MECHANICAL DEVICE FOR CLIMBING PALM TREES

by

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INTRODUCTION

The present method of harvesting palm tree crops in Nigeria is hazardous, slow and inefficient. The farmers who now harvest the palm tree crops use bush vines as shown in Plate I as the only device to climb the palm trees. Many farmers have had fatal falls off the trees, and the few who survived such accidental falls are permanently crippled.

In recent years the number of farmers that harvest Nigerian palm trees crops has steadily declined, and the production of palm tree produce has substantially decreased. The loss in this agricultural production will probably continue to increase because many young farmers are reluctant to learn the traditional art of climbing and harvesting the palm trees. The farmers want to see the harvesting of palm trees mechanized.

The use of hydraulic buckets which are mounted on large mobile units will not be suitable because the palm trees in Nigeria are not cultivated, but grow on rough terrain which will not be suitable for operating large mobile vehicles. It appears that the development of a simple portable device which is capable of conveying a farmer to the top of a palm tree and safely bring him down may be useful to the Nigerian peasants, and save some of the crops that are now lost.

The probable economic contribution to Nigeria of a portable climbing device has been the primary reason for the project: the development, design and construction of an experimental mechanical device for climbing palm trees.

EXPLANATION OF PLATE I

A view showing the traditional method of climbing palm trees. The farmer is using a bush vine to support himself.

PLATE I

REVIEW OF LITERATURE

There is no known literature on a mechanical climbing device at the time of doing this project. Although several methods of harvesting various crops which are produced by trees have been at least partially mechanized, there is no known self-propelled mechanical device which is attached to the tree for lifting an operator to the top of a palm tree and bring him down.

PRELIMINARY STUDY OF PALM TREE PHYSICAL CHARACTERISTICS

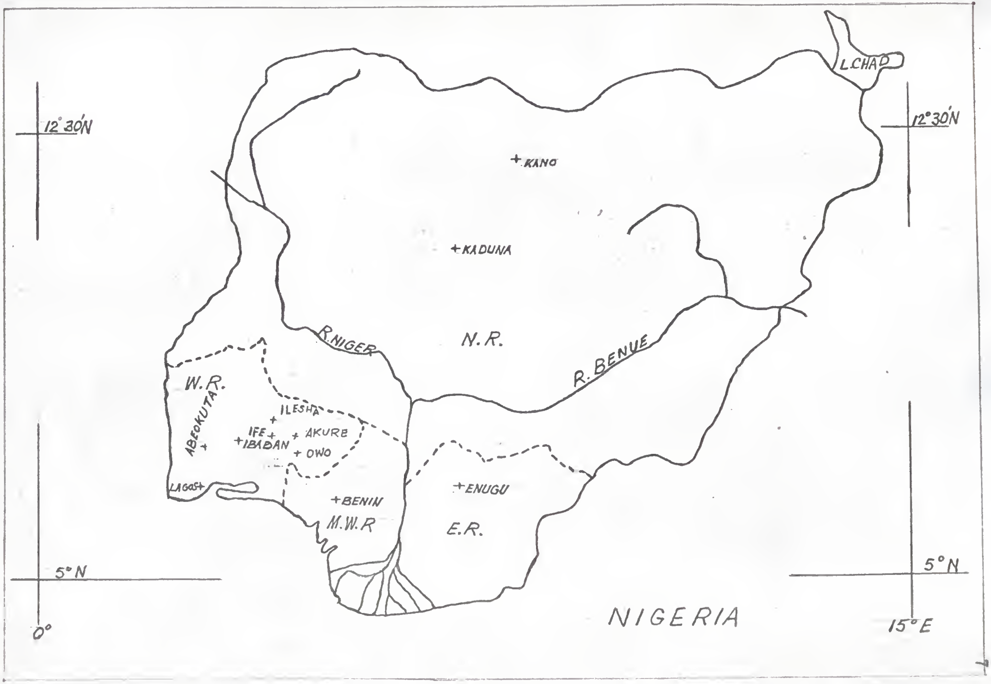
The Ministry of Agriculture and Natural Resources of Western Nigeria provided valuable information on the measurements of the girths for 170 palm tree samples. The samples came from Ibadan, Ife, Ilesha, Okitipupa and Owo districts as shown in Fig. 1. The number of palm trees which was sampled is relatively small compared to the total population of the palm trees in Nigeria; however, the data gave an important guide to the basic design of the mechanical device for climbing palm trees.

Each palm tree was measured at intervals of four feet, from the base to the top. The data from the five districts was plotted on graph paper to estimate the distribution of the girths at the various intervals as shown in Fig. 2. The taper was estimated for typical palm trees from each district. The variation of the circumference is from 59 to 25 inches, and the average taper of a 40-foot tree is approximately 0.07 in. per foot. The device is large enough to mount on palm trees that have a maximum circumference of 76 inches (24-in. dia.), and this represents 95.9% of the sample.

The depth of the scars varies from 1/2 to 1 1/2 inches, and the length of the scars is from 4 to 6 inches. The characteristic roughness and irregular holes of the bark of the palm trees will give good traction to rubber tires.

EXPLANATION OF FIGURE I

A map of Nigeria showing the area (W. R. Western Region) where the sample of 170 palm trees originated, and the southern regions : (W.R. Western Region; M. W. R. Mid-west Region; E. R. Eastern Region) of Nigeria where palm trees normally grow.


12° 30'N
12° 30'N
L.CHAD
+ KANO
+ KADUNA
N.R.
R.NIGER
R. BENUE
W.R.
ABEOKUTA +
ILESHA
IFE +
+ IBADAN
+ AKURE
+ OWO
LAGOS +
+ BENIN
M.W.R
+ ENUGU
E.R.
5°N
5°N
0°
15°E
NIGERIA

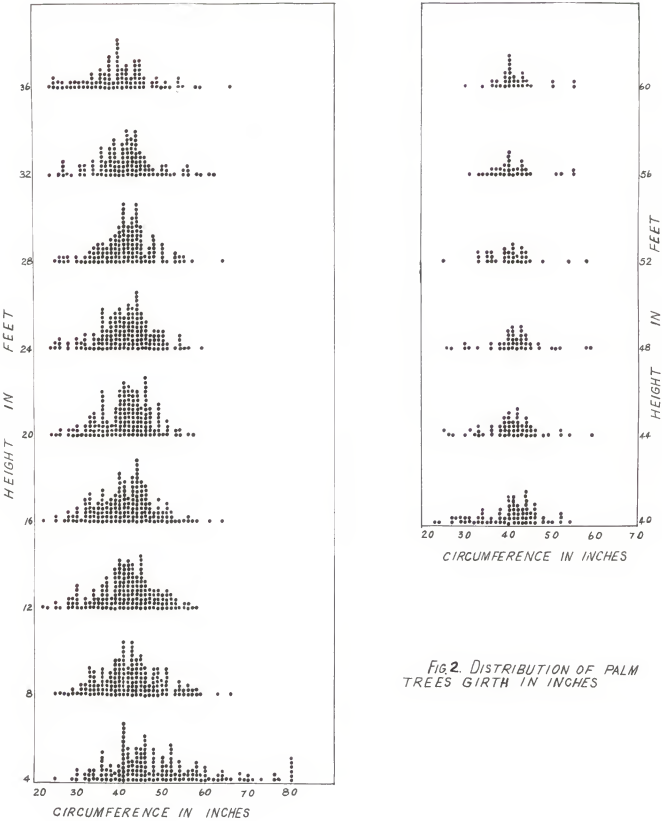


FIG. 2. DISTRIBUTION OF PALM TREES GIRTH IN INCHES

PROCEDURE

Design Guides

The following criteria were observed during the design:

1. The maximum weight of the machine without operator not to exceed 300 lbs.
2. The machine to be able to transport one operator weighing up to 200 lbs.
3. The machine to be self-propelled.
4. The device to be easy to fasten to palm trees.
5. The speed of climbing to be 15 feet per minute.
6. The operator to be able to move around the top of the tree on the machine.
7. The operator to be able to lock the device safely to the tree.
8. The wheels to be adjustable to large and small palm trees.
9. The device to have reversible travel motion.
10. The machine to have a safety locking mechanism to prevent the device from slipping.

Preliminary Design Study

The following are the possible types of mechanical device for climbing palm trees:

1. Hydraulic buckets mounted on tractors or mobile unit.
2. Portable winch at the base of the tree and cable permanently fastened to the top of each tree.
3. Self propelled and portable mechanical device which climbs the tree itself.

The third suggestion will probably be the most suitable for the conditions on Nigerian farms.

Several models of the climbing device for palm trees were constructed, mounted on 8-inch pipe, and were observed to see how stable each model was. The observation strongly suggested the arrangement of the experimental mechanical device for climbing palm trees.

The rectangular shape made the design simple and easy to construct. The gross weight of the device should not exceed 500 lbs., and the horse-power requirement is computed on this weight. The power requirement is approximately 0.397 horse-power, and the rate of lift is 15 ft. per minute. The slow speed is achieved by the use of a Briggs and Stratton four-cycle gasoline engine (6:1 gear-reduction), and Morse Chain worm gear reduction (50:1 gear-reduction) and the reducer sprocket to wheel drive sprockets (3:1 gear-reduction). This is a total of 900:1 gear-reduction. Calculations for power requirement and other necessary calculations are shown in Appendix B.

The gasoline engine and worm gear are connected by the V-belt reversible clutch. The power is transmitted to the wheels through chains and sprockets. The four wheels are to be driven in the first field test, but the rear or the two pressure wheels can also readily be driven if the traction is not sufficient.

The wheels and the sprockets are keyed to a 1 inch steel shaft, and the ends of each shaft are supported by the self aligning pillow block bearings. The keyways are cut long enough to enable adjustment of the wheels for small or large circumference palm trees. Part of the frame and wheel assembly is shown in Plate II. The component parts are not necessarily shown in their proper respective position. Plate III shown the engine, gear reducer, hydraulic cylinder and other component parts. A listing of the component parts and sequence of drawings for machine assembly is shown in Appendix C.

The front wheel assembly is pivoted to enable the machine to ride over humps and other irregular spots on the trees. The rear wheel assembly provided necessary pressure to support the weight of the machine and the pressure for traction. The pair of compression springs will support a pressure of 200 lbs./in. and each rear wheel is always under compressive force when the device is mounted on the trees.

The pressure wheel assembly has two adjustments: size and pressure adjustments. The tree size adjustment is the changing of the position of the rear assembly in the increment of 2 inches and multiples of 2 inches to match the device to any palm tree in the designed range of 8 to 24-inch diameter trees. The operator has to move the rear wheel assembly in the desired direction and fasten it with pins. The pressure adjustment is made by applying sufficient hydraulic pressure to the rear wheel assembly; the wheel frame has a telescoping arrangement, and the frame is moved forward gradually until a minimum pressure is applied. The hydraulic system will

EXPLANATION OF PLATE II

A view of the wheel assembly, the frame, compression springs. The component parts are not necessarily shown in the proper respective position.

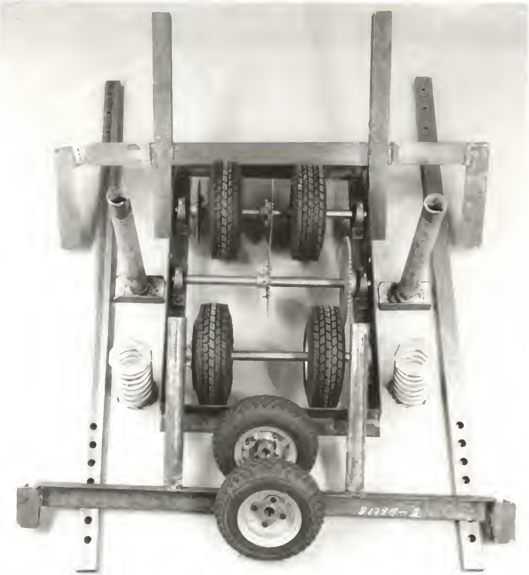


PLATE II

EXPLANATION OF PLATE III

A view of the gasoline engine, worm gear, speed reduction unit, sprockets and roller chains.

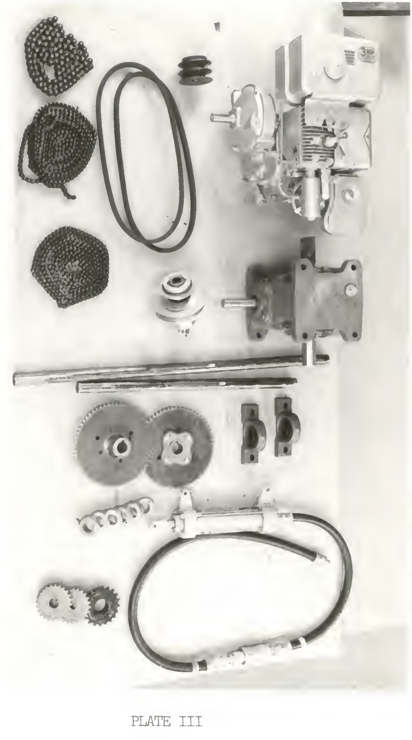


PLATE III

develop from 0 to 8500 psi. The device will begin to move up the tree trunk when the compressive force is large enough to support the weight and give traction. When the palm tree has a large taper, the device will not travel up the tree until more pressure is applied to the rear wheels.

Testing of Mechanical Device for Climbing Palm Trees

The following points are to be observed during the test:

1. The traction of four-wheel drive and six-wheel drive respectively.
2. The influence of speed on the stability of the device in operating position.
3. The minimum supporting compressive force that will hold the machine on the palm tree.
4. The minimum pressure that will cause traction on the wheels and the movement of the device.
5. The minimum pressure in the tires, and satisfactory pressure for normal operation.
6. The effects of low and high pressures of the tire on tire traction.
7. The operation of the V-belt clutch, and the control.
8. The effect of the worm gear as a locking unit.
9. The general stability of the device and the position of the operator.
10. Operator acceptance.

The ideal testing condition for this machine is on palm trees; the tapering of the tree, the hardness and roughness of the bark which are unique characteristics of the palm trees cannot be readily simulated; however, tests on other trees have provided some information about the probable performance of the device, and further tests will be made on Nigerian palm trees.

The basic design of the device uses six wheels, with four of the wheels being driven, and the other two wheels acting as idlers. The mechanical device for climbing trees is shown attached to a log in Plate IV.

EXPLANATION OF PLATE IV

A view of the mechanical device for climbing palm trees mounted on a tree during testing in Manhattan, Kansas, U. S. A.

PLATE IV

DISCUSSION

Preliminary Design Study

The experimental mechanical device for climbing is designed to carry only one operator to the top of the palm tree, provide the platform for the operator and bring him safely down after harvesting the palm fruit. The fruit is not carried on the device, but is allowed to fall to the ground.

Two small models were constructed, and mounted on 8-inch pipe, and the stability was observed before the present full size experimental machine was built. There were four basic units in the machine attached to the platform frame, the vertical drive wheel assembly, the pressure wheel assembly, the hydraulic system, and the power transmission assembly.

The pressure wheel assembly was fastened to the rectangular tubing side member with pins, and this made possible adjusting the device to the size of each tree in the designed range of 8-24 in. diameter. The compression spring on the telescoping members of the pressure wheel assembly enabled all the wheels to ride over high spots on the bark of the trees.

The hydraulic system forced the idler wheels against the tree after the device was put around the tree. The hydraulic system provided easy control for the device, and it consisted of the high pressure hose, with quick disconnecting coupling, the single-acting cylinder, and all-position hydraulic hand pump.

The computed power requirement was 0.397 hp, but a 3 hp air-cooled 4-cycle gasoline engine was used to run the machine. The worm gear, the reversible V-belt clutch, the chain and sprockets were used in the power transmission. All the drive wheels were keyed to the shafts, and each shaft was supported by the self aligning bearings.

Testing of the Mechanical Device

A dry cottonwood tree with a base diameter of about 20 inches was cut to about 10 feet long, and was brought into the laboratory. It was braced at the base and supported at the top by guy wires. It was not possible to make all the necessary observations in the test, but the primary question as to whether the machine for climbing palm trees would ever climb was proven. The device did climb.

The device was assembled on saw horses, and the cottonwood log was placed in the middle of the device. The device was adjusted to the diameter of the "simulated palm tree"; the hydraulic pressure was gradually applied to the pressure wheels, and the worm gear first was operated by hand. The manual operation of the gear revealed serious weakness in the compressive members of the platform frame. The pressure wheel assembly and the transmission assembly parts of the frame were under severe twisting stress, and some of the angle iron members were bent. The structural weakness was temporarily corrected by bracing of the stressed members to the drive wheel frame with common wire. The correction made the testing possible.

The following encouraging results were observed:

1. Four wheels provided enough traction to cause the machine to climb.
2. The minimum hydraulic pressure of 375 psi supported the weight of the machine (320 lbs.) and caused sufficient traction for climbing.
3. Pressure of 22 to 23 lbs. in the tires had the greatest surface contact between the tree and the tires.
4. The V-belt clutch made effective control possible; ascent and descent motions, and stationary position of the machine on the tree.
5. The worm gear provided an effective locking mechanism for holding

the device at any place on the tree.

6. The rate of ascent was approximately 13 ft./min.

Weaknesses in the design were that:

1. There was structural partial failure in the platform frame.
2. The stability was poor when the device was in a locked stationary position on the tree.
3. The fastening of the device around the tree was slow.
4. The weight of 320 lbs. was not portable.

CONCLUSION

The result of the laboratory test of the experimental climbing device strongly supported the originally conceived idea of conveying an operator on the mechanical device that is fastened around palm trees or similar trees. The present experimental machine needs redesigning and refinements to:

1. Strengthen the members that are in tension.
2. Make easier fastening of the device to the palm tree.
3. Reduce the weight of the device by the use of high strength aluminum for the frame.
4. Add a control valve in the hydraulic system to prevent excessive pressure on the wheels.
5. Test the effect of a rigid wheel assembly as compared to the present pivoting drive wheel assembly.

Further tests of the device are planned in Nigeria, when some of the present flaws in the design of the mechanical device for climbing palm trees will be corrected.

ACKNOWLEDGMENT

This project has been made possible by the kind efforts and encouragement of my professor and the officers of the Rockefeller Foundation and Ministry of Agriculture and Natural Resources (W. Nigeria). Dr. G. H. Larson, Professor and Head, Department of Agricultural Engineering strongly recommended the project to Mr. Jesse Perry, the fellowship officer of the Rockefeller Foundation, for the grant to buy the materials. The Rockefeller Foundation of New York, U. S. A. made a grant of $500.00 for the materials.

The people of Nigeria and the Permanent Secretary and Controller of Agricultural Services (W. Nigeria) deeply value the grant from the Rockefeller Foundation.

Most of the faculty of the Agricultural Engineering Department offered valuable suggestions and guidance in the development, design and construction of the machine; Professor Gustave E. Fairbanks, my faculty and major advisor, constantly gave constructive criticisms of my work, offered guidance and all necessary engineering advice. Professor Paul N. Stevenson also offered valuable suggestions in the development and design of the machine, and he guided the entire laboratory phase of the project.

The Department of Statistics assisted in the analysis of the raw data of the palm trees, and the Department of Applied Mechanics permitted the use of their instruments to measure compression spring constant.

The Chief Agricultural Extension Services Officer (W. Nigeria) and some of his field staff collected the basic information about the palm trees in Western Nigeria.

The contribution of everyone mentioned above was important to the project, and the recommendation, suggestions, guidance and advice are sincerely appreciated.

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APPENDICES

APPENDIX A

Table I. Circumference Measurements of Palm Trees at Various Heights in Inches. Source: Ibadan (East)

Tree No	Height of Tree in Feet															
	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64
A 1	44	41	37	36	36	34	39	36	37	34	33	33	33	35	34	
2	36	31	29	33	34	34	35	34	32	33	33	42	35	31	30	
3	45	41	41	43	42	43	43	46	46	40	39	40	41	36	37	
4	48	43	43	41	41	43	43	43	36	48	45	44	35	34	39	
5	48	40	40	44	45	42	44	42	38	44	44	44	39	40	40	
6	41	33	39	43	42	43	43	45	40	52	36	38	35	40	37	
7	46	48	45	44	42	46	44	46	48	42	42	41				
8	41	39	40	39	36	44	43	43	38	35	34					
9	50	53	48	45	48	47	44	43	45	44	41	40				
10	51	48	45	48	37	46	41	38	44	40	38					
11	41	45	47	36	39	40	44	45	40	38						
12	44	43	44	39	42	36	35	35	34	34	39					
13	44	43	42	43	42	44	43	41	39	36	42	40				
14	45	39	40	36	36	47	47	36	34	34						
15	46	41	43	40	41	38	42	41	44	44						
16	50	51	47	49	45	42	41	42	40	38	39					
17	34	30	30	34	32	31	43	42	38	40						
18	43	40	37	37	35	30	33	35	29	27	25	26	25	16		
19	38	40	42	40	38	36	34	32	42	38	36	31				
20	32	34	32	32	40	39	42	38	35	29	32	30				
21	35	33	23	34	42	43	40	34	32	28	27	27				
22	37	38	42	43	41	39	38	37	34	32						
23	36	34	22	22	18	16	15	12	13	12	14	12				
24	38	35	34	32	30	24	26	27	25	29	26					
25	43	34	32	36	44	44	41	36	37	34	31					

Table II. Circumference Measurements of Palm Trees at Various Heights in Inches. Source: Ibadan (Moor Plantation)

Tree No.	Height of Tree in Feet															
	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64
B 1	55	43	42	24	33	32	36									
2	59	41	42	45	47	49	53									
3	57	39	31	32	51	48										
4	55	49	43	44	44	36	41	43								
5	52	41	42	38	36	42	36	41	42							
6	60	50	43	40	40	41	40	42	40							
7	41	43	44	39	38	39	39	39	34	40						
8	58	50	46	44	47	49	47	47	50							
9	49	43	37	44	39	42	41									
10	53	50	44	47	43	50	53	62								
11	52	44	45	48	47	49	45	49								
12	45	45	40	40	43	40	43	43	45							
13	40	40	39	42	43	39	46	43	44							
14	45	45	40	36	46	41	40	41								
15	51	48	42	44	40	38	40	40	42							
16	45	40	40	43	43	42	41	40	40	40	59					
17	52	45	42	41	41	44	42	42	40	43	44					
18	44	41	44	41	42	40	40	39	40							
19	46	41	38	38	41	39	39	39	49							
20	29	33	43	36	30	40										
21	58	44	45	44	44	41	45	51	58							
22	84	58	54	47	43	44	53									
23	66	51	49	46	46	47	47	46	51							
24	44	43	45	41	44	42	39	38	38							
25	81	66	52	48	49	37	45	50								
26	38	36	36	30	24	18										
27	40	39	39	38												
28	54	45	44	41	40	38	38	36								
29	44	49	49	45												
30	56	54	52	51												

Table III. Circumference Measurements of Palm Trees at Various Heights in Inches. Source: Ife

Tree No.	Height of Tree in Feet															
	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64
C 1	59	56	55	47	46	48										
2	43	42	45	40	39	41	44	36	40	41	40	47	48	51		
3	46	37	43	47	47	46	47	50	55	54	52	50	54	52	50	
4	70	51	58	64												
5	56	54	47	61												
6	41	42	39	45	46	44										
7	45	46	46	49	47	47	44	44	45	44	43	52				
8	58	39	41	36	46	54										
9	69	54	53	45	49	50	57	59								
10	60	44	46	49	49	44	45	44	54							
11	80	51	49	51	49	51	48	50	49	46	48	51				
12	64	41	41	39	40	43	41	44	41	49						
13	52	41	36	37	34	38	40	48								
14	80	46	45	42	43	44	57	46								
15	73	47	43	46	46	44	43	55								
16	76	49	50	46	41	38	37	42	35	46						
17	82	41	41	42	45	48	48	51								
18	76	54	51	52	45	50	48	61								
19	60	49	36	45	38	36	44	37	44							
20	60	53	51	50	46	44	45	52	66							
21	58	44	53	47	34	45	50	44	45	44	49					
22	65	47	41	46	41	39	43	41	39	41	39	44				
23	64	36	39	38	39	40	39	41	40	39	36	59				
24	63	46	44	42	35	39	41	39	51							
25	51	34	37	38	39	36	35	36	34	38	41					

Table IV. Circumference Measurements of Palm Trees at Various Heights in Inches. Source: Ife.

Tree No.	Height of Tree in Feet															
	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64
D 1	41	34	48	46	36	44	44	43	41	48	43	41	36	40	40	
2	39	43	43	42	40	40	41	41	41	42	38	40	40	38	40	
3	41	40	40	41	41	41	41	40	40	41	41	41	41	40	40	
4	44	45	45	46	46	45	45	45	46	46	46	45	44	44	44	
5	48	48	51	50	54	54	48	48	48	45	42	41	41	40	40	
6	40	35	34	37	35	38	34	44	39	37	38	36	37	37	36	
7	54	49	48	54	46	48	48	44	46	41	44	47	43	43	43	
8	41	37	39	38	36	40	39	39	40	46	40	41	41	41	41	
9	45	44	45	41	44	45	45	43	45	36	42	41	33	36	36	
10	46	46	45	44	44	45	44	44	44	44	43	43	45	44	44	
11	50	48	47	46	46	45	45	45	44	44	44	45	44	43	43	
12	48	45	45	43	42	41	44	45	41	40	40	43	33	33	38	
13	46	45	45	44	44	42	42	44	42	42	44	44	43	43	41	
14	48	46	46	45	45	45	44	44	45	44	44	43	43	42	42	
15	46	46	44	44	44	45	45	44	44	45	45	43	43	42	42	
16	62	50	50	52	52	55	55	56	52	50	46	40	40	39	39	
17	44	39	39	39	39	38	36	39	38	41	39	40	39	37	40	
18	36	38	38	33	33	34	32	32	30	33	33	43	43	43	43	
19	42	36	33	30	37	36	36	36	33	30	30	36	36	38	39	
20	52	44	44	40	43	42	42	43	43	42	39	36	36	39	43	
21	42	36	36	40	40	39	38	41	37	36	31	30	42	45	45	
22	48	40	40	41	43	43	41	41	40	41	41	38	39	39	39	
23	48	42	41	41	41	44	44	44	43	43	42	42	41	41	41	
24	42	42	41	43	43	44	44	43	43	43	42	42	40	40	40	
25	42	39	39	43	43	43	42	42	42	40	40	39	39	40	40	

Table V. Circumference Measurements of Palm Trees at Various Heights in Inches. Source: Ilesha

Tree No.	Height of Tree in Feet															
	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64
E 1	42	41	40	35	30											
2	41	38	49	51	49											
3	45	41	43	44	49	45	42	37								
4	45	44	42	49	37	45										
5	36	36	37	40	41											
6	41	38	41	40	40											
7	46	43	37	33	40											
8	47	45	43	40	41	41	43									
9	37	34	33	37	40	43										
10	42	46	40	39	33	35										
11	52	43	39	41	41	38	37									
12	46	44	40	45	42	46	46									
13	43	43	41	42	39	41	38	42	45	45	45	43	42			
14	42	42	41	39	43	42	42	39	41	41						
15	33	33	35	35	37	37	37									
16	36	33	34	33	34	36	35	37								
17	41	39	35	35	37	36										
18	41	37	34	33	45	42	41	39	36							
19	54	49	42	40	42	36	50	47	36	42	40					
20	41	38	26	37	36	37	39									
21	33	32	30	30	36	34	34									
22	36	37	36	32	40	35	34									
23	41	27	37	33	36	40	38	38	36	39						
24	42	39	39	38	36	37	40									
25	33	31	30	36	33	32	36									

Table VI. Circumference Measurements of Palm Trees at Various Heights in Inches. Source: Okitipupa

Tree No.	Height of Tree in Feet															
	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64
F 1	50	36	34	31	34	32	33	31	25	23						
2	52	51	51	51	49	54	54	56	54	52	52					
3	36	31	28	27	34	36	27	27	26							
4	48	40	37	34	36	25	30	37	37	31						
5	38	32	30	29	32	31	32	32	30							
6	30	29	28	29	29	26	26	27	26							
7	32	26	25	25	26	26	27	27	25							
8	30	28	28	28	29	28	28	29	28	28	25					
9	39	33	30	32	33	33	35	34								
10	30	29	29	28	28	30	31	31	29	30						
11	37	32	30	28	21	30	30	28	27	27						
12	34	33	29	30	28	28	28	26	27							
13	34	25	25	25	25	25	25	34	31							
14	40	35	32	32	32	32	33	31	31	31						

Table VII. Circumference Measurements of Palm Trees at Various Heights in Inches. Source: Okitipupa

Tree No.	Height of Tree in Feet															
	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64
G 1	68	57	51	49	48	49	64	41								
2	51	38	35	35	26	26	38	24	24	24						
3	63	59	48	44	46	35	41	36								
4	52	44	42	43	46	44										
5	71	57	52	52	51	51	50	47	54							
6	54	43	43	44	44	43	43	42	42	46						
7	57	55	55	53	50	50	50									
8	57	41	36	35	42	37	37	38	38							
9	58	40	40	45	42	44	42	42								
10	46	42	41	44	42	40	40	40	38							
11	61	51	50	49	57	54										
12	44	42	40	40	41	40	40	38	38							
13	25	36	47	46	46	46	44									
14	68	47	46	46	51											
15	50	56	53	58												
16	54	45	45	43	44	46	48									
17	53	56	56	56	54	56	55	56	59							
18	56	55	46	46	46	50	54	58								
19	64	49	52	51	53	53										
20	43	48	48	45	45	46	50	53								
21	47	43	46	44	47	42										
22	60	58	56	55	51	49	51	55	49	52	54	58	58	55		
23	50	51	50	57	53											
24	77	63	57	56	49	48										
25	52	48	49	50	56	59										

Table VIII. Taper of Circumference in Palm Trees at the Heights of 40 Feet in Inches

Tree No.	Districts of Sample						
	A	B	C	D	E	F	G
1	10	—	—	+7	—	27	
2	3	—	2	+3	—	0	27
3	5	—	+8	0	—	—	—
4	0	—		+2	—	17	—
5	4	—	—	3	—	—	—
6	11	—	—	3	—	—	8
7	4	1	1	13	—	—	—
8	6	—	—	+5	—	2	—
9	6	—	—	9	—	—	—
10	11	—	—	2	—	0	—
11	3	—	34	6	—	10	—
12	10	—	15	8	—	—	—
13	2	—	—	4	+2	—	—
14	11	—	—	4	1	9	—
15	2	—	—	1	—		—
16	12	5	30	12	—		—
17	6	9	—	3	—		—
18	13	—	—	3	—		—
19	0	—	—	12	12		—
20	3	—	—	9	—		—
21	7	—	14	12	—		—
22	5	—	24	7	—		8
23	24	—	25	5	2		—
24	9	—	—	+1	—		—
25	9	—	13	2	—		—
	177	15	158	118	16	65	43

Total = 592

$$\text{Taper} = \frac{592}{69} \times \frac{1}{40\pi}$$

$$= 0.0665 \text{ in. per foot}$$

APPENDIX B

SAMPLE CALCULATIONS

Power Requirement

$$HP = \frac{2\pi rFN}{33000 \times 12}$$

where π = 3.1416

r = Effective radius of the wheels (5 inches)

F = Force required to lift device

N = Revolutions per minute of the wheels

33000 = Ft. lb./min. equivalent of 1 HP

12 = Inches per foot

$$HP = \frac{2 \times 3.14 \times 5 \times 500 \times 5}{33000 \times 12} = 0.1985$$

Assume efficiency of device to be about 50%.

$\frac{.1985}{0.50}$ = 0.397 HP required to lift the device

Hydraulic Pressure Required For Necessary Traction

Coefficient of friction between the rubber tires and the bark of the palm tree is assumed to be 0.3.

$$\mu = \frac{F}{N}$$

where μ = Coefficient of friction (0.3)

F = Lifting force (500 lbs.)

N = Normal force

then $N = \frac{F}{N} = \frac{500}{0.3}$ = 1667 lbs. of force required to give the rubber tires the necessary traction.

Size of Frame Members

$$S = \frac{MC}{I}$$

where S = Unit stress in psi

M = Bending moment in lb. inches

C = Distance from the outer fiber to the neutral axis in inches

I = Moment of inertia in in.^4.

then $SI = MC$

and $\frac{M}{S} = \frac{I}{C}$ = Section modulus of the beam

$$M = \frac{1667 \text{ lb.} \times 25 \text{ in.}}{2} = 20860 \text{ lb. in.}$$

Assume design stress for structural steel to be 20,000 psi

then $\frac{M}{S} = \frac{20,860}{20,000} = 1.043$ which is the required section modulus of the frame member.

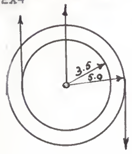
The steel handbook shows that angle iron 3 in. by 2 in. with a 1/2 in. web has a section modulus of 1.0.

Size of Shaft

Analyze bottom drive shaft

$\frac{500}{4}$ = 125 lbs. vertical load on shaft at each wheel

$\frac{1667}{2\text{x}4}$ = 208 lbs. normal load on shaft at each wheel



$$\frac{3.5}{F_{\text{sprocket}}} = \frac{5}{2 \times 125}$$

$$F_{\text{sprocket}} = \frac{3.5 \times 2 \times 125}{5} = 175 \text{ lbs.}$$

$$\Sigma M_{B(vertical)} \quad -F_A \times (6.5 + 7.375 + 6.5) + 175\ (4 + 7.375 + 6.5) +$$

$$125\ (7.375 + 6.5) + (125 \times 6.5) = 0$$

$$(-F_A \times 20.375) + (175 \times 17.875) + (125 \times 13.875) + (125 \times 6.5) = 0$$

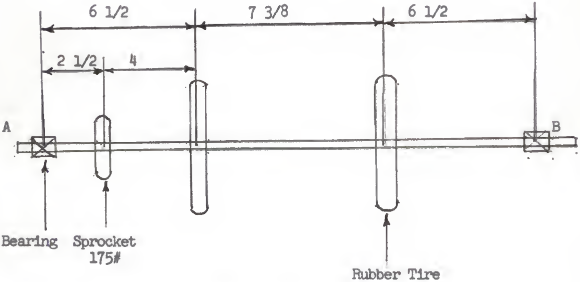
$$-20.375\ F_A + 3130 + 1735 + 812 = 0$$

$$F_A = \frac{3130 + 1735 + 812}{20.375} = \frac{5677}{20.375} = 279 \text{ lbs.}$$

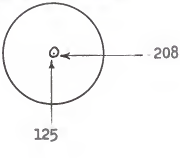
$$\Sigma M_{left\ wheel} = \sqrt{(-1110)^2 + (1350)^2}$$

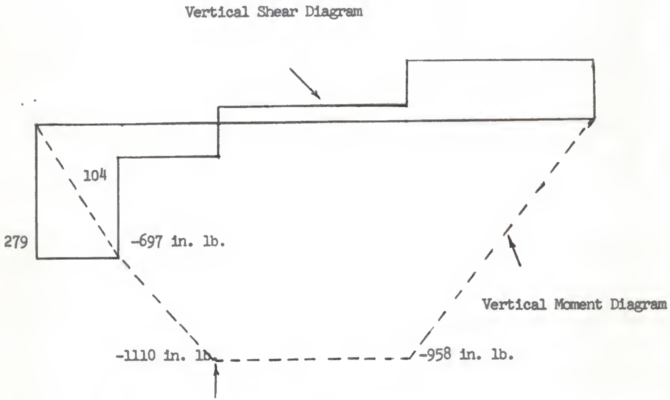
$$= \sqrt{1,232,100 + 1,820,500} = \sqrt{3,052,100}$$

$$= 1748 \text{ in. lb.}$$

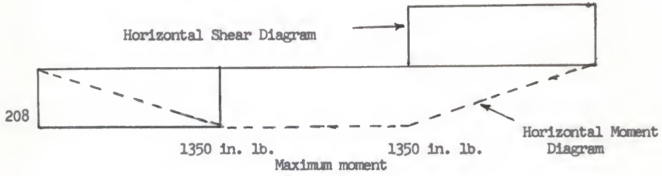


Load on each wheel





Maximum vertical moment = 1110 in. lb.



Assuming . 5 HP delivered to the 2 shafts 5 rpm of shaft, the torgue on the shaft will be $T_{shaft} = \frac{63{,}000\ HP}{N} = \frac{63{,}000 \times .5}{5} = 6{,}300$ lb. in. on 2 shafts $\frac{6{,}300}{2} = 3{,}150$ lb. in. on each shaft.

Shaft diameter can be found from the following formula which is for shafts subjected to both bending and torsion:

$S_s = \frac{16}{\pi D^3} \quad (K_t T)^2 + (K_M M)^2 \quad ^{\frac{1}{2}}$ where

S_s = Shear stress of shaft (use 20,000 psi)

D = Shaft diameter

K_t = Numerical combined shock and fatigue factor applied to torsion = 3.0

T = Torsion on shaft

K_m = Numerical combined and shock fatigue factor applied to the computed bending moment.

Rewrite for D^3

$$D^3 = \frac{16}{3.14 \times 20{,}000} \left[(3 \times 3150)^2 + (3 \times 1748)^2\right]^{\frac{1}{2}}$$

$$D^3 = \frac{16}{62{,}800} \left[(9450)^2 + (5244)^2\right]^{\frac{1}{2}}$$

$$= \frac{16}{62{,}800} \left[89{,}500{,}000 + 27{,}500{,}000\right]^{\frac{1}{2}}$$

$$= \frac{16}{62{,}800} \left[117{,}000{,}000\right]^{\frac{1}{2}}$$

$$= \frac{16}{62{,}800} \times 10800$$

$$D^3 = 2.75$$

$$D = 1.4 \text{ in.}$$

The 1.4 in. shaft diameter was determined by using maximum loads and maximum factors of safety.

APPENDIX C

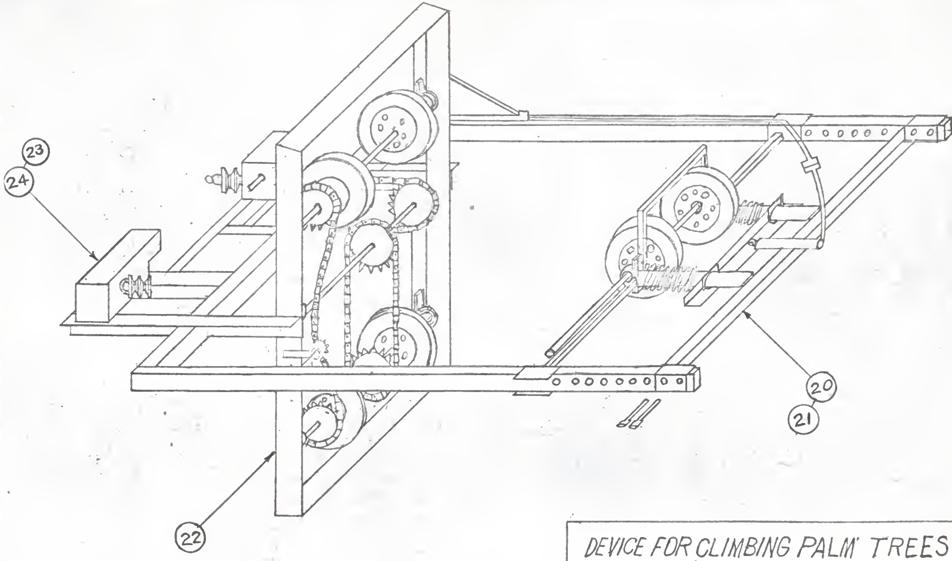
REQD	PART NAME	MATERIALS	NEXT ASSEM
1	4-CYCLE ENGINE	BRIGGS & STRATTON	22
1	WORM GEAR REDUCER	MORSE CHAIN CAST IRON	22
6	WHEEL ASSEBLIES	4.10-3.5 x 4	20
6	SPROCKET.	$\frac{3}{8}''$ PITCH 60T STEEL	20
2	SPROCKET.	$\frac{3}{8}''$ PITCH 24T STEEL	20
1	SPROCKET	$\frac{1}{2}''$ PITCH 60T STEEL	20
1	SPROCKET	$\frac{1}{2}''$ PITCH 20T STEEL	22
40"	ROLLER CHAIN	$\frac{3}{8}''$ PITCH STEEL	20
49"	ROLLER CHAIN	$\frac{1}{2}$ PITCH STEEL	22
8	PILLOW BEARING	SELF ALIGNING, CAST	22
2	STANDARD PIPE	$2\frac{1}{2}''$ DIA x 18"	21
2	EXTA STRONG PIPE	2" DIA x 18"	21
176"	RECTANGULAR TUBING	LOW CARBON STEEL $2'' \times 1'' \times \frac{1}{8}''$	21
30'	ANGLE IRON	L.C. STEEL $2\frac{1}{2} \times 2 \times \frac{3}{16}$	21
1	HAND HYDRAULIC PUMP	0 - 8.500 PSI	21
1	HYDRAULIC HOSE	$\frac{3}{8}''$ x 5 HIGH PRESSURE	21

REQD	PART NAME	MATERIALS	NEXT ASSEM
1	V-BELT CLUTCH	STEEL	23
1	DOUBLE V-BELT PULLEY	$\frac{3}{4}''$ DIA SHAFT	23
2	COMPRESSION SPRING	$7\frac{1}{2}'' \times 4'' \times \frac{1}{2}''$ CARBON STEEL	21
2	V-BELT	38" & 42" x $\frac{21}{32}$ RUBBER	21
4	WHEEL SHAFT	SAE 1035 STEEL ROD	24
	LOCK WASHER	C S STEEL $\frac{7}{16}''$ MEDIUM	
26	MACHINE BOLT	STEEL $\frac{7}{16} \times 1\frac{1}{2}$ HEX HEAD $\frac{7}{16}$-20 UNC-2A	24
4	PIN	SAE 1035 STEEL ROD	21
26	NUT	STEEL SEMI-FINISHED HEX HEAD $\frac{7}{16}$-20UNC-2A	
12	MACHINE BOLT	STEEL $\frac{1}{4} \times 1\frac{1}{2}$ HEX HEAD $\frac{1}{4}$-20UNC-2A	21
12	NUT	STEEL SEMI-FINISHED HEX HEAD $\frac{1}{4}$-20UNC-2A	21

DEVICE FOR CLIMBING PALM TREES

PARTS LIST

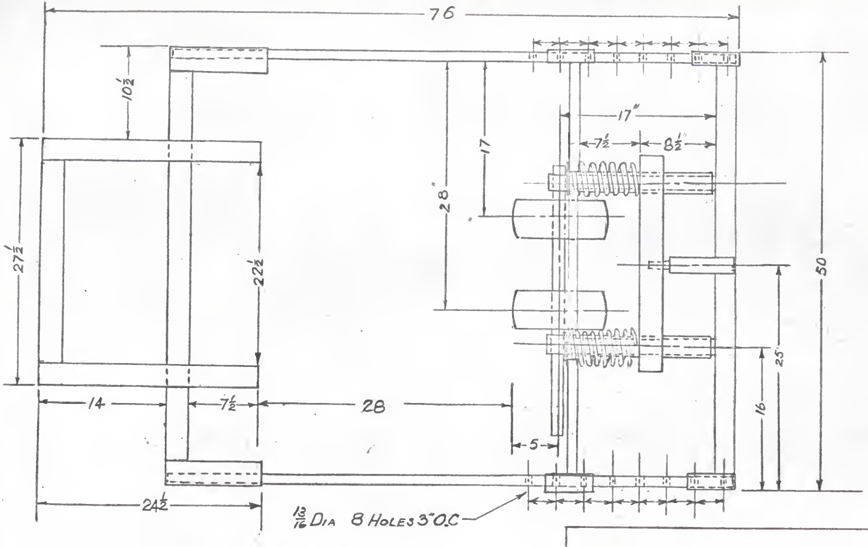
DFTMN OGUNKOYA	DATE FEB 16, '65	NEXT ASSEM 19
APPROV OGUNKOYA	SCALE NONE	DWG 18



DEVICE FOR CLIMBING PALM' TREES

DEVICE ASSEMBLY

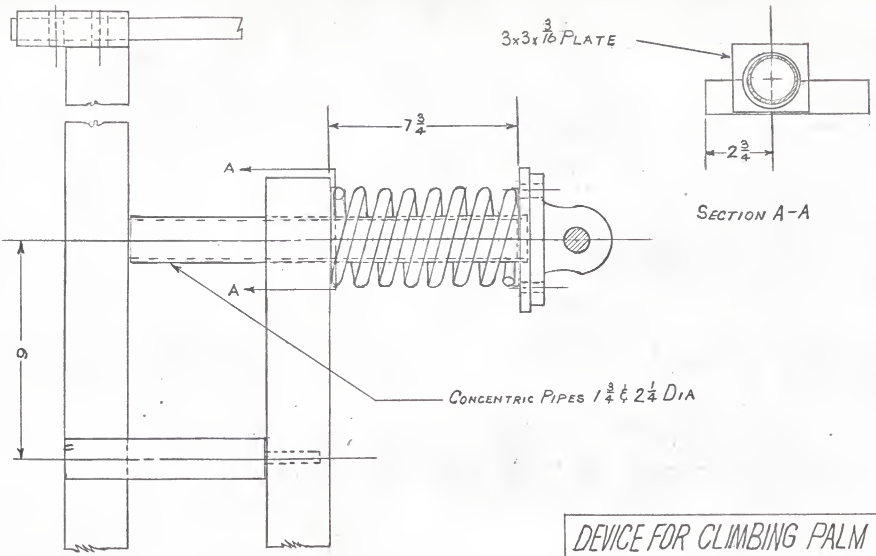
DFTMN ogun 2/23/65 DATE FEB 23, 65 NEXT ASSEM 20
APPROV ogun 2/23/65 SCALE NONE DWG 19



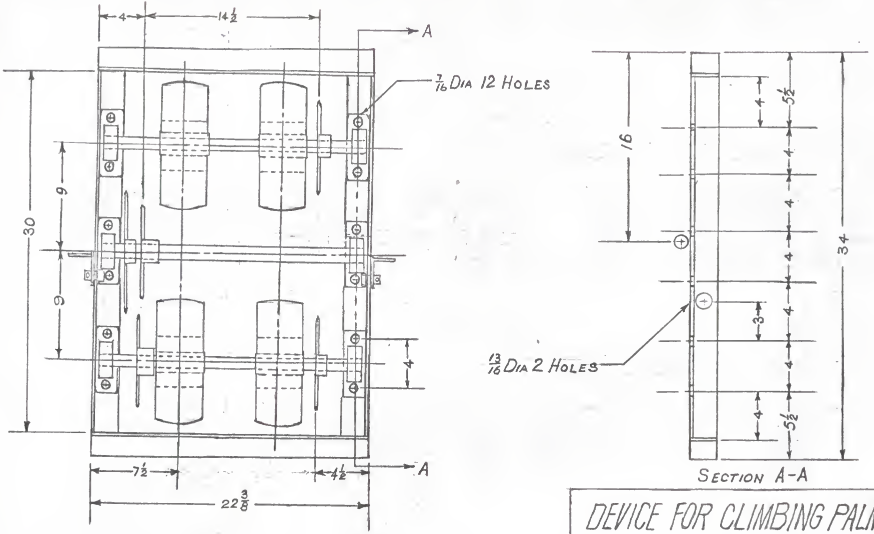
DEVICE FOR CLIMBING PALM TREES

PRESSURE WHEELS DETAILS

DFTMN OGUNKOYA APPROV OGUNKOYA	DATE MAR 2, 65 SCALE $\frac{3}{32}$" = 0' 1"	NEXT ASSEM 21 DWG 20



DEVICE FOR CLIMBING PALM TREES		
SPRING DETAILS		
DFTMN OGUNKOYA	DATE MAR 16, 65	NEXT ASSEM 22
APPROV OGUNKOYA	SCALE $\frac{1}{4}$" = 0' 1"	DWG 21

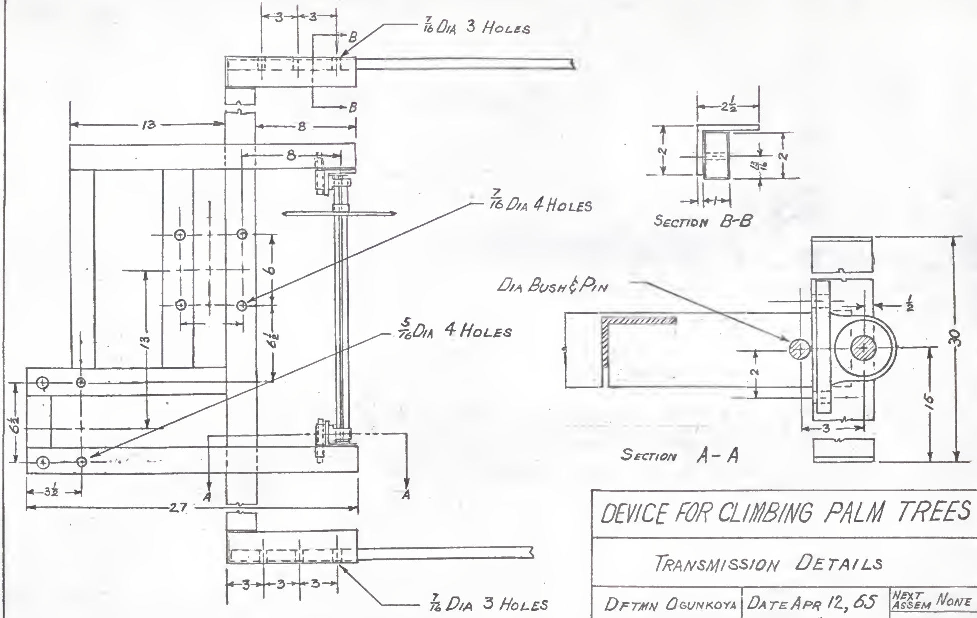


Note
1. Four Corners of Frame are Weld Joints
2. ¼"×⅛" Keyway entire Length of each Shaft
3. Wheels Slide to Adjust to Tree Size

DEVICE FOR CLIMBING PALM TREES

DRIVE WHEEL DETAILS

Dftmn Ogunkoya	Date Mar 30, 65	Next Assem 23
Approv Ogunkoya	Scale ⅛" = 0' 1"	Dwg 22



DEVICE FOR CLIMBING PALM TREES		
TRANSMISSION DETAILS		
DFTMN OGUNKOYA	DATE APR 12, 65	NEXT ASSEM NONE
APPROV OGUNKOYA	SCALE 1/8" = 0'-1"	DWG 23-4

MECHANICAL DEVICE FOR CLIMBING PALM TREES

by

CHRISTOPHER BOLAJI OGUNKOYA

B. S. Oregon State University 1959

AN ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agricultural Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1965

The present method of climbing palm trees in Nigeria is manual, slow and unsafe for the farmers. The farmers do not want to climb the palm trees, and much of the palm tree crop is lost every year.

The data were collected by the Ministry of Argiculture and Natural Resources in Western Nigeria. The circumferences of 170 palm trees were taken at intervals of four feet and were plotted on graph paper to estimate the distribution of the girths. The circumference ranges from 25 to 80 inches at the height of four feet above the ground. The average height of the palm tree is 45 feet, the taper is 0.07 in. per foot, the bark scars vary from 1/2 to 1 1/2 inches in depth and from 4 to 8 inches in length.

A small model of the device was constructed and the stability studied before the full size experimental climbing machine was built. The device had the following basic parts: the platform frame, the vertical drive wheel assembly, the pressure wheel assembly, the hydraulic system, and the power transmission assembly. The pressure wheel assembly was detachable for fastening the device around the base of the trees; the device was large enough for 12 to 24 inches diameter palm trees.

The computed power requirement was 0.397 hp, but a 3.0 hp 4-cycle internal combustion engine was used to power the machine. The V-belt transmitted power from the engine to the worm gear, and the sprockets and chain connected the output shaft of the worm gear to the drive wheels. The V-belt clutch provided effective control of the machine in operation.

The device would stop moving up the tree when the taper or the reduction in tree diameter was large enough to reduce the compressive force that gave traction to the wheels; this would cause the wheels to spin, and the operator had to apply more pressure to the hydraulic system.

The weak members of the frame prevented the construction of the operator's seat on the climbing machine, and it was not possible to have the operator ride on the device.

A dry cottonwood log was brought into the laboratory for the test. The machine climbed, remained locked to the tree and descended from the simulated palm tree up to the height of three feet. The limited laboratory performance encouraged further improvement on the experimental mechanical device for climbing palm trees.

The interesting observations were: four of the six wheels gave effective traction, the hydraulic pressure of about 375 lbs. gave traction to the wheels, the tire pressure of 22-24 lbs. had maximum surface contact between the tires and the bark of the tree. The weak points were: weak platform frame, poor frame stability, slow fastening of the pressure wheel assembly and the excessive weight of the machine.

The use of high strength aluminum materials for the construction of the platform frame and other improvements in the design would make the machine more portable than the present device.

Further field tests of the mechanical device for climbing palm trees are planned to be done in Ibadan, Nigeria.