DESIGN OF A TRACTOR
FOR
FARM AND ROAD WORK

BY

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THE DESIGN OF A TRACTOR FOR GENERAL FARM and ROAD WORK

A THESIS

PRESENTED BY

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Index to Drawings Appended.

The above drawings are given as an example of the various sorts which were made for the complete construction of the machine.

"THE DESIGN OF A TRACTOR FOR FARM AND ROAD USE."

It is the object of this Thesis to show the developement of the design of a Tractor for use on a general farm, and for limited use on the road in hauling loaded wagons and the like, and one which will be adaptable to the following services,

1. It is desired to design a machine which will be capable of doing the plowing both in the spring when the ground is soft and spongy, and in the fall when the ground is usually very hard and difficult for horses to work.

2. The machine should be capable of fitting or smoothing the ground with harrows of various descriptions, and any other tools which might be used for the purpose.

3. The tractor should also be capable of pulling planters for seeding the ground without a great deal of pressure under the wheels, which would pack the soil and

render it unproductive. This work of planting however I consider of minor importance as it is not the desire to try to design a machine which will entirely replace horse labor on the farm, but one which will do the heavy work and do it economically and faster than horses are capable of doing it, with the same amount of human labor. The cultivation of corn and other row crops is another use to which I do not believe the tractor which is adaptable to haevy work should be put. The tractive effort necessary to the pulling of cultivators is so light that it would not be economical to run a tractor of the weight necessary for plowing, to do so small an amount of useful work.

4. The next use to which the Tractor should lend itself to advantage, in the course of the season's work on the farm, I think is in the pulling of mowing machines and binders for the harvesting of hay and grain crops. This work should be done at the

speed at which the binders or mowing machines operate most successfully and a sufficient number of these machines should be drawn so t that the load will approach the normal rated load of the Tractor, in order that the work may be done economically. The above remarky apply also to the drawing of corn harvesting machinery of various kinds such as binders, pickers, and ensilage cutting machines which operate in the field. The tread of the tractor wheels should be of such width that it will steer easily in the corn rows without the necesity of running one wheel on the cut row.

5. The Tractor should be equipped with a suitable and efficient belt pulley of sufficient size to give good belt grip and which can be run at the speed most common to the various farm machines such as threshers, silo fillers, corn shellers, feed grinders, and husking machines. This is one of the most important uses of the farm tractor and

from my experience and observation nearly forty percent of all the wotk done with the tractor is done with the belt pulley in driving the above mentioned machines or sawing wood, or doing other belt work. This is also one of the points which is most frequently overlooked by the Tractor Manufacturers and provided for only in a makeshift manner.

6. The balance of the machine and the distribution of weight are two most important features in the design of a tractor and should be given close attention.

7. The steering of the machine should be easily accomplished by the operator and short turning with a heavy load with a heavy load attached to the machine is important. This is important as it is usually necessary to hitch the load to the Tractor at a point near the rear end of the machine, and when the machine is turned, it causes a side draft which tends to keep the machine going in a

straight line, and causes the front wheels to slide on the ground and in the case of some three wheel machines has actually caused the machines to turn over, This must be taken care of in some manner to insure satisfactory operation. The steering gear should be of an irreversible pattern so that no obstacle in the path of the front wheel can cause the turning of the machine. This enables the operator to set the machine to travel in a straight line and then give his attention to the load he is pulling.

8. It is my opinion that a machine with two drive wheels in the rear and with two steering wheels in front is the most satisfactory pattern for the following reasons. A machine of this pattern can be designed with sufficient road clearance. It can be easily steered when traveling either forwards or backwards. nThe load is attached to the machine directly under the driving axle so that the tendency of the bull pinions to

climb on the bull gears and thus destroy toe balance of the machine can be exactly equalized by the moment of the load about the rear axle as a center. The transmission and other heavy parts of the machine can be carried directly over or about the rear axle, thus giving the correct distribution of weight. The machine is more stable on uneven ground than machines of other pattern. Side draft may be more nearly eliminated. The rear wheels are near to the operator who can thus see more readily where the machine is working with relation to the furrow bank.in plowing. The plows may be kept in more constant position. The machine is more rigid than other types when standing still and running belt driven machines.

9. It is desired that the machine should give at least 10000 houms of satisfactory service and with this in view the best of materials must be used. It has been decided to use a four cylinder Automobile

type motor for the machine, as it has proven best in actual service and for the additional reason that the average farmer of today has had some experience with automobile motors and if he has not, he can readily find a repair shop which will give him satisfactory service in case of needed repair or adjustment.

10. The motor must be of sturdy design with large bearings and ample water jackets. The water jackets must inclose the valve chambers and the spark plug tappings as it has been found that with the motor running at nearly full load for continuous runs of ten hours and longer that the spark plugs and exhaust valves become greatly over heated and cause trouble if they are not provided with some cooling medium.

11. The motor must also be equipped with a suitable governor which will keep the motor speed constant when the machine is at work under varying conditions of load.

12. It has been thought advisable to

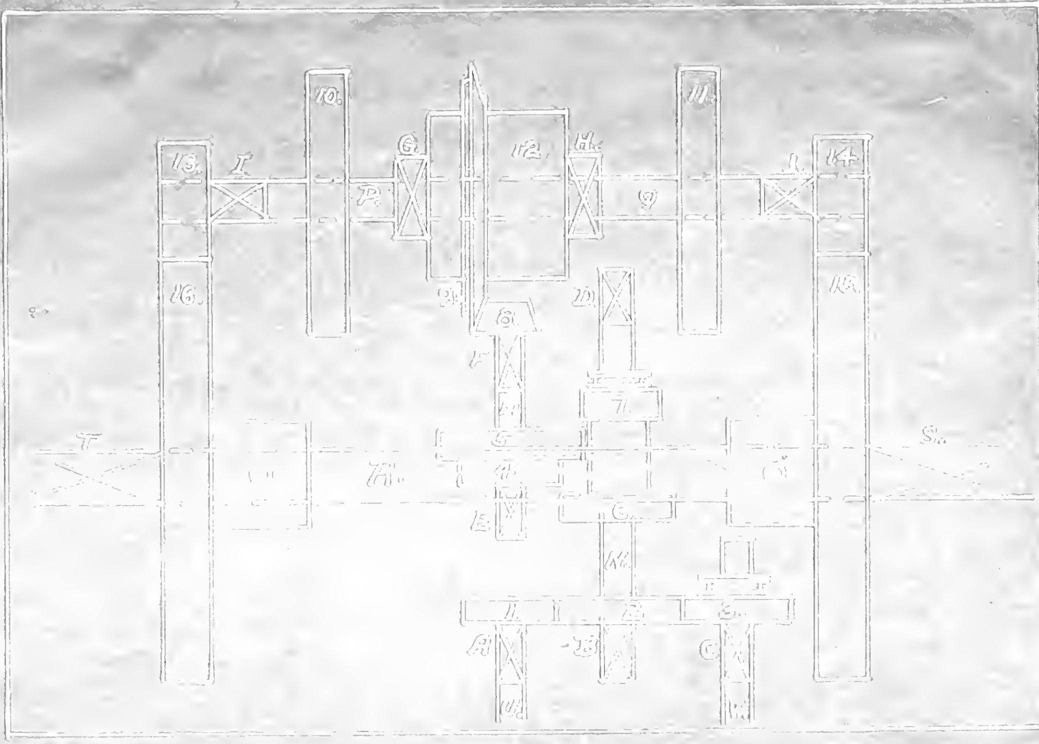

FIGURE - 6.

use gasoline as fuel as with this type of motor a considerable degree of economy can be attained with this fuel with the proper carburetn and preheating of the fuel. It has been found unsatisfactory to use kerosine in this type of motor and even in other types for several reasons. One reason is the loss in volumetric efficiency due to the extremely high temperature to which the kerosine must be heated in order to vaporize it. Another reason is that the kerosine works down past the pistons and mixes with the oil in the crank case of the motor and thus destroys the proper lubriation of bearings and cylinders causing scoring and cutting if the oil is not renewed quite frequently. It has been found that with a four cylinder motor of 4-1/4" X 5-1/4" with a piston clearance of 12 thousandthsof an inch, fitted with three piston rings per piston, running at a speed of 1000 r.p.m. and pulling 20 h.p., about a half a gallon of kerosine can be distilled from the oil in the crank case. At this

rate it is seen that it would be advisable to change the oil in the crank case after every day of use and this would be as great an expense as the difference in cost between gasoline and kerosine. Aside from the cost it would be questionable whether or not the average farmer would change the oil often enough to insure satisfactory service from the machine.

13. It was thought advisable to design the transmission so the the machine would have two speeds forward and one reverse. The speeds chosen were determined by the speeds at which the various farm machines should be drawn. These machines may be divided into to classes. The one class requires a heavy pull at slow speed. Plows are the most important tools in this class and it was found by consulting various plow makers that a speed of 2-1/4 to 2-1/2 miles per hour was the most satisfactory plowing speed. This is also a good speed for

heavily loaded wagong on the road and was adopted as the low speed of the machine. The other class of farm machinery is the reaper and mower class, which should run at a speed of about four miles per hour in order to give the cutting knives sufficient speed to do the work and at the same time not run so fast as to cause overheating of the cheap and ineffective bearings usually found in this class of machinery.

14 It is desired that the machine should pull at least three plows of the fourteen inch size in and kind of soil where plowing should be done, and four plows where conditions for plowing are favorable.

15. There should be sufficient belt power to run the machines usually found, or used in connection with, the average general farm or a hundred acres or more. This has been found to be about thirty horse power

16. All parts of the machine must

be inclosed and properly lubricated to insure the desired length of life of the machine and the lubrication must be dependable and easily attended to. The machine must be well covered to exclude dust and rain. The controlls should be at the rear end of the machine within easy reach of the operator who should ride at a point where he can easily manipulate the levers on his plow or other drawn machine.

With these points in view it was decided to first design the power plant of the machine and build the rest of the machine around it. It was decided that the motor and the transmission should be bolted together to form a single unit which could then be set into a frame carried by the wheels. In order to assure good lubrication as many of the moving parts as possible were put inside the transmission case in a bath of lubricant.

After many other designs were made and some of them tried in actual practice

Sp
Sp
Sp
Lo
Lo
Hi
Hi
R
Bo
Bo
B
B
Di
Pi
Be
Be
Bu

Sp

Lo

Hi

Be

Bu

and after many tests had been made covering a period of several years the design of the transmission shown in figure 1. was adopted as being the most desirable for the purpose, and from this the desing of the transmission as shown in Blue Print T-171 was worked out.

Refering to figure 1, shaft U is connected to the motor through a friction clutch. Drive gear No 1, drives No 2. and No. 2 drives No. 3. Gear No. 3 is mounted on shaft V and this shaft runs to the front of the machine where there is a bevel gear set which drives the belt pulley shaft which is mounted cross-wise on the machine. Gear No 2. is mounted on shaft N which also carries the change speed piniond 6 and 7. These piniond engage gears Nos. 4 and 5 respectively for high and low speed. There is a reverse gear mounted under and meshing with Nos. 5 and 7. Shaft M carries gears 4 and 5 and also bevel pinion No8. The Bevel gear is mounted on the fiff-erential, No.12, which in turn is carried by

bearings G and H. The differential shafts, P and Q extend to the outside of the machine where the bull pinions 13 and 14 are mounted and mesh with the bull gears 16 nad 17. These bull gears are mounted on the hubs of the rear wheels ans the wheels are carried on the axle on roller bearings. The rear axle is held in position by the transmission case easting.

In order to arrive at the proportions for the gears and bearings it was necessary to determine the amount of draw bar pull required to do the work for which the machine was intended. Taking the plowing as the heaviest work required on the machine it was found with a traction dynamometer in heavy clay soils and under usual conditions to require about 1000 pounds pull at a speed of 2-1/4 miles per hour for pulling a fourteen inch plow six to eight inches deep. It was therefore assumed that the machine dhould develope a draw bar pull of 4000 pounds at a speed of 2-1/4 miles per hour or 195 feet

per minute. It was learned by experience that a five foot wheel with a twelve inch face gave good results under these conditions. It therefore would require a wheel speed of 12.6 r.p.m. and would require $\frac{4000 \times 198}{33000}$ or 24 horse power at the draw bar to do the work required.

Assuming an efficience of the wheel drive of 80%, the horse power required at the bull pinions of the machine would be $\frac{24}{.80}$ or 30 horse power. Dividing this by two it would mean a horse power of 15 on each bull pinion. In like manner assuming an efficiency of 95% for each gear reduction the horse powers at the various points were figured as given here.

Horse	Power	Required	At Draw Bar	24
"	"	"	" Bull Pinions	30
"	"	"	Each " "	15
"	"	"	" Bevel Pinion	31.6
"	"	"	Low Sp. Pinion	33.3
"	"	"	Spur Drive Pin.	35

The next step in the design was to determine the size and material necessary for the shafts to do the work requited. To do this it was first necessary to select the motor for the machine so that the speeds and the gear

ratios could be figured. It was found above that the horse power required at the spur drive pinion No 1 and consequently the power that the motor should be capable of delivering to the transmission was 35. It was thought advisable to select a motor which would develope forty horse power at a speed of 900 r.p.m. and one was found of suitable design and construction which would exactly fit these requirements. This motor is a four cylinder 4-1/2" X 6" motor made by the Buda Co. of Harvey Ills. The horse power and torque curves for this motor are shown in Figure 4 as determined with a Sprague Electric Dynamometer at the factory of the Motor makers. It is thus seen that the total gear reduction in low speed must be from 900 r.p.m. to 12.6 r.p.m. or a ratio of 71.5 to 1.

The individual steps in the gear reduction were proportioned to divide the speeds and pressures on the bearings in such a menner

Name.	H.P.	R.P.M.	Material.	Diam From $d=\sqrt[3]{\frac{c \times H.P.}{R.P.M.}}$	Actual Diam.	Splines or Keyways.	Heat Treatment.
Clutch Shaft	35	900	Carb St.	1.42"	$1\frac{1}{2}$"	Taper	C. H
Counter Shaft.	33.3	643	Carb St.	1.57"	2"	4-Spl.	C-H.
Pinion Shaft	31.6	316	Carb St	1.95"	2"	$\frac{1}{2}$" Ky.	C-H.
Differential Shaft	15	78	Ni St.	1.93"	2"	4-Spl	C-H.
Belt Pulley Drive Shaft.	35	562	Carb St.	1.67"	$1\frac{3}{4}$"	4-Spl.	C-H.
Pulley Shaft	33	468	Carb St	1.77	2"	$\frac{1}{2}$" Ky.	C-H.

FIGURE - 3.

that bearings of the right size and capacities could be obtained at moderate prices. These various gear sizes are given in figure 2.as are also the speeds od the shafts.

The diameters of the shafts were figured from the formula for the diameter of shafts subjected to simple torsion as given in Halsey's Handbook, namely $d = \sqrt[3]{\frac{321000 \times h.p.}{S \times r.p.m.}}$ in which d is the diameter of the shaft in inches, and S is the fibre stree at outer fibre in pounds per square inch. A value of 4280 was assumed for S for carbon steel and twice this value for alloy steel. The formula thus becomes

$$d = \sqrt[3]{\frac{75 \times h.p.}{r.p.m.}} \quad \text{for carb steel.}$$

$$d = \sqrt[3]{\frac{37.5 \times h.p.}{r.p.m.}} \quad \text{for Alloy steel.}$$

The values of the various factors were substituted in the above formulae and the results are given in figure 3.

The next step was the calculation of the width of face of the gears necessary for the transmission of the power at the various points.

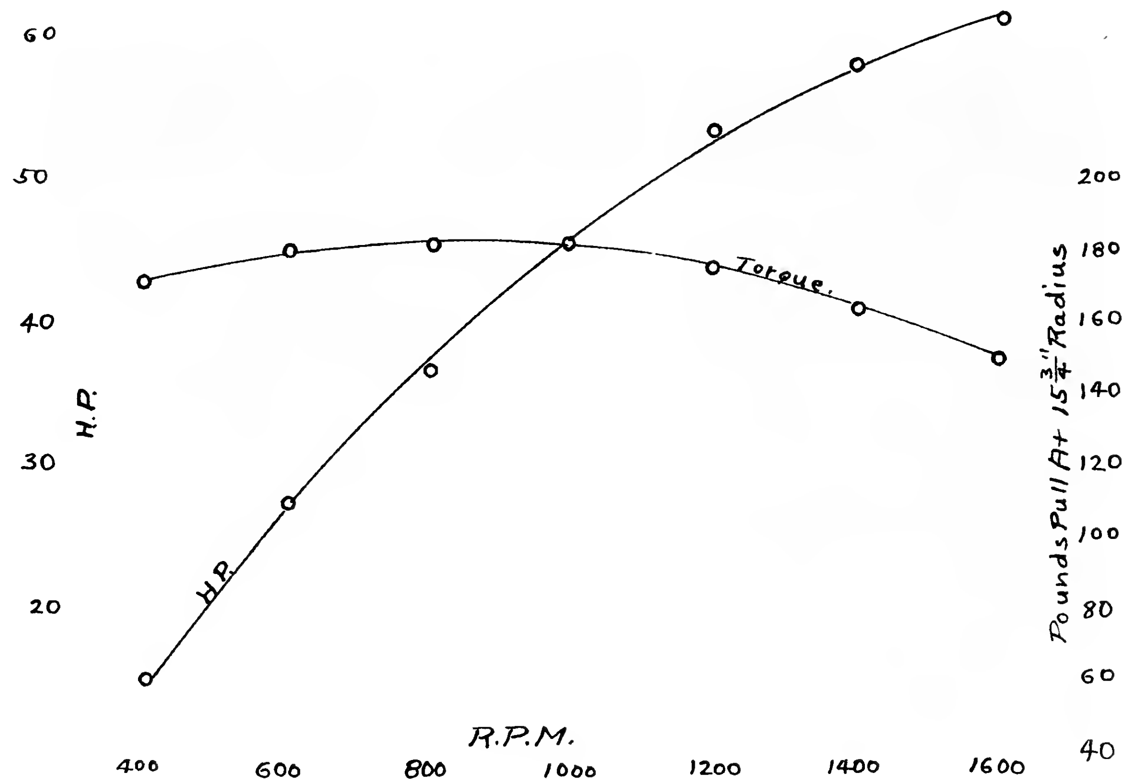
60
50
40
30
20
H.P.
H.P.
Torque.
200
180
160
140
120
100
80
60
40
Pounds Pull At 15 3/4" Radius
R.P.M.
400
600
800
1000
1200
1400
1600

Fig 4.

The Lewis formular for the strength of gear teeth was used in these calculations. This formula states that $W = SPf\gamma$, in which W is the working load at the pitch line in pounds, S is the allowable fibre stress in pounds per square inch, and f is the width of face of the gear in inches, and γ a factor depending upon the number of teeth in the gear. The values of the factor γ are given by Lewis and may be found is Halsey's Handbook or in other mechanical handbooks. The value of the allowable fibre stress depends upon the speed of the pitch line and is also given by Lewis in tabular form.

As an example of these calculations we will consider the spur drive pinion with a pitch diameter of 5", running at 900 r.p.m. and transmitting 35 h.p. The diametral pitch is assumed to be 4 and 3-1/2% nickel steel with .25 carbon will be used.

The speed of the pitch line is

$$\frac{\pi \times 5 \times 900}{12} = 1180 \text{ ft/min.}$$

The value of

$$W = \frac{35 \times 33000}{1180} = 976 \text{ pounds.}$$

The value of S for the given pitch line speed is found, from the Lewis Table, to be 12000 lbs/sq. inch. The value of γ from the Lewis Table is .102 The circular pitch is .7854 It is also necessary to use the factor .85 in the denominator to increase the face width for gears which are constantly in mesh. Substituting the above values in the formula it becomes

$$f = \frac{976}{12000 \times .7854 \times .102 \times .85} = 1.19''$$

It has been found in my experience with tractors that gears figured from this formular are not sufficiently wide for tractor servise and therefore the formula is used as a guide and the results are then increased. In this case the face width is increased from 1.19" to 1.5". This is necessary to give the desired wearing qualities to the gears. All other gears were figured in like manner and the results are given in Figure 2. In the case of bevel gears the same method was used escept that the factor $\frac{d}{D}$ in which d is the small diameter of the bevel gear and D the large diameter, was

multiplied by the actual number of tahth to get the equivalent number of teeth for which to select the factor γ.

The selection of suitable bearings was the next step and the pressures on all bearings were calculated from the tooth pressures and the moments about the bearings as centers.

Taking the bull pinion bearing I as an example the pressure was calculated in the following manner. The tooth pressure is seen from table 2 to be 5220 pounds. The distance from the center of the pinion to the center of bearing I is 3.5" The distance from the senter pf the pinion to the center of baering G about which moments are taken is 11.5 " The distance from the center to tenter of bearings is 8" Therefore P or the pressure on bearing I is $\frac{5220 \times 11.5}{8}$ or 7580 lbs.

Roller bearings were decided upon and the recomendations of manufacturers of this class of bearings were obatined and selection was made from these recomendations.

The transmission case was then designed to inclose the transmission and is show on blue print No T-170 which accompanies this Thesis.

The weight distribution was carefully figured and was so arranged that three fourths of the weight came on the rear or driving wheels and one fourth in front. This has been found be experience to be the most satisfactory distribution. If more weight is put in front the front wheels sink into soft ground and if less weight is put in front the front wheels have a tendence to leave the ground when the machine is started suddenly and difficulty in steering is experienced.

The convertional steering gear of knuckle typr was adopted except that it is actuated by a cable with a suitable tightening device wound around a drum which in turn is moved by a worm and gear connected to the hand steering wheel. This was used instead of the conventional drag link and the wheels

of the machine when turned to the required angle of 45° would interfere with a drag link if one were used.

The front axle of the machine was hung on a shaft in such a way that is is free to oscilate about the longitudinal axis of the machine. Thus the frame is suspended from three points only.

The frame of the ma chine was constructed of 5" steel channel as shown in the accompanying drawings.

The cooling of the motor is accomplished be means of a honeycomb radiator the size of which was determined by experiment, under actual working conditions both when the machine was standing still and when it was in motion under a tractive load. This cooling surface id 75 square feet and consists of 35 B & S. gauge copper sheets

The speed of the motor in regulated by a governor of the centrifugal type connected to a worm and gear driven by the cam-shaft

of the motor. through a small flexible shaft. The governor mechanism is entirely inclosed and runs in oil.

It has been found that a Rayfield carburetor with a water jacket through which the cooling water of the engine is circulated and which heats the carburetor to a temperature of about 180° F. and the use of a hot air stove to heat the intake air gave the best results. The fuel consumed has averaged about a gallons and a half per acre in heavy clay soil and without the heather ans with several other makes of carburetors the best that could be accomplised was three gallons per acre.

The draw bar of the machine was located directly beneath the rear axle at a radius equal to the radius of the bull gear. A chain is attached to this draw bar on each side of the machine and pass through the draw chain guide at the rear end of the machine. These chains may be fixed in position at the guide

bar by means of pins or may be allowed to float at that point as desired.

The top of the transmission case was left unobstructed so that pepairs or adjustments could be made at any time without disturbing any other part of the machine.

In selecting the belt pulley sixe and speed it was necessary to consult the amkers of harvesting and agricultural machinery. I regret to say that it was found that there is no standard belt speed for machines of this sort but it was noticed that the favored speed ranged from 2800 to 3000 feet per minute. It was therefore decided to use a pulley of 24" diameter running at a speed of 468 r.p.m. thus giving a belt speed of 2940 ft per minute at the normal speed of the motor. The belt pulley drive may be disconnected by operation of the change speed lever which is located at the rear of the machine within easy reach of the operators seat

This gear lever operates in slots so

that it is impossible for more than one gear speed to be in mesh at the same time and also prevents the belt pulley from running when the machine itself is in motion. This obviates the danger of the operator being caught in the belt pulley while making adjustments on the machine or putting on the belt.

The fuel tank is in full view of the operator and is supplied with a gauge to show the gasoilne level The tank has a capacity of 30 gallons which is enough to run the machine at full laod for a period of eighteen hours.

The machine is also equipped with a sight feed oil glass through which the oil is pumped in full view of the operator.

There is also a water gauge connected to the radiator by means of brass tubing so that the operator may see at all times the water level in the radiator.

A small pulley is mounted on the belt drive shaft and providion is made for

bolting a small grinding head to the frame of the machine for use in sharpening the cutting knives of the various machines operated.

I high tension machine is used in place of the customary low tension magneto so that no batteries are needed for starting the motor.. The spark advance lever is connected to an automatic short circuiting device so that in extreme retard position the ignition is short circuited and the motor stopped. This obviates the necessity of a separate ignition switch.

The speed of the engine may be regulated by means of the hand throttle which automatically disconnects the governor when it is used.

The seat and the operators platform are spring mounted. It was not thought advisable to mount the transmission on springs as at the extremely slow wpeed there is very little vibration and the bumps which are encountered

are of a slow heavy nature . These jolts would cause severe shock to the bull pinions and any uneven ground would cause the axes of these to runout of line if springs were interposed between them. This would cause excessive wear on the bull pinöons and gears.

The wheels od the machine are all punched for the attachment of either conical or square lugs or angle cleats. They are regularly fitted with flat channel cleats riveted to the rims for use when the ground id dry and hard.

The fan is mounted on inclosed ball bearings and it is thus evident that there is not a single working part of the machine exposed to the air. An air cleaner is used in connection with the carburetor so that no dust is taken into the motor with the air to cause scoring of the cylinders.

The clutch is of the dry plate type and is inclosed in a compartment cast into the transmission case and is operated by a foot

pedal within easy reach of the operators seat. This pedat is equipped with a lock so that the pedal may be left down and the clutch disingaged.

Provision is made on the motor for a small electric generator so that a lighting system may be installed for night work either in the field or on the belt.

In the transmission sketch will be noticed two brake drums 10 and 11. These are surrounded by contracting brake bands which are operated by means of foot pedals so that the operator may apply the brake on either wheel at a time or on both together. The purpose of this arrangement of brakes is to make possible short turning with a load. The brake on the inside of the turn is applied and thus the outside wheel is forced to do the driving and takes the load around the corner.

In conclusion I will say that the machine has been constructed in all its

essential parts and has been in continuous service on the farm for about three years. It has given very good service in the hands of various inexperienced men and under various conditions of soil. It is now being constructed in every detail as shown on the accompanying drawings and patents on the amchine and its parts have been applied for.

Respectfully submitted

By