August 2, 1951

To the Graduate Council:

I am submitting herewith a thesis written by James Lee Butler entitled "Development of a Tractor Powered Fence Post Driver". I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Engineering.

M. A. Sharp

Major Professor

We have read this thesis and recommend its acceptance:

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Accepted for the Council:

E. A. Walter

Dean of the Graduate School

DEVELOPMENT OF A TRACTOR-POWERED FENCE-POST DRIVER

A THESIS

Submitted to
The Graduate Council
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science

by

James Lee Butler

August 1951

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CHAPTER I

INTRODUCTION

When livestock and crops are grown jointly, some kind of fencing is needed for the confinement of livestock and for the protection of crops. Besides these necessities, Wooley (1) states that a well fenced farm decreases difficulty in hiring help, increases the farmer's credit standing at the bank, increases his standing among his neighbors, and adds much in personal satisfaction.

In the early days of our country fences were built from products removed from the field. Rail or pole fences were built from the trees removed in the clearing operation. Sometimes the fence was built from the stumps which were piled in a tangled row. Often in stony areas the fence was built of stones removed from the field to make tillage easier.

Fences of this type have largely been superseded by wire fences, either barbed or woven or a combination of the two. The development of machinery to manufacture wire fencing at a low cost enabled farmers in most areas to buy the wire and build fences more cheaply than they could by other methods. Even though wire fences in most cases are cheaper, the cost is still high. In 1910 it was estimated that the replacement cost of the existing fences in the United States would be 8.3 per cent of the total value of all farm property, 12 per cent of the value of all farm land, and 54.1 per cent of the value of all farm buildings (2).

Even with this seemingly high value, Lyman (3) reported in 1929 that from 25 to 50 per cent of existing fences, averaging about 30 per cent the country over, were inadequate to turn livestock.

The following statement by Miller (4) may give the reason for the poor condition of farm fences. "There are so many demands on the farmer's capital and labor that it is so easy not to provide for fences."

The cost of fencing varies with the topography, the condition of the soil, efficiency of labor, and type of fence being erected. The figures given by Kelley (5) in 1940, the only variables being the type of fence and method of setting posts, showed that from about 4 to 17 per cent of the total cost of fencing must be apportioned to labor. The labor rate used as a basis for these figures was $1.50 per day. Under the present conditions the percentage of total cost due to labor would probably be much larger than these figures indicate.

The purpose of this work is to develop a faster and cheaper method of setting fence posts.

CHAPTER II

ANALYSIS

In the state of Tennessee alone, between six and seven million wooden fence posts are used each year (6). Assuming that these posts could be set at the rate of ten per hour, it would take about 650,000 hours to set them. If the number of posts set per hour could be increased by fifty per cent, it would mean an annual saving of roughly 220,000 hours of labor in Tennessee.

Kelley (5) observed that approximately twice as much time was spent digging holes and setting posts as was spent driving the posts.

The recent development of a power driven auger has greatly reduced the labor necessary for erecting a fence when the posts are set in dug holes. When this method is used, the posts must still be tamped in by hand. This operation alone normally takes approximately as much time as driving the post by hand.

Driving posts by hand was the preferred method of setting fence posts on the Kingsley Dam Irrigation Project near Keystone, Nebraska (7). One hundred and forty-one miles of fence was constructed along the supply and lateral canals running from the reservoir to the irrigated farm lands. The creosoted wood line posts for this fence were driven by two-man crews, each using a 50 lb driver. These drivers were made from a 32 in section of 4 in pipe, one end being closed and weighted. Handles were fastened in such a manner that two men could work together in the driving operation.

It is believed that a machine working on the principle of a pile driver can be attached to a farm type tractor and greatly speed up the setting of fence posts. The use of such a machine would also require a less arduous type of labor.

Previous Power Operated Fence Post Drivers

A tractor powered fence post driver (Fig. 1) was built for J. N. Odom, University of Tennessee General Superintendent of Farms, by the University of Tennessee Agricultural Engineering Department in the early part of 1950. This post driver was designed for a large crawler type tractor. The driving head was made from a 4-1/2 ft section of 8 in pipe, one end being closed and equipped with an eyebolt to receive the cable. Additional steel was welded on near the bottom of the pipe to lower the center of gravity and to increase the weight. This made the total weight approximately 310 pounds.

Posts were driven by lifting the driving head with the winch and allowing it to drop. The length of drop (8) was about 3 ft, creating an impact energy of about 900 ft-lb if friction is neglected. The number of strokes required varied with the resistance of the soil, the range being from 5 to 12 strokes to set the post, 4 in by 4 in, 2 ft deep. A uniform post height of 4-1/2 ft was obtained by driving each post until the bottom of the driving head touched the ground.

Since this machine was not equipped with guides, it was necessary for a man to stand on the ground and guide the driving head onto the post. This practice was the cause of constant nervous strain on both the tractor operator and the man guiding the driving head because a mistake

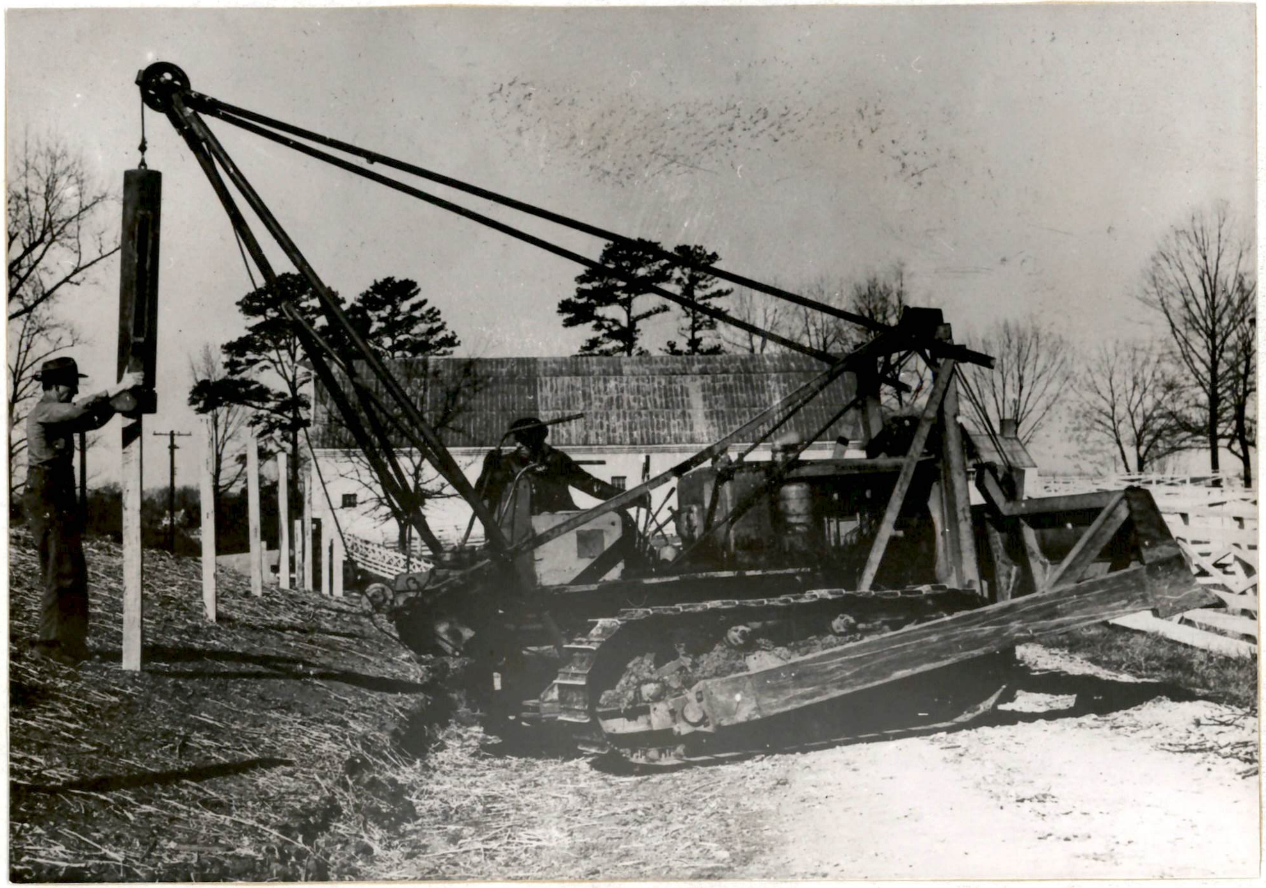


Figure 1
Fence Post Driver Mounted on Crawler Type Tractor

by the tractor operator could have caused serious injury to the other.

Several hundred posts were set with this machine and the only sustained time check (8) showed that 120 posts were set in 7 hours. The best record was made when 30 posts were set in 90 minutes.

These results indicate that the use of a similar machine mounted on a farm type tractor might be feasible.

Functional Requirements

In order for such a machine to function as desired, it should meet the following requirements:

1. The driving head must have sufficient weight to drive the post without an excessive number of blows.
2. It must not be too heavy to be operated by the farm type tractor.
3. It must not make the tractor unstable on slopes normally considered safe for tractor operation. A slope of 20 per cent was assumed.
4. The driving head must swing freely to allow the post to be set vertically when driven on sloping ground, yet it should not swing once the driving operation has started or when the tractor is in motion.
5. The driving head should clear the ground by about 7 ft to allow a 7 ft post to be set under it.
6. The mechanism that raises and lowers the driving head must be simple and easy to operate.

7. It should be designed to stop and hold the driving head at any elevation in its range of operation.

8. It should be easily attached to and removed from the tractor.

The cost of such a machine is also a factor because of the small number of days of annual use.

CHAPTER III

DESIGN AND CONSTRUCTION

The driving head of the previously described machine proved to be satisfactory and was used as a basis for the design of this machine.

A model TO-20 Ferguson tractor was available, and since this is a popular type of tractor, it is the type for which this post driver was designed.

After a study of the functional requirements of the machine and the capacities of the tractor, it was decided that a cable and winch for lifting the driving head would be satisfactory.

If the winch were mounted directly on the power take off (hereinafter referred to as pto) shaft of the tractor, it would greatly simplify the construction. This would mean lower cost because additional shafts, bearings, and supports would not be needed.

From the tractor service manual (9), it was found that the pto speed is 0.36 times the engine speed and that the lowest governed engine speed is 400 rpm. At this engine speed the pto speed is 144 rpm. It was decided that the lifting speed of the driving head should be in the range of 2 fps. At the pto speed of 144 rpm a drum diameter of 3 in will give this velocity. The 1.13 hp required under these conditions is within the range developed by the engine.

Cable

In order for a cable to bend around a 3 in diameter drum without creating excessively large bending stresses, the cable must be small and flexible. It was decided that a 5/32 in airplane cable with a breaking strength of 2600 lbs should be tried.

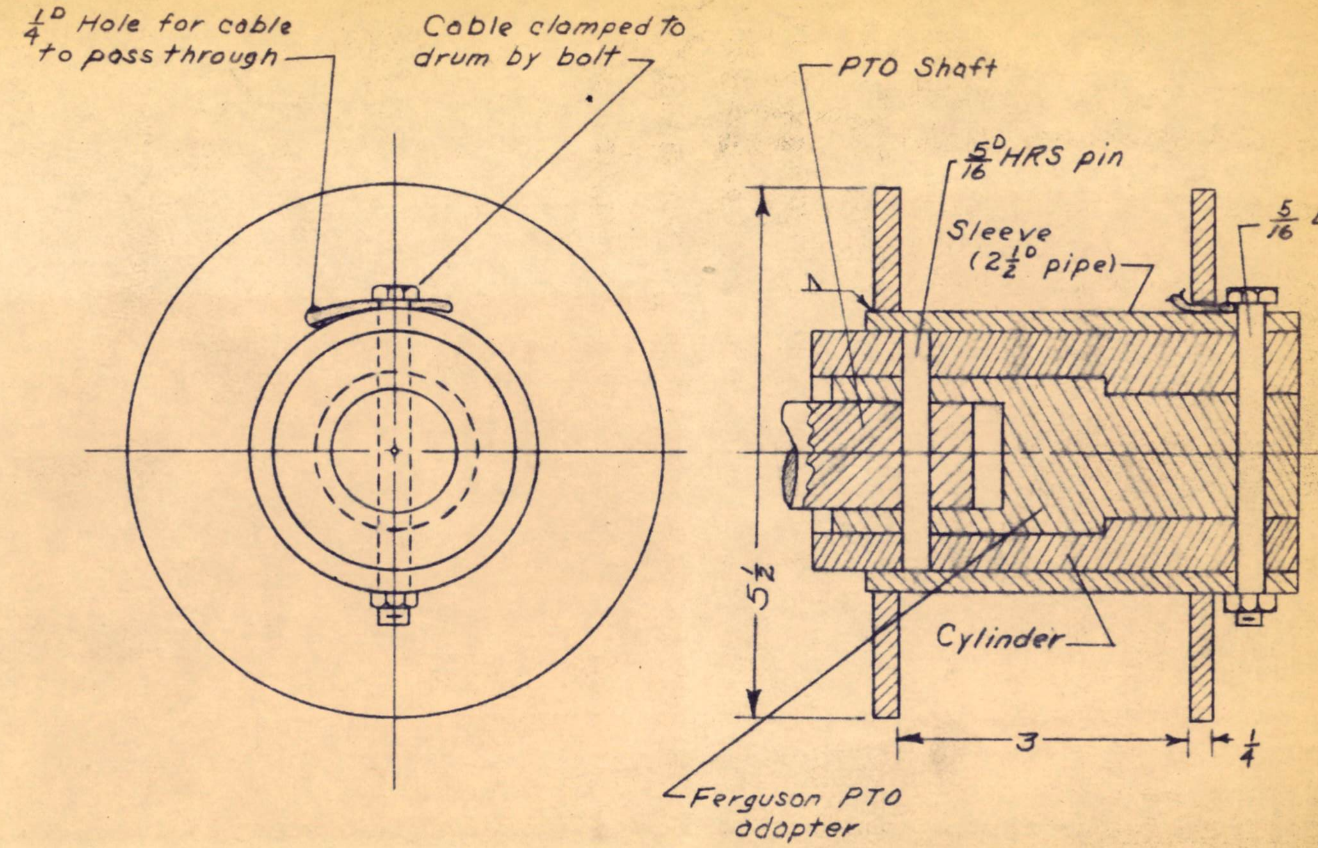
Some assumptions were necessary to calculate the maximum load on the cable. It was assumed that there was enough slack in the cable to allow it to attain the calculated velocity of 2 fps before the driving head began to move, and that there was no slippage in the clutch. It can be shown that the impact load created under these conditions is 470 lbs, making the total load on the cable 780 lbs. The factor of safety is then 3.4.

Drum

The Ferguson tractor has a 1-1/8 in splined pto shaft, on which the drum is mounted, extending 2 in beyond the bearing. This shaft has a 5/16 in diameter hole 5/8 in from the outer end. An adapter, consisting of a 1-1/8 in splined sleeve and a 1-3/8 in splined shaft, is made by the tractor manufacturers to increase the pto shaft diameter to 1-3/8 in, an ASAE standard size.

A drum capacity of 9 ft, or approximately 12 turns on a 3 in diameter drum, is sufficient for the conditions under which this machine is designed to operate. Since other uses requiring more cable capacity might be found for such a drum, the drum was made 3 in long with flanges 1-1/4 in high (see Fig. 2). A 1/4 in hole was drilled in the outer flange so the cable could be passed through it and clamped by the bolt holding the sleeve to the cylinder.

The drum was made in two pieces so it could be mounted near the bearing to keep the bending moment on the pto shaft at a minimum, and



Scale: $\frac{1}{2}'' = 1''$

Figure 2
Assembly View of Drum Showing Method of Attaching to Power Take Off Shaft

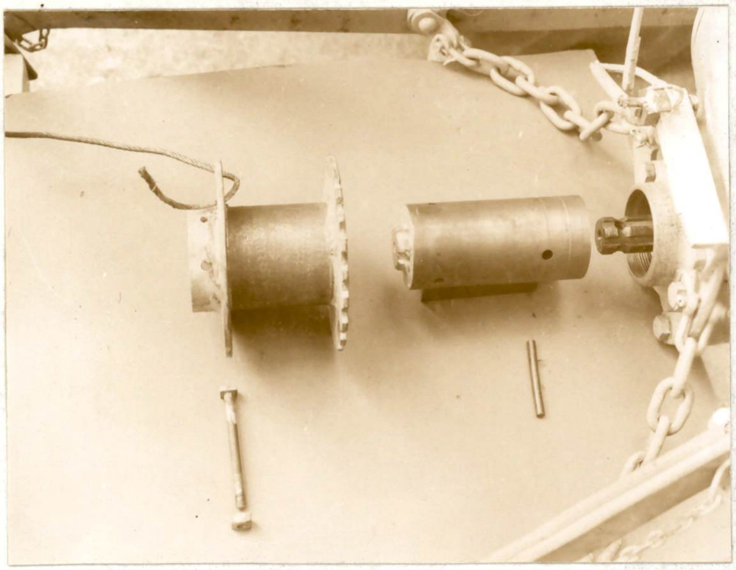


Figure 3
Disassembled View of Drum

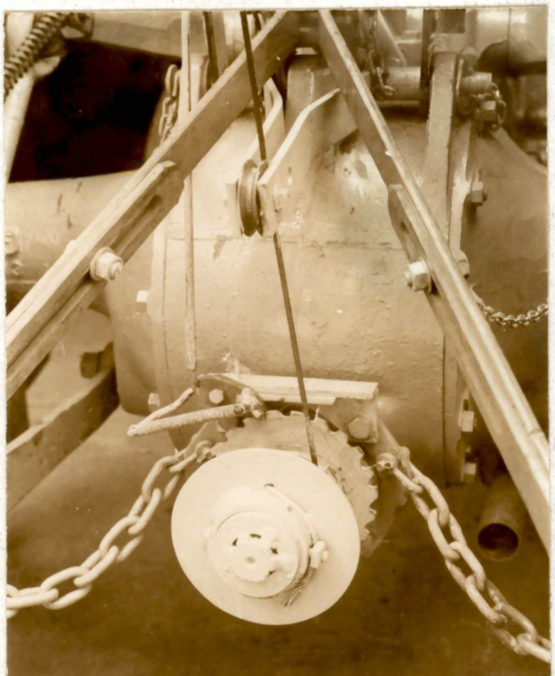


Figure 4
View of Drum With Pawl Engaged to
Prevent Counter-Clockwise Rotation

to allow the bolt which fastens it to the shaft to be set outside the flanges. This drum mounted on the pto shaft allows the cable to wind on it a maximum distance of 4 in from the bearing. This bearing was found to be satisfactory for this load by checking the rated load for a similar bearing in the New Departure Bearings Catalog.

If the cylinder that slips over the pto shaft were not splined, the entire load would be carried by the 5/16 in steel pin fastening it to the shaft. A failure of this pin could cause serious damage to the splined shaft. The pin could also be bent slightly and cause its removal to be extremely difficult. To avoid these possibilities the adapter mentioned previously was used. The cylinder was bored to fit over the adapter and a 5/16 in hole drilled through both cylinder and adapter.

It can be shown that the greatest unit stress will occur in the bolt that clamps the cable and holds the sleeve to the cylinder. Because this bolt is in double shear, it can be shown that a 5/16 in hot rolled steel bolt is sufficient to carry the load.

Since it is desirable to hold the driving head at any elevation in its range of operation, some kind of lock was needed to keep the drum from rotating. Under the operating conditions which will be encountered, the ratchet and pawl type should be satisfactory.

Ratchet teeth were cut on the inner flange of the drum and a pawl mounted above it as shown in Fig. 4. A lever was located near the driver's seat so the pawl could be easily engaged or released. An overcenter spring was used to hold the pawl in either position.

Framework

This tractor is designed for most implements to be mounted behind it. In order to make use of the sockets and pins normally used to attach equipment, it was decided that the boom should be mounted behind the tractor.

The sheave over which the cable passes should be mounted far enough away from the tractor to allow the driving head to drop freely on slopes of 20 per cent. It should also be high enough above the ground to allow the driving head 7 ft of vertical movement. Since the overall height of the driving head is 5 ft, the sheave hub should be about 12 ft above the ground. To meet these requirements the boom shown in Fig. 5 was designed so that the sheave was mounted 2-1/2 ft behind the tractor and 12 ft above the ground.

Because of its simplicity and light weight, the "A" frame type of construction was used. Assuming that each compression member carries half the maximum load, the force in each member is 650 lbs. A 1-1/2 in diameter pipe was found to be sufficient to carry this load.

The drawbar on this tractor cannot be used if the compression members are to be secured by the lynch pins because there is space only for the stabalizer bar and lifting arm between the drawbar hub and lynch pin. A drawbar, the same length as the original, was made by welding two 1-1/2 in by 1-1/2 in by 3/8 in steel angles to form a channel. A piece of cold rolled shafting 7/8 inches in diameter was welded to each end and holes to receive the lynch pins were drilled 2-1/2 in beyond the end of the channel to allow the compression member, stabalizer bar, and

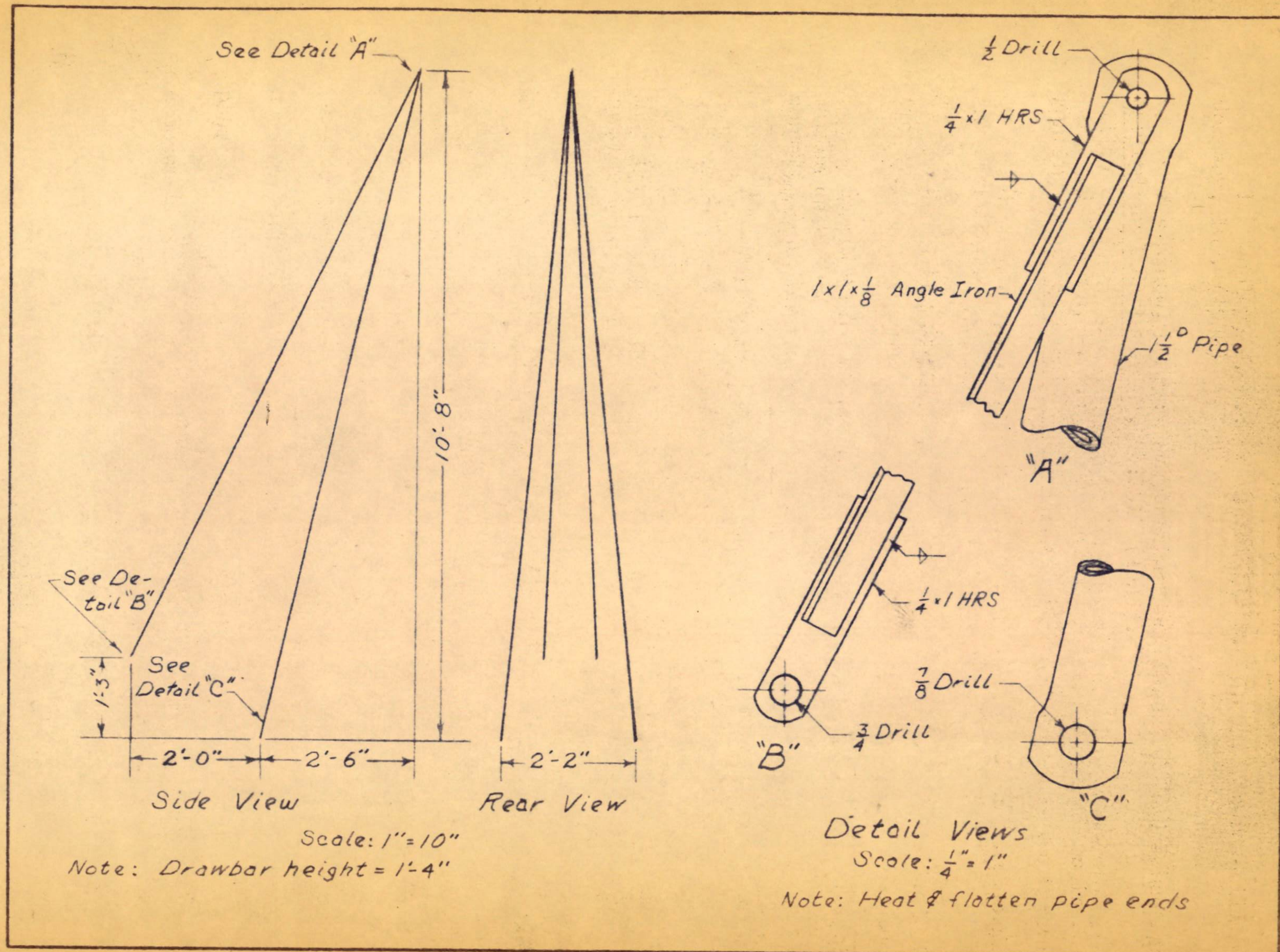


Figure 5
Details of Boom Construction

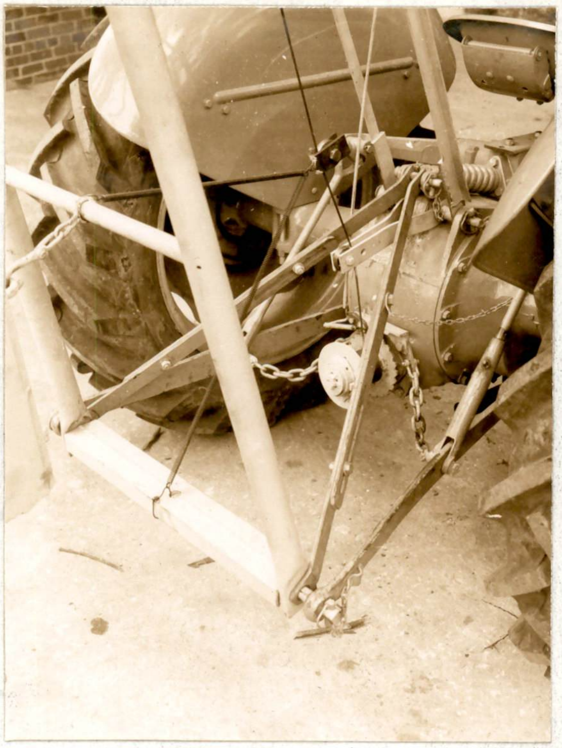


Figure 6
Method of Attaching Boom to Tractor

Figure 7
Completed Machine With Driving Head
in Transporting Position

lifting arm to be mounted and secured by the lynch pins (see Fig. 6).

Two tension members were used so this part of the boom would not interfere with the cable from the sheave to the drum. It can be shown that the maximum tension in each member, assuming that each carries half the load, is 200 pounds. A small cable would be sufficient for the tensile requirements, but these members should also be able to withstand a small compressive load created by the driving head swinging forward when the tractor is in motion. For these members 1 in by 1 in by 1/8 in angle iron was used.

Since these members are to be fastened to the tractor by a 3/4 in diameter pin, there would not be enough area left on each side of the hole in the angle iron to carry the load. To correct this, a 1/4 in by 1-1/4 in hot rolled steel strap 6 in long with a 3/4 in diameter hole drilled in it was welded to the end of the angle iron.

To prevent the driving head from swinging while the tractor is in motion, a cross-member with a hook attached to it was welded between the compression members. An eyebolt was welded to the front of the driving head so it could be secured to the hook and reduce the movement of the driving head.

Sheaves

An 8 in diameter sheave was mounted at the top of the boom to allow the driving head to be raised to its maximum height without striking the compression members. Because of the angle between the sheave and drum, it was necessary to use a guide sheave to feed the cable onto the drum. This sheave was supported by two 1/4 in by 1-1/4 in hot rolled steel straps mounted on the 3/4 in pin that fastens the tension members to the tractor.

Guides

If the post is not set firmly by the first blow and if there is any slack in the cable, the driving head may swing sidewise and cause the post to lean. To prevent this, two guide pipes one inch in diameter and 10 ft long were bolted to a universal joint which is suspended from the boom at the sheave hub (see Fig. 8). Two eyebolts spaced 2 ft apart, the lower one being 2-1/2 ft from the bottom, were welded on each side of the driving head for the guide pipes to pass through. With this arrangement the driving head should not swing after it is down over the post.

Figure 8
Universal Joint Used to
Fasten Guides to Boom

Figure 9
Lever for Hand Operation of Clutch

CHAPTER IV

PERFORMANCE

Since it will be used only a few days a year, it is assumed that this machine will be stored in a disassembled form. It can be attached to the tractor from this form by two men in approximately 10 minutes.

The posts used in the time tests were 4 in by 4 in varying in length from 6-1/2 to 7 ft. These were sharpened by splitting off each corner with an axe, leaving the bottom roughly diamond shaped. Only one or two blows per corner were required, allowing the post to be sharpened in approximately one minute.

In the first tests there was difficulty with the drum rotating after the driving head struck the post. This caused a backlash which had to be straightened out before the driving operation could continue. It was thought that a hand operated clutch lever would enable the operator to better control this backlash. The lever shown in Fig. 9 was made and attached to the tractor. This lever made the operation much smoother but it still required a skilled operator to stop the backlash.

In an attempt to keep the cable from becoming entangled on the drum during the backlash the following devices were tried:

A pipe for the cable to pass through, extending to within 1/2 in of the drum, was suspended from the straps supporting the guide sheave. This device was unsatisfactory because the cable pivoted about the bottom of the pipe as the drum spun backward and looped over the flanges, becoming badly entangled.

A shield to keep the cable from coming over the flanges of the drum was mounted inside the flanges. A horizontal slot 1/2 in by 2 in was cut in the shield to allow the cable to pass through. This shield proved to be unsuccessful because the cable came through the slot as the drum unwound and looped about it.

An idler sheave was mounted on two springs as shown in Fig. 10. These springs pull the idler sheave and cable downward and over the guide sheave when the driving head strikes the post, thereby taking up the slack cable unwound from the drum.

Some difficulty was had in keeping the post vertical as it was being driven. This difficulty was caused by the post leaning inside the driving head until it was touching the top on one side and the bottom on the other. A smaller diameter driving head would reduce this tendency, but in order to eliminate it, the driving head would have to be so small that it would be impractical.

Posts were driven vertically by having a man, equipped with a hook to go in the end of the guide pipes, pull the driving head in the opposite direction to which the post was leaning.

The tests performed with this machine indicate that two men should be able to set posts at the rate of 15 to 20 per hour.

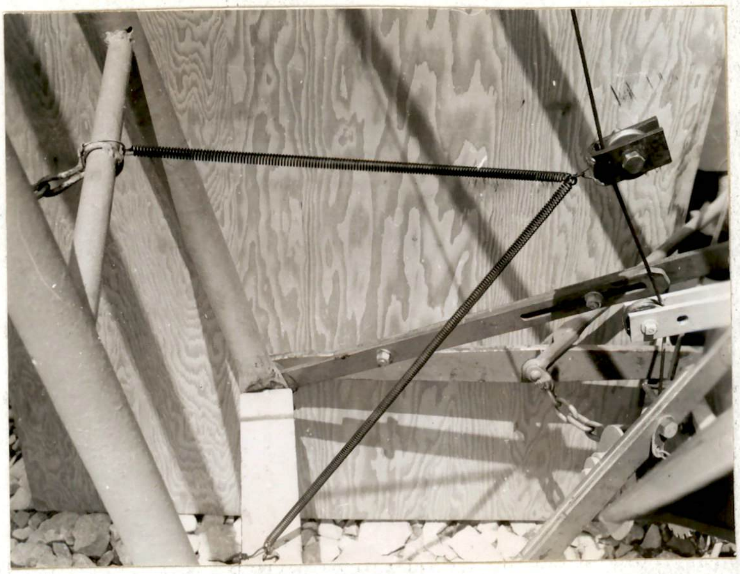


Figure 10
Spring Mounted Idler Sheave
to Take Up Slack in Cable

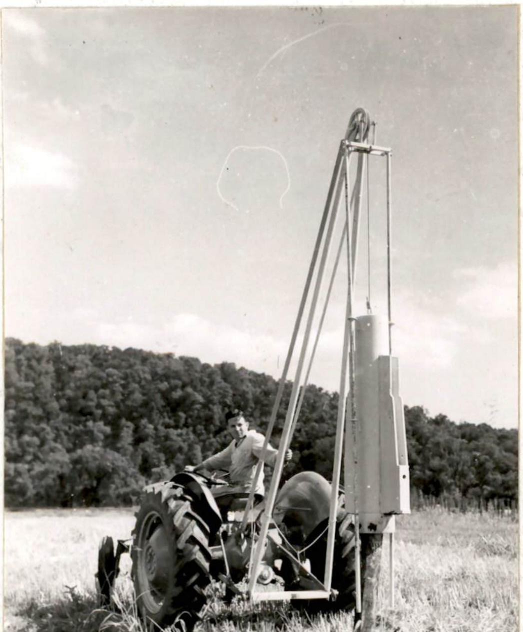


Figure 11
Post Being Driven by Tractor Power

CHAPTER V

DISCUSSION

A further investigation of this subject should include the possibility of making the driving action automatic. The principle used on the board drop hammer probably could be used for this. The hydraulic system found on many tractors also should be investigated as a means of operating the driving head.

A mechanical sharpener for the posts should be investigated. Such a device to sharpen round posts could be made similar to a pencil sharpener and mounted on the pto shaft. If this were done, the bracket for holding the post could be mounted on the drawbar.

Mechanical methods of keeping the post vertical while it is being driven should be developed. A concave surface opening downward in the top of the driving head might be used in conjunction with a rounded cap set on top of the post. The use of this should always bring the post to the center of the driving head and keep it vertical.

CHAPTER VI

SUMMARY

The number of wooden fence posts used annually in Tennessee was reported. The various methods of setting fence posts were discussed and compared. A fence post driver mounted on a crawler type tractor was described. The functional requirements for a fence post driver mounted on a farm type tractor were listed and studied.

The post driver was built and mounted on a Ferguson tractor. A drum was mounted on the power take off shaft so that the driving head can be raised and dropped by engaging and disengaging the tractor clutch.

Tests made with this machine indicate that its use is feasible.

The possibilities of mounting such a machine on the farm type tractor were not exhausted and it is recommended that further studies be made.

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