9.5	10	10	10	—
3. Years of useful life							
a. Low	6	4	4	4	3	3	3
b. Average	10.3	7.8	7.2	7.2	6.1	6.5	7.0
c. High	15	13	13	13	11	10	15
4. Hours ^d of useful life, average estimated	11,168	6,620	6,464	6,792	6,398	—	6,765

^a One set traded in and one set retreaded.

^b Three sets traded in on new tires.

^c One set traded in on new tires.

^d Calculated from cooperators' statements concerning hours of use per month during the past and their estimate of the years of future use. No estimate was made for the 0-6 months use group, because their use for an average of three "spring-rush" months is not representative of their probable year-round utilization.

Expensive repairs were infrequent. Only five cooperators reported single expense items of \$5 or more, and the highest reported was only \$10.

ESTIMATED USEFUL LIFE

All but six of the 199 sets of tires were still in service; even the sets not in use had been retreaded or traded in on new tires rather than discarded. Therefore, the user's judgment of future life is the only basis on which to form an estimate of the probable useful life.

These estimates are given in table 6 and show a range of 3 to 15 years with an average of 7 years. Too much significance should not be attached to the 55-66 column because of the small number of cases. Further, it should be pointed out that no tractor tire has been used as long as 10 or 15 years. Even the average estimate of 7 years goes back before the introduction of these tires. In view, however, of the tread conditions listed in table 5 an average life of 7 or at least 6 years seems entirely reasonable. It should be remembered, however, that under adverse conditions the shorter 3- or 4-year life reported by certain cooperators may well be experienced.

The distribution of the various estimates of useful life is shown graphically in fig. 3. Except for the disproportionately large number reporting an expected life of 10 years and the correspondingly small numbers reporting 9 and 11 years the distribution is quite normal with the expected life estimated most frequently at 7 years. This checks with the mean of 7 years given in line 3b of table 6.

The average estimated useful life in hours for five groups is also shown in table 6. For these five groups as a whole the estimated useful life is 6,765 hours, an average of about 1,000 hours per year.

The possibilities of retreading tractor tires are receiving attention and at least one company is offering this service at a cost approximately one-half the price of new tires. Final judgment on the practicability of retreaded tires will have to wait, of course, until time has allowed a test of their use-

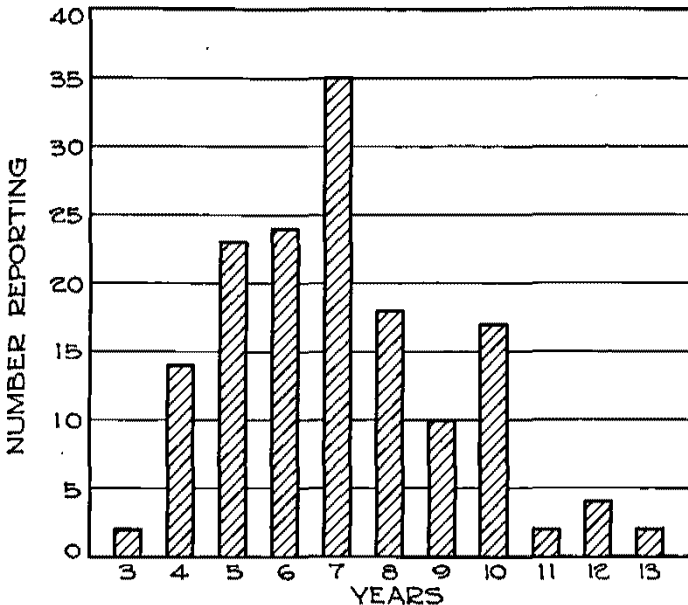


Fig. 3. Estimated useful life.

fulness. Recent experience with retreaded truck tires indicates, however, the possible success of retreading.

SAVING IN FUEL

The estimated difference in fuel for the same drawbar work¹ resulting from the substitution of rubber tires for steel lugs is shown in table 7. The 176 reports ranged from 0 to 50 percent reduction for rubber tired tractors, with an average reduction of 22 percent. Ten of the cooperators reported specific data to support their estimates. These 10 estimates had a narrower range of 10 to 40 percent and a slightly higher average of 24.5 percent. The distribution of the 176 estimates is shown by fig. 4. Except for the disproportionately large number in the 10 percent class, apparently at the expense of the 5 and 15 percent classes, the

¹ The installation of pneumatic tires does not, of course, affect the fuel required for belt work.

distribution appears to be quite normal and well centered on the average of 22 percent given in line 1c of table 7.

The 22 percent average and the 0 to 50 percent range both check well with a national survey made in 1934 (15) where the answers from 451 widely scattered users averaged 24.8 percent, with the identical range of 0 to 50. It is also interesting to note that the first controlled tests which were reported in 1933 indicated fuel savings of 9 to 25 percent (8) (13).

This marked fuel saving is explained by the increased tractive efficiency which is caused by the lower rolling resistance of tractors equipped with rubber tires. Trials at this and other stations (9) (16) indicate a one- to two-thirds decrease in rolling resistance. Carefully controlled trials to determine the comparative tractive efficiency of rubber tires operated with optimum adjustments of load and speed, indicate possible fuel savings of 5 to 30 percent, depending on soil conditions, (3) (9) (14) (18).

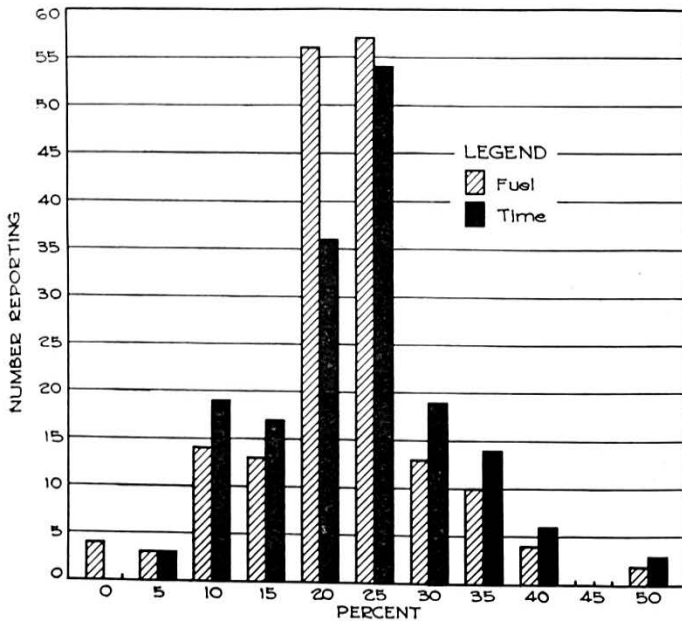


Fig. 4. Saving in fuel and time.

The wide variation in fuel savings reported by cooperators probably results from differences in the effectiveness with which they were able to adjust loads and speeds for the various field operations. Engineering investigators have experienced this same difficulty and have reported fuel savings, for a wide range of conditions, varying from -4 to 33 percent (1) (8) (9) (10) (13) (14) (15).

TABLE 7. OPERATING SAVINGS.

	Months used, inclusive						Total experience
	55-66	43-54	31-42	19-30	7-18	0-6	
1. Percent reduction in fuel							
a. Number reporting	5	11	30	56	43	31	176
b. Smallest	15	10	10	5	0	5	0
c. Average	19	22	24	22	20	24	22
d. Largest	23	25	40	40	33	50	50
2. Percent reduction in time							
a. Number reporting	5	9	30	56	45	27	172
b. Smallest	10	5	10	10	5	5	5
c. Average	14	13	25	23	23	24	23
d. Largest	20	25	40	50	50	50	50

SAVING IN TIME

Increased drawbar accomplishment may result from (a) the use of higher traveling speeds to, from and between fields, (b) higher operating speeds in the field and (c) the use of wider implements. In nearly all cases rubber tires make higher traveling speeds practicable.

Likewise, if the proper adjustments⁴ of wheel weights, drawbar load and gear ratio can be made, the increased efficiency resulting from lower rolling resistance should provide a percentage saving in time equal to the percentage fuel saving. Although such adjustments cannot always be made, it is remarkable how nearly the average savings in time shown in table 7 parallel the average savings in fuel reported by the corresponding groups. For the 172 estimates received the range is 5 to 50 percent and the average 23 percent. Again this checks well with the national survey made in 1934 where

⁴ Optimum adjustments are discussed under "Factors Favoring Effective Use," page 185.

for 462 replies the range was 0 to 50 percent and the average 20.8 percent.

The distribution of estimates of saving in time is shown also by fig. 4. This distribution like that for saving in fuel appears to be quite normal except for the 5, 10 and 15 percent values.

USE OF HIGHER GEAR

This item was reported by 157 of the cooperators. The other 42 either failed to report or stated that they had purchased tires with the tractor and had had no opportunity to compare speeds with similar tractors on steel wheels. Of those who answered 146, or 93 percent, stated that they were using a higher gear for some or all operations. Of this group 85, or 54 percent, reported that a higher gear was used for practically all operations. Thirty-five, or 22 percent, specifically reported the use of a higher gear for operating plows, and disk and spike tooth harrows. Again these reports check the returns received from the national survey in 1934 (15) when 91 percent of those who reported on this item indicated a change to a higher gear.

WIDER MACHINES

Fewer users had increased the width of machines. Only 62 or about 40 percent of those who had reported on this item had increased the width of one or more field machines. The use of a wider plow was mentioned specifically by 47 and wider disk harrows by 20. Eighteen cooperators reported the use of a wider spike tooth harrow or the addition of a spike tooth harrow to a disk harrow or roller.

The most common change in plow sizes was from two 14-inch to two 16-inch bottoms reported by 16 operators. The change from two to three bottom plows was reported by 11. The increase in total plow widths reported varied from 14 to 72 percent with the average about 30 percent.

This frequent increase in the width of machines used after changing to rubber tires should not be interpreted as indicating a greater tractive capacity. In many cases the maximum drawbar pull at which traction fails is lower for

pneumatic tires than for steel traction wheels (3) (14) (18). Under good traction conditions, however, where the drawbar pull with steel wheels is limited by engine power, the lower rolling resistance of rubber tires often results in a higher maximum drawbar pull.

HIGH LUG TREAD DESIGNS

Ninety-seven of the cooperators reported their observations concerning the relative traction characteristics of the new high lug treads compared to the older types sold before 1935. Two reported the tractive capacity as about the same, 13 as slightly better, 32 as definitely better and 50 as greatly improved. One cooperator reported that under good traction conditions he preferred the older treads but agreed that for year-round work the newer deeper designs were better.

USE OF WATER^c FOR WHEEL WEIGHTS

Experience with the use of water for wheel weight was reported by 40 farmers. All but three were satisfied with this method of adding weight. Two of these gave no reason for their dissatisfaction. The third objected to the difficulty encountered in removing water when less weight was desired.

One user reported a marked decrease in the tendency to excessive bouncing when crossing ridges. This observation is supported by carefully controlled research (4).

UTILITY OF TRACTOR TIRES

Over 98 percent, that is, all but three cooperators, indicated without qualification that if they were buying a new tractor it would be equipped with pneumatic tires. Of these three, two were undecided and only one was definite in his disapproval of the general utility of rubber tires for farm tractors. It should be noted that these users had had only 3, 14 and 15 months, respectively, of experience with the use of rubber tired tractors. The user who was definitely unfavorable was using a smaller rubber tired tractor to supplement the work of a larger tractor equipped with steel wheels.

^c An anti-freeze, usually calcium chloride, must be added except where there is no danger of freezing temperatures.

Many of the users added highly favorable comments such as, "Rubber tires on a tractor are as essential as they are on the family car or the farm truck," and "A farmer pays for rubber tires whether he has them on his tractor or not."

CHARACTERISTICS OF RUBBER TIRES COMPARED WITH STEEL WHEELS

The characteristics of pneumatic tractor tires and the related advantages and disadvantages reported by the cooperators may be summarized as follows:

1. More expensive construction resulting in higher first cost.
2. Less rugged construction resulting in such disadvantages as: (a) Higher average depreciation costs, (b) possibility of inconvenience and loss of time from punctures, (c) possibility of accidental but expensive damage.
3. Greater resilience resulting in the advantages of: (a) Operation at higher speeds, (b) operation on hard surface roads, (c) reduced tractor breakage and wear, (d) increased operator comfort under most operating conditions; and the minor disadvantages of: (a) Excessive bouncing when crossing ridges spaced at regular intervals, (b) slightly less stability for belt work, (c) expense resulting from the installation of rubber tires on at least part of the drawn equipment if used at high speeds.
4. Less disturbance of the soil resulting in the advantages of: (a) Minimum damage to farm roads, meadows and pastures, and lanes, (b) less dust and dirt to annoy operator and cause wear on tractor, (c) less rapid digging in when traction fails; and the disadvantages of: (a) Lower maximum drawbar pull on many soil conditions (3) (14) (18), (b) a more objectionable track in loose tilled soil (5).
5. Lower rolling resistance resulting in the very important advantages of: (a) Less fuel for the same drawbar work, (b) more work accomplished in the same time.



Fig. 5. Pneumatic tires on the tractor make pneumatic tires on field machines desirable. Used automobile tires will often serve satisfactorily. (Photo courtesy C. K. Shedd, Bur. of Agr. Engr., U. S. Dept. of Agr.).

The advantages may be summarized as: Reduced fuel and labor requirements, higher speeds, operation on hard surface roads, less damage to farm roads, lanes, meadows and pastures, decreased tractor breakage and wear, and greater comfort.

The disadvantages may be summarized as: Higher first cost, possibility of delay and expense from accidental damage, the expense of also equipping at least part of the drawn equipment with rubber tires, lower maximum drawbar pull under many conditions, excessive bouncing under certain conditions, more objectionable tracks in loose tilled soil and decreased stability for belt work.

ANNUAL COST OF USE OF TRACTOR TIRES

Depreciation and interest charges are the important items of tractor tire costs. The average 28-cent repair cost shown in table 5 is of minor importance, and there are no additional housing costs as the result of equipping with pneumatic tires. In fact, 1 percent of the first cost would appear to be an ample

annual allowance for all other than depreciation and interest. The annual costs shown in table 8 include depreciation on the sinking fund basis, interest charges at 6 percent and this 1-percent allowance.

The average additional retail cost for pneumatic tires for 17 all-purpose models offered by seven companies Jan. 1, 1939, was approximately \$200. If, on the basis of the figures of table 6, a useful life of 6 or 7 years is assumed, the annual cost of use of the tires on a two-plow, all-purpose tractor will be about \$40, as shown at the intersections of the 6- and 7-year lines with the \$200 column of table 8.

TABLE 8. ANNUAL COST* OF USE OF TIRES-DOLLARS.

Useful life, years	First cost, dollars					
	50	100	150	200	250	300
4	14.93	29.86	44.29	59.72	74.65	89.58
5	12.37	24.74	37.11	49.48	61.85	74.22
6	10.67	21.54	32.01	42.68	53.35	64.02
7	9.46	18.91	29.37	37.82	47.28	56.73
8	8.55	17.10	25.65	34.20	42.75	51.30
9	7.85	15.70	23.55	31.40	39.25	47.10
10	7.29	14.59	21.89	29.18	36.48	43.77

* Calculated on the sinking fund basis (see condition percent tables, Iowa Engineering Experiment Station Bulletin No. 70, 1924) with a 6 percent interest rate and including an annual charge of 1 percent of the first cost for repair and insurance. The selection of a 6 percent interest rate is somewhat arbitrary, although this is the rate commonly charged for financing farm equipment purchases. Changing the interest rate 1 percent will change the annual cost by approximately $\frac{1}{2}$ of 1 percent of the first cost.

COMPARISON OF COST AND SERVICE

Although \$40 is an appreciable annual charge the experience of these farmers indicates that in many instances it is readily justified even if all advantages except the fuel and labor saved are neglected. These savings of fuel and labor on what would be a day's work with a two-plow tractor would amount to about 80 cents. This estimate is based on the following conservative assumptions: Daily fuel requirement of a steel wheeled tractor, 15 gallons at 10 cents per gallon (10); operator's wage, \$2.50; and fuel and labor saved by rubber tires, 20 percent each (see table 7). With this daily saving of 80 cents, a situation requiring 50 days, that is, 500 hours work, with a steel wheel tractor would justify the estimated annual expenditure of \$40 for the use of a set of tires.

Even if a still more conservative estimate of only 10 percent saving in fuel and labor is assumed, 100 days (1,000 hours) of work would justify the purchase of a rubber tired tractor. In fact, with present prices the purchase of pneumatic tractor tires can be justified on the basis of increased capacity. The reported average saving of 23 percent in time required for the same work is equivalent to nearly 30 percent increase in capacity. This 30 percent increase in capacity compares favorably with the 24 percent average increase in retail price for adding rubber tires to the 17 models previously mentioned. Thus, on the basis of these figures, the same money will purchase a tractor of equal or greater drawbar work capacity when equipped with rubber tires.

FACTORS FAVORING EFFECTIVE USE

To assume that the economic advantages of pneumatic tires automatically accompany their purchase is, however, a serious mistake. The purchaser who takes this attitude is likely to attain only minor savings in fuel and labor.

If the savings discussed in the previous section are to be accomplished, careful consideration must be given to effective utilization. Statements by the cooperators and reports of other investigations as well as engineering analysis indicate that the utility of a tractor equipped with pneumatic tires is increased by intensive use and higher operating speeds. Adjustments between speed, wheel weight and drawbar load which will utilize as fully as practicable the capacity of the tractor engine and yet avoid excessive slippage of the traction wheels are also very important.

Further, the special characteristics of rubber tires are of greater relative advantage where a farm is located on a hard surfaced road, fields are widely separated or fuel prices and wages are high.

Specifically the operator of a rubber tired tractor should plan to use: (a) The highest practicable speed, (b) the widest implement which the engine and tires can pull satisfactorily at this speed and (c) enough wheel weight to provide effective traction.

LITERATURE CITED

- (1) Symposium on pneumatic tires for agricultural tractors including reports from 14 experiment stations. *Agricultural Engineering*, 15:36-74. 1934.
- (2) Manufacture and sale of farm equipment and related products. Bureau of Census. 1936-38.
- (3) Davidson, J. B., Collins, E. V. and McKibben, E. G. Tractive efficiency of the farm tractor. *Iowa Agr. Exp. Sta. Res. Bul.* 189. 1935.
- (4) Delzell, H. W. Liquid weight in farm tractor tires. *Society of Automotive Engineers Jour.* 41, 5:35. 1937.
- (5) Hawthorne, F. W. Farm tests of low-pressure tractor tires. *Agricultural Engineering*, 15:61, 63. 1934.
- (6) Hurlburt, L. W. Comparative tests results of rubber tires and steel wheels for tractors. *Agricultural Engineering*, 14:217-218. 1933.
- (7) Hurlburt, L. W. and Smith, C. W. The effect of tire size on drawbar pull and travel reduction. *Agricultural Engineering*, 18:53-57. 1937.
- (8) McCuen, G. W. Ohio tests of rubber tractor tires. *Agricultural Engineering*, 14:41-44. 1933.
- (9) McCuen, G. W. and Silver, E. A. Rubber-tired equipment for farm machinery. *Ohio Agr. Exp. Sta., Bul.* 566. 1935.
- (10) Murdock, H. E. Tests on use of rubber tires and steel wheels on a farm tractor. *Mont. Agr. Exp. Sta., Bul.* 339. 1937.
- (11) Reynolds, L. A., Humphries, W. R., Speelman, S. R., McComas, E. W. and Youngman, W. H. Utilization and cost of power on corn belt farms. *U. S. Dept. Agr. Tech. Bul.*, 384. 1933.
- (12) Samuelson, L. W., Hurlburt, L. W. and Smith, C. W. The effect of tractor tire size on drawbar pull and travel reduction. *Agricultural Engineering*, 17:143-149. 1936.
- (13) Shields, J. W. Pneumatic tires for agricultural tractors. *Agricultural Engineering*, 14:39-40. 1933.
- (14) Smith, C. W. and Hurlburt, L. W. A comparative study of pneumatic tires and steel wheels on farm tractors. *Neb. Agr. Exp. Sta., Bul.* 291. 1934.
- (15) Smith, C. W. A study of user's experience with rubber-tired farm tractors. *Agricultural Engineering*, 16:45-52. 1935.
- (16) Wileman, R. H. Pneumatic tires vs. steel wheels for tractors. *Agricultural Engineering*, 15:62-63. 1934.
- (17) Wileman, R. H. Effect of tire size on tractor efficiency. *Agricultural Engineering*, 19:27-28. 1938.
- (18) Wright, S. J. and Wilson, J. S. Studies of tractor wheel performance. *Implement and Machinery Review*, 64:693-695. 1933.