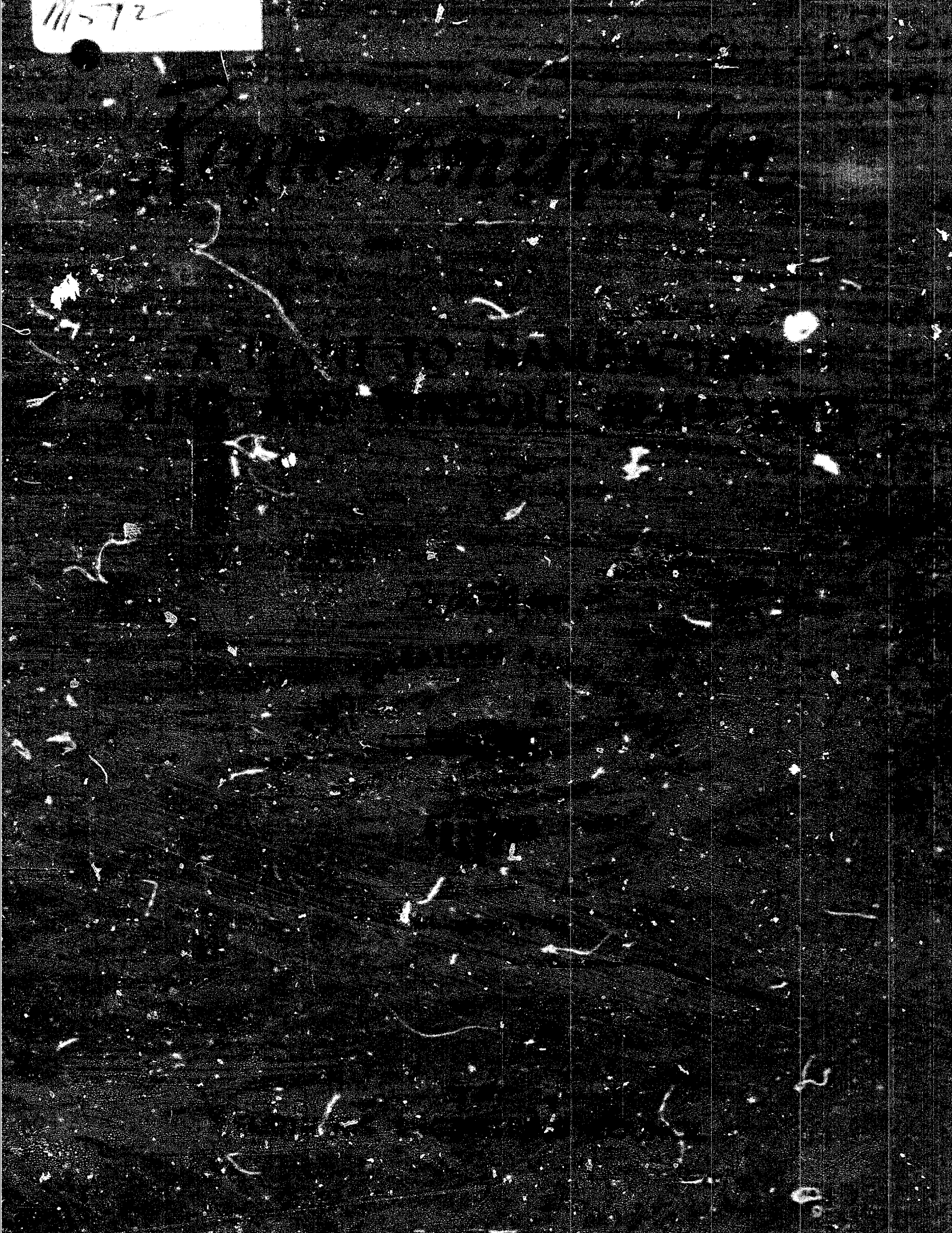

REQUIREMENTS FOR A PLANT TO MANUFACTURE PUMPS AND WINDMILL HEAD UNITS

AN ESTIMATE

Prepared for

FOREIGN OPERATIONS ADMINISTRATION
Washington, D. C.

Requirements for a Plant to Manufacture Pump and Windmill.

TJ .15 Methods Engineering Council. NTIS
M5. Requirements for a Plant to Manufacture Pump and Windmill Head Units. Jan. 1954.
[illegible] p.
Prepared for FOA.

1. Windmills. 2. Industrial plants. 3. Pumping machinery. I. Title.

Donald E. Farr
Vice President

John J. Wilkinson
Consultant

Lawrence B. Grella
Managing Consultant

January 4, 1954

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AN ESTIMATE

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This report presents general designs of three simple types pumps and a windmill head unit suitable for driving two of these pumps. It gives a general method of manufacturing these items, a preliminary layout of the factory, and the cost of establishing the factory and manufacturing these pumps and windmill units.

The report is based on the needs and the available labor in under-developed countries and stresses most simple design and lowest capital cost.

OBJECTIVE.

This project was undertaken in order to prepare estimates of the unit cost, and the cost of establishing and running a factory to manufacture:

25 Small Shallow Well Lift Pumps per day
25 Small Deep Well Lift Pumps per day
10 Large Shallow Well Lift Pumps per day
5 Windmill Head Units per day

RESULTS:

We estimate the requirements for this installation are as follows:

Size of Building		12,000 square feet
Number of Employees		
Direct Labor		23
Indirect Labor		12
	Total	35
Cost of Building		$36,000
Cost of Equipment		$56,300
Operating Capital		
*Not including Well Pipe		$85,000
*Including Well Pipe		$308,000

*Either may be used, or a reduced inventory of well pipe may be carried. These Operating Capital figures cover 90 working days Raw Inventory of imported items, and 30 working days Raw Inventory of local purchased items including castings. This well pipe is listed because we believe the man buying a pump will naturally expect to obtain his pipe from the same

source. It is an optional service to purchasers of pumps; the Operating Capital requirements are, therefore, shown both with and without this service. The allowed storage space includes pipe storage and the pipe threading machine has ample capacity to handle this pipe.

Unit Cost of Products

Small Shallow Well Pump + Point	$5.70
Small Deep Well Pump + Point	7.45
Large Shallow Well Pump + Point	18.10
Windmill Head Unit	44.40
Well Pipe -- cost per foot.	
Small Shallow (1 1/4" inside diameter)	.41
Small Deep (2 1/2" inside diameter)	.81
Large Shallow (3" inside diameter)	1.25

PROCEDURE:

Design of Pumps and Windmill Unit

Our first step was to decide on the design of pump and windmill to be produced, and to standardize and simplify these items as much as possible.

We eventually decided on the following.

a. All pumps will be of simple LIFT type -- the disadvantage of not being able to supply water under any pressure apart from gravity head is, we feel, offset by greatly reduced production cost and maintenance

b. The small pump will be based on a 2 5/16" diameter piston x 6" stroke, giving an output of 190 gallons/hour at 30 strokes/minute.

c. For shallow wells less than 22 feet deep, the piston will move in e pump body. For deep wells more than 22 feet deep, the same piston will move in a seamless steel barrel attached to the well pipe at a point within 15 feet of the water supply. The well pipe above this pump barrel will be large enough to enable the piston to be drawn up to the surface for maintenance without pulling up the well pipe.

d. For shallow wells, the lower valve will be at the base of the pump body and will be made of leather. For deep wells, the lower valve will be at the base of the barrel in the ground, and will be made of cast iron or brass. This design makes it unnecessary to replace the valve, which can only be reached by pulling the well pipe out of the ground, and reduces manufacturing and material costs.

e. The large pump -- for shallow wells or irrigation purposes only -- will be based on a 4 13/16" diameter piston x 6" stroke, giving an output of 900 gallons/hour at 30 strokes/minute.

f. The large pump piston will move in the pump body and the lower valve will be made of leather.

g. The large pump may be operated by one or two men, it may be fixed in one place, using a solid well pipe reaching to the water, or it may be transportable, using a flexible hose to reach to the reservoir, tank, or canal to be pumped.

h. A well drive point, which incorporates a strainer, has been included in the unit cost of each type of pump, but the cost of well pipe per foot has been stated separately since the depth of well and length of pipe to be used will vary with the location.

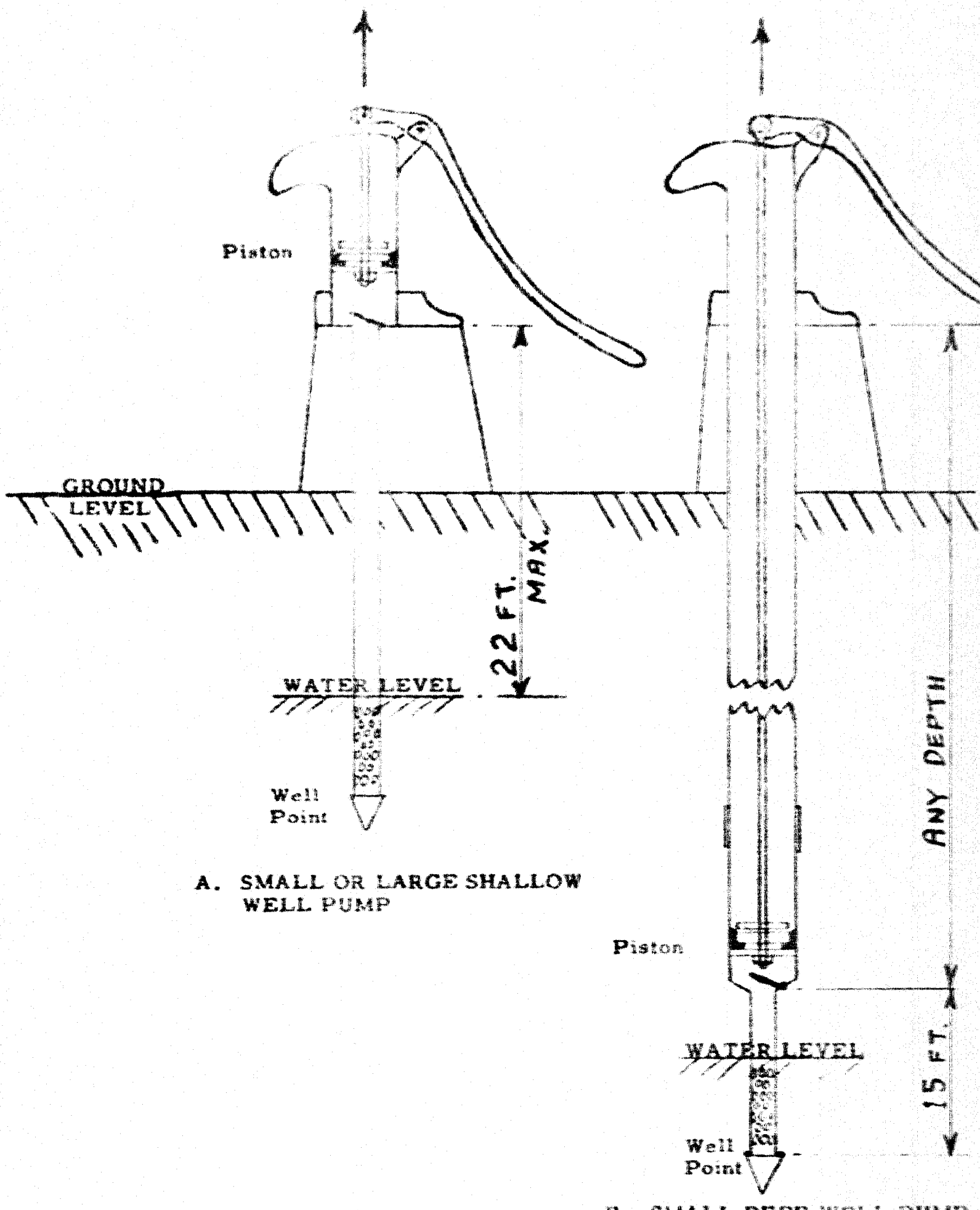
i. Piston cup leathers and valves are assumed to be made from local tanned hides. If there are religious objections to animal hides, as in India, these cups and valves can be made of rubber, neoprene, or canvas reinforced rubber. Local supply or imports of these items must be assumed under these circumstances.

j. The windmill head unit is designed to be fixed on a locally built wooden tower, directly over the small hand pump which feeds to locally built water storage tanks or canals.

k. This windmill unit is of very simple design and is easily and cheaply manufactured -- accordingly, certain disadvantages are apparent. These disadvantages will not jeopardize good operation, but will cause some inconvenience -- e.g., the guide vane to cut off pumping will be manually controlled; lubrication at individual points will be required fairly frequently; and some noise and sluggishness may be apparent.

Sketches of these designs and suggested arrangements are shown in Figures 1, 2, 3, 4, 5, and 6. They are detailed only to the extent necessary to establish reasonable estimates of manufacturing processes and costs.

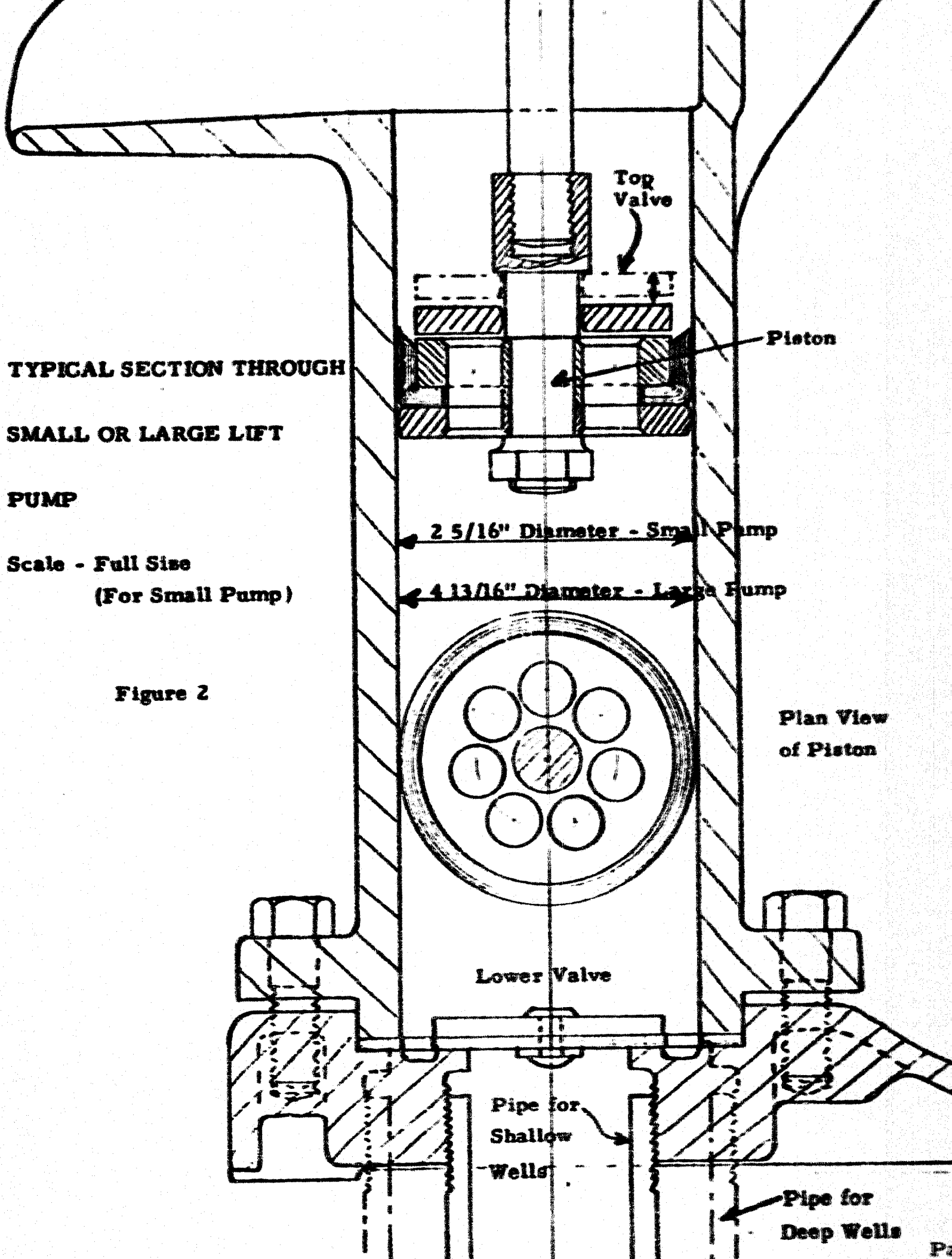
IF DESIRED



A. SMALL OR LARGE SHALLOW WELL PUMP

B. SMALL DEEP WELL PUMP

SKETCH OF TWO PUMP ARRANGEMENTS



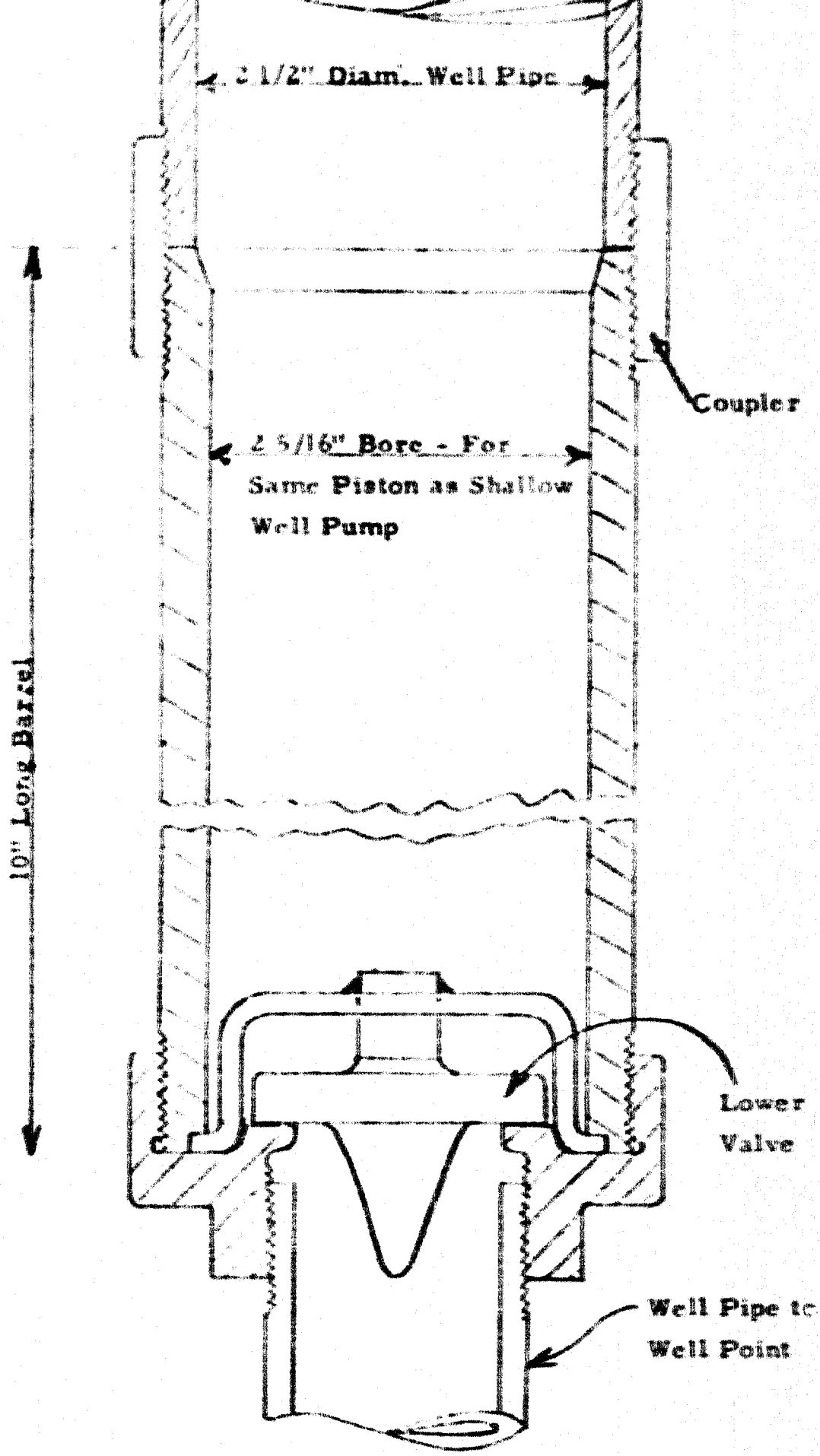
TYPICAL SECTION THROUGH

SMALL OR LARGE LIFT

PUMP

Scale - Full Size
(For Small Pump)

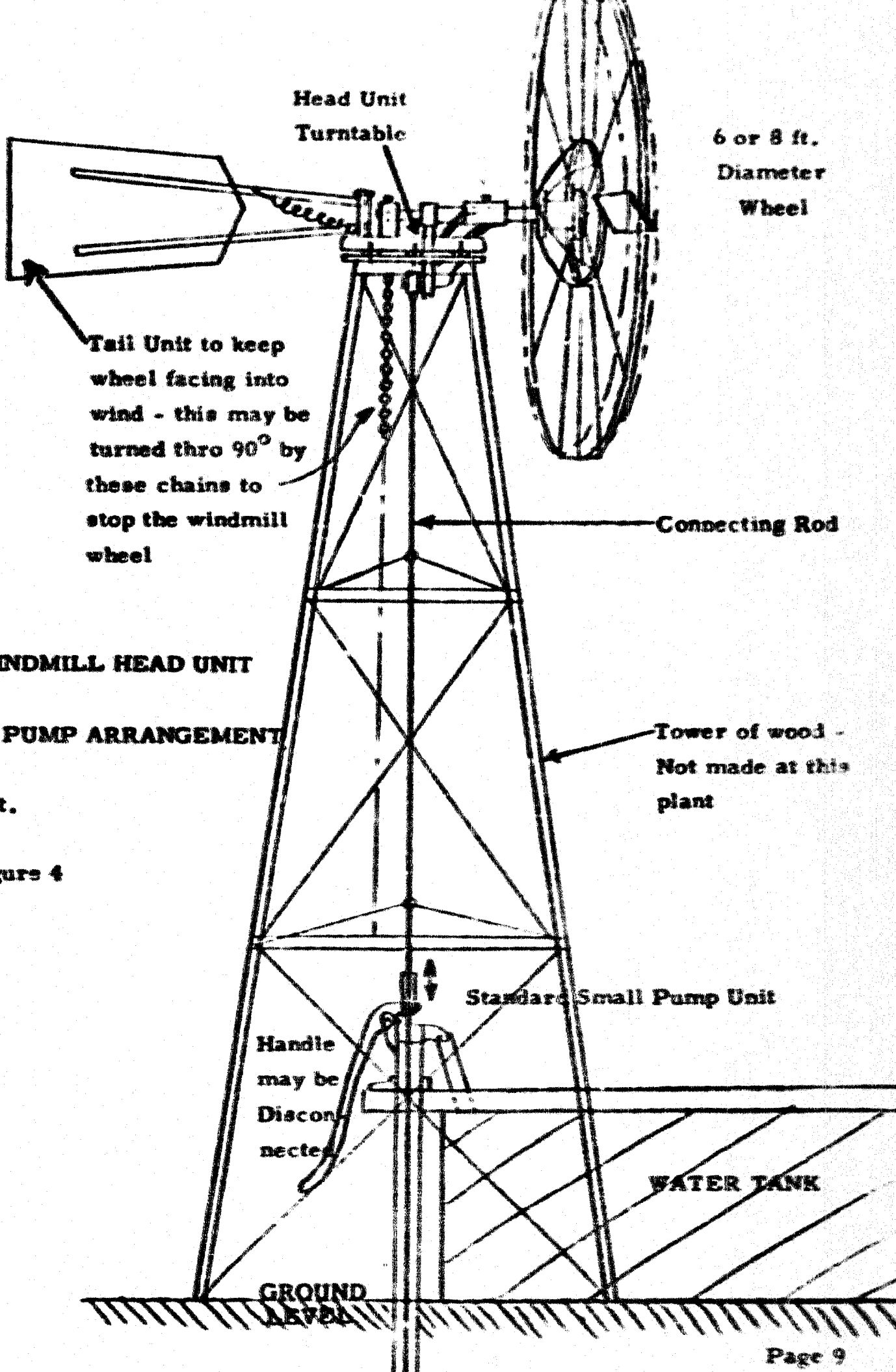
Figure 2



SECTION THROUGH BARREL OF DEEP WELL SMALL PUMP

Scale - Full Size

Figure 3

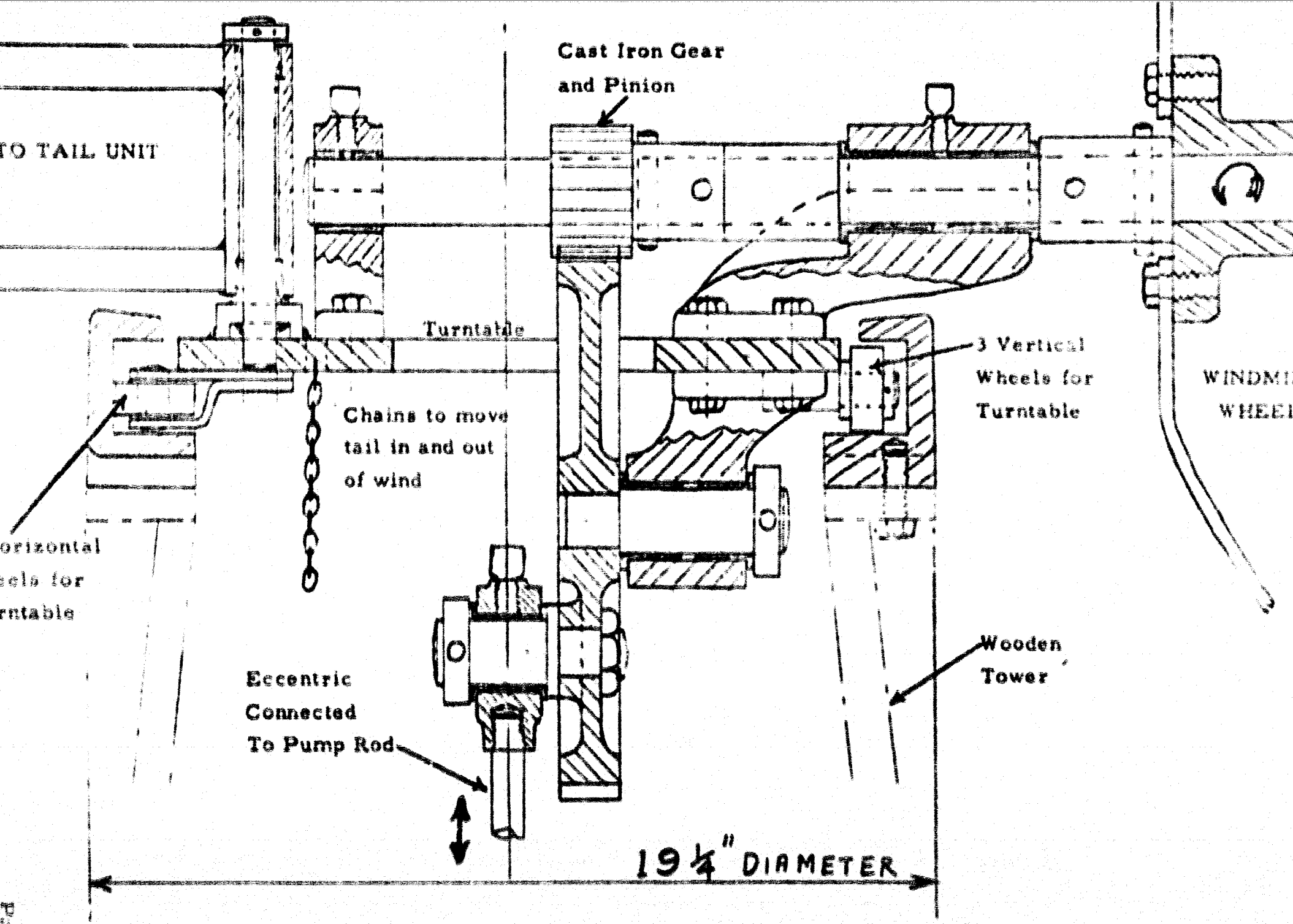


KETCH OF WINDMILL HEAD UNIT

OWER _ AND PUMP ARRANGEMENT

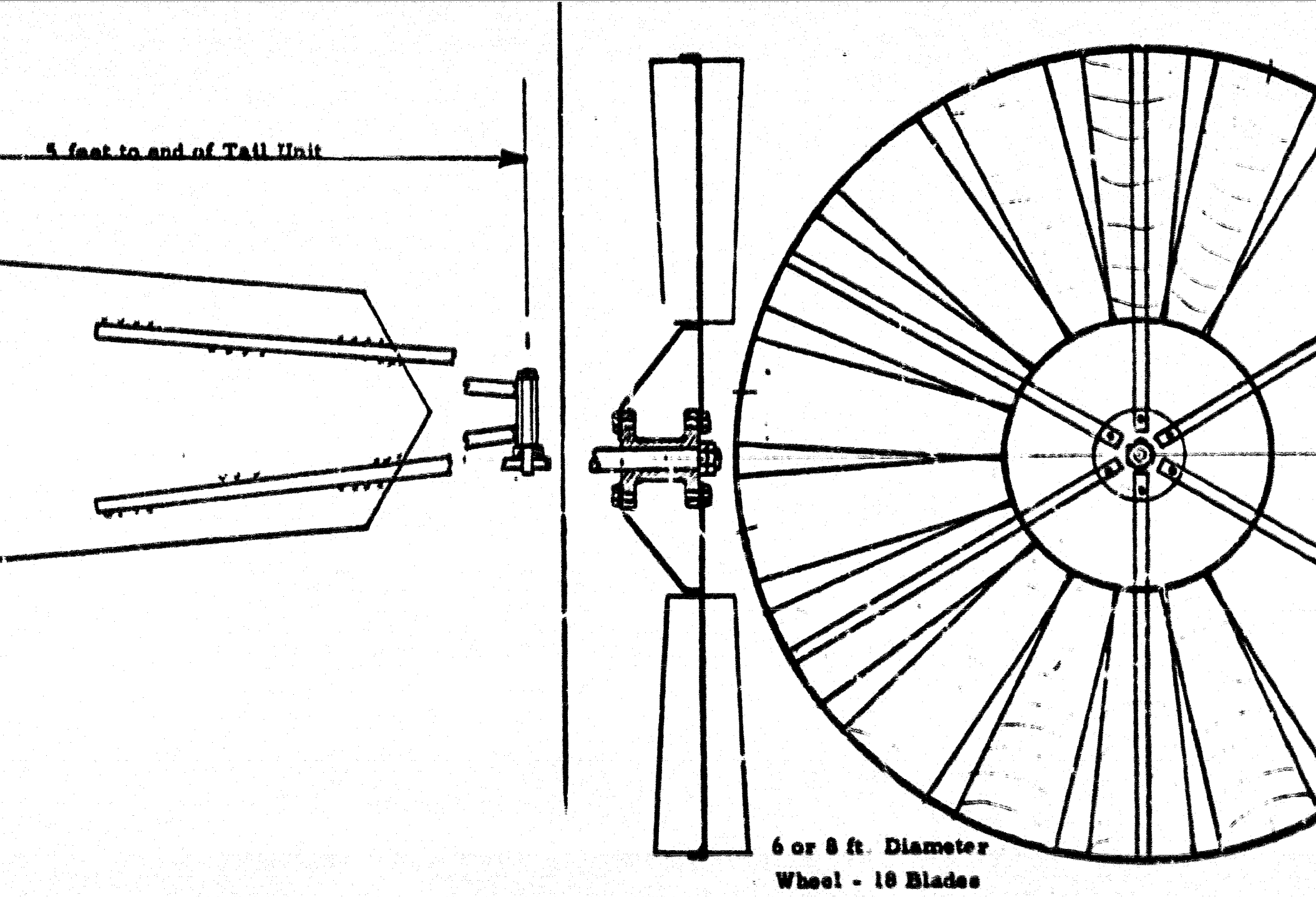
ale - 1" = 2 ft.

Figure 4



SECTION THROUGH WINDMILL HEAD UNIT

Scale - 1" = 3"



DETAILS OF TAIL UNIT AND WINDMILL WHEEL

Scale - 1" = 12"

Figure 6

Assumptions

It was necessary to make certain assumptions in order to make our estimates. These were:

1. All equipment will be purchased at United States prices.

2. All materials not produced locally will be priced at current United States prices.

3. Adequate suppliers of average quality gray iron castings are available locally for our designs.

4. Adequate supplies of forged blades are available locally.

5. Adequate transportation facilities will be available at the plant site.

6. Adequate heat, light, water, and electricity are available at the site.

7. Average labor costs are $2.10 per hour, and double-shift work is permissible.

Shop Operation Data

We next made up lists of parts for each item and detailed the operations required to manufacture each of these individual parts. At the same time, we specified the type of equipment to be used -- whenever possible, this was general-purpose equipment which could be used for a variety of work on each product.

Production Equipment

Generally, the machines selected are the best for the work involved -- taking into account the small quantity of production. In certain cases, the capital outlay for expensive machines was reduced by using a less expensive piece of equipment, even though some increase in man-hours will result. This increase in man-hours is only acceptable when the low labor rate of $0.30 per hour is used.

We were then able to estimate times for the individual operations and, hence, determine how many hours per day each machine or piece of equipment would be used. A number of machines must be operated more than eight hours per day to meet these production figures. This is accomplished by using duplicate machines and/or operating more than eight hours per day. The more expensive machines are to be operated two shifts per day, rather than buy additional equipment.

Chart A lists the production equipment required, estimated number of production hours per day on each machine, quantity of each required, and estimated United States cost. Some of this equipment is not used full-time for production of pumps, but must be bought and installed for certain operations and/or foreseeable use either for production or plant maintenance.

With the equipment listed, a good deal of machine and plant maintenance can be carried out within the plant itself.

No woodworking machinery for towers, tanks, and platforms is included. It is assumed that another local plant will do this work.

CHART A

Production Equipment Requirements

	Machine Description	Hours One Day's Production	Machines Required	Price Each	Total Price
1	Large Turret Lathe (24" swing)	28.1	2*	$6,800	$13,600
2	Small Turret Lathe (9" swing)	11.4	1*	2,000	2,000
3	2-spindle Drill	7.6	1	2,000	2,000
4	3-spindle Drill	7.6	1	2,800	2,800
5	Tube Cutting and Threading Machines				
	a. Power -- up to 4"	3.6	1	2,100	2,100
	b. Hand -- up to 6"	2.0+**	1	250	250
6	25-ton Pneumatic Press	5.0+**	1	2,000	2,000
7	Oil Dip Tanks for Leathers	8.0	4	50	200
8	Welding Equipment				
	a. Electric Welding Set	6.8	1	700	700
	b. Gas Welding Equipment	1.0+**	1	150	150
9	#2 Production Milling Machine	2.0	1	9,000	9,000
10	Power Cut-off Saw	.8+**	1	600	600
11	Shear -- foot operated	1.0+**	1	500	500
12	3-Roll Bender -- hand	2.0	1	450	450
13	Paint Spray Equipment				
	a. Prime Coat	4.0	1	500	500
	b. Finish Coat	4.0	1	750	750
14	Pedestal Grinder	--	1	200	200
15	Portable Drills (3/8")	--	2	80	160
16	Portable Grinder	--	1	80	80

CHART A (Cont'd.)

Production Equipment Requirements

	Machine Description	Hours One Day's Production	Machines Required	Price Each	Total Price
17	Air Compressor and Receiver	--	1	$2,800	$2,800
18	Jib Cranes	--	2	300	600
19	Hand Operated Overhead Crane	--	1	2,500	2,500
20	Fork Hand Trucks and Handling Pallets, and the like	--	2	500	1,000
				Total	$44,940

* Indicates overtime or double-shift required

** "2.0+" indicates 2.0 hours production plus cutoff of raw material in stock room and plant maintenance. Similarly for other "plus" values in this table.

Grouping of Equipment

Since all products of this plant will be produced on the same equipment, the operation does not lend itself to straight line production methods. It is more logical to group the machines according to the type of operations performed on them.

The suggested grouping of plant equipment and machines is given below -- with further details of the machines where useful:

1. Raw Material Storage and Steel Cutoff
   - 1 - Overhead Crane -- runs into Machine Shop
   - 1 - Power Hack Saw
   - 1 - Tube Cutting and Threading Machine
   - 1 - Tube Cutting and Threading Machine -- Portable

2. Machine Shop
   - 2 - Large Turret Lathes (24" swing -- 30" centers)
   - 1 - Small Turret Lathe (9" swing -- 24" centers)
   - 1 - Two-spindle Drill Press + Tapping Head
   - 1 - Three-spindle Drill Press + Tapping Head
   - 1 - 25-ton Press
   - 1 - #2 Milling Machine
   - 1 - Shear -- 1/16" thick x 42" wide material
   - 1 - Three-roll Bender -- 1/16" thick x 42" wide material
   - 1 - Pedestal Grinder
   - 2 - Portable Drills
   - 1 - Portable Grinder
   - 2 - Jib Cranes

3. Assembly

   Workbenches, vises, lockers, and the like for six assemblers and helpers.

4. Welding

1 - Electric Welder

1 - Gas Welder

2 - Welding Tables

5. Leather Forming

4 - Impregnating Tanks

6. Painting

1 - Primer Paint Spray Equipment

1 - Finish Coat Paint Spray Equipment

7. Receiving and Shipping

2 - Desks and Chairs

2 - Filing Cabinets

8. Finished Stores

Storage Racks

Storage Bins

9. Office

5 - Desks and Chairs

4 - Filing Cabinets

2 - Typewriters

1 - Adding Machine

Labor Force

From the required hours of operation for each machine and the assembly time, we determined that a direct labor force of 23 people is required. For a labor force of this size it is necessary for the operators to be qualified to operate more than one machine.

We estimate that an indirect labor force of 12 people will be required. This includes a salesman and a man for field work on the products.

This gives a total of 35 people for the entire plant, distributed as follows.

Raw Material Storage and Cutoff	3 men
Machine Shop	9 1/2 men
Assembly	6 men
Welding	2 men
Leather Forming	1 man
Painting	1 1/2 men
	23 men

Receiving, Finished Stores, and Shipping	2 men
Materials Handling and Janitor	3 men
Purchasing, Sales, Field Work and Office Staff	4 men
Manager, Superintendent and Foreman	3 men
	12 men

Jigs, Fixtures, and the Like, and Office Equipment

To produce and assemble components we require certain non-durable tools and office equipment as listed below:

Special Chuck Jaws	$480
Drill and Welding Jigs	$2,720
Fixtures	$2,600
Taps	$520
Dies	$240
Gauges	$1,850
Form Dies for Cup Leathers	$910
Office Equipment	$2,000
Total	$11,320

Summary of Equipment Costs

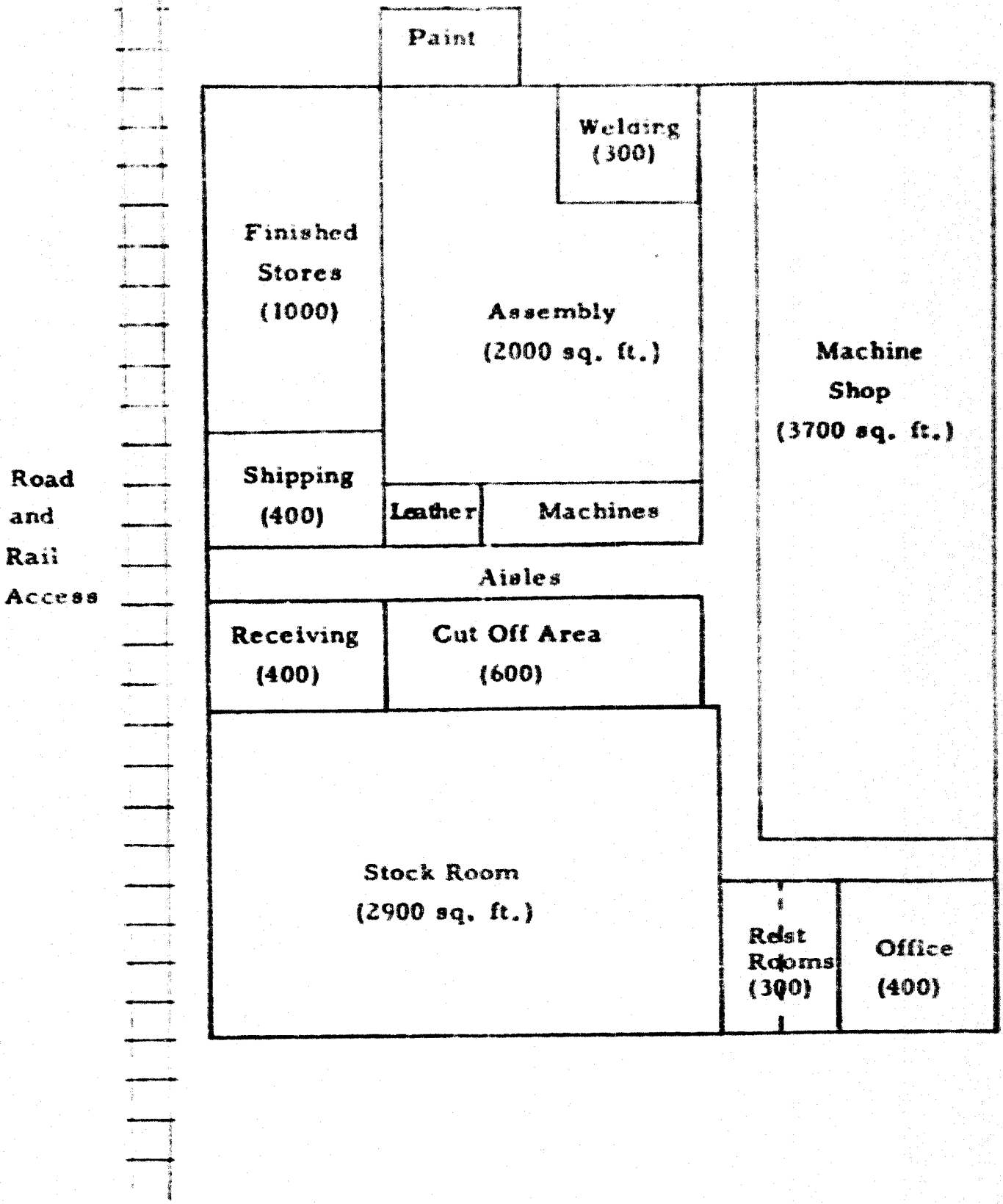
Production Equipment	$44,940
Jigs, Fixtures, and Office Equipment	11,320
Total	$56,260
(Use value of	$56,300)

Space Requirements

We next determined the approximate floor space required for these operations, the specified equipment, 90 days' Raw Inventory, 30 days' Finished Stock, and adequate aisles and in-process storage. A total floor area of 12,000 square feet will be required -- divided approximately as follows.

Office	400 square feet
Receiving and Shipping	800 square feet
Rest Rooms	300 square feet
Stock Room	2,900 square feet
Cutoff Area	600 square feet
Machine Shop	3,700 square feet
Welding	300 square feet
Assembly and Paint	2,000 square feet
Finished Stores	1,000 square feet
Total	12,000 square feet

A preliminary rough layout of this plant is shown in Figure 7.



PRELIMINARY PLANT LAYOUT

Scale - 1" = 20 ft.

Figure 7

Building Cost

The Quonset type steel building should be adequate for this plant. The cost of such a building -- 120 feet x 100 feet -- with essential wiring and plumbing is estimated at $36,000.

Material Requirements

The material requirements for one day's production were established in five categories and are listed below. The seamless tube for the well pipe is listed separately, as this is not directly a part of the pump and windmill production requirements -- it is based on a shallow well 20 feet deep for both small and large pumps, and a deep well 100 feet deep for the small pump. The material for windmill towers, water tanks, and the like is not included.

Raw Material	One Day's Production		
	Total Weight	Cost per Lb.	Total Value
Local Cast Iron	2,604 lbs.	$0.085*	$222.00
Steel Bar	1,913 lbs.	$0.06	$115.00
Steel Tube (production)	738 lbs.	$0.14 Average	$103.00
Brass/Bronze	228.5 lbs.	$0.42	$ 96.00
Hardware and Leather	--	--	$ 71.40
Steel Tube (well pipe)	18,440 lbs.	$0.135 Average	$2480.00

* $0.085 per lb. is used assuming that local casting prices will be 50% of good quality United States prices ($0.17 per lb.) All other costs per pound are United States prices.

Raw Material Inventory

We recommend that 90 working days of Imported Raw Material Inventory and 30 working days of locally supplied Castings and Hardware be carried at the plant.

This is equal to:

Cast Iron	78,120 lbs. at $0.085	$6,660
Hardware	10,730 lbs. approx.	$2,142
Steel Bar	172,170 lbs. at $0.06	$10,350
Steel Tube (Prod.)	66,420 lbs. at $0.14	$9,270
Brass/Bronze	20,565 lbs. at $0.42	$8,640
Total -- 348,000 lbs. Raw Inventory -- Value		$37,062
Steel Tube (well pipe)	1,659,600 lbs. at $0.135	$223,200

Overhead Rate

The overhead rate has been calculated per direct labor hour, and used to estimate unit costs of the products. All labor, both direct and indirect, is figured at $0.30 per hour -- this assumes local labor supply to be equal to or less than this value.

The overhead rate is determined as follows:

Item	Cost	Depreciation per Year	Number of Years
Building	$36,000	$2,400	15
Non-durable Tools	9,320	4,660	2
Office Equipment	2,000	400	5
Production Equipment			
Chart A -- Items 1, 2, 3, 4, 5, 6, 9, 10, 11, and 12	35,300	3,530	10
Chart A -- Items 7, 8, 13, 14, 15, 16, 17, 18, 19, and 20	9,640	1,928	5
	Total --	$12,918 per year = $250 per week	

Total overhead expenses:

Depreciation	$250 per week
Indirect labor -- 12 men -- 40 hrs. at $0.30	$144 per week
Office Supplies	$ 50 per week
Power, Light, Heat, and Water	$125 per week
Total --	$569 per week

Hence, overhead per direct labor hour = $\frac{569}{25 \times 8 \times 5}$ = $0.63 per hour

Unit Cost

Now we can calculate the unit cost of manufacturing the different items. From the Shop Operation data compiled before, we extract Total Labor Time, Weight of Materials Used, Number of Setups, and the like to add to the above overhead costs. The results are tabulated on Chart B on the following page. This shows all the above details and the split up of Labor, Material, and Overhead for each unit.

CHART B
UNIT PRODUCT COST

Item	Time or Weight	Dollar Cost	Total Cost	Time or Weight	Dollar Cost	Total Cost	Time or Weight	Dollar Cost	Total Cost	Time or Weight	Dollar Cost	Total Cost
1. LABOR												
Direct	63.9	.32		79.0	.40		118.3	.59		268.8	1.35	
Setups	10.0	.05		12.6	.06		13.5	.07		55.5	.28	
	73.9 mins.	$ .37	.37	91.6 mins.	$ .46	.46	131.8 mins.	$ .66	.66	324.3 mins.	$ 1.63	1.63
2. MATERIAL												
Cast Iron	21.9	1.87		24.9	2.12		69.9	5.95		146.9	12.50	
Steel Bar	6.4	.36		6.9	.39		38.0	2.28		243.2	14.60	
Steel Tube	5.4	.76		13.6	1.91		26.3	3.68		--	--	
Brass/Bronze	2.2	.93		2.2	.93		6.1	2.56		11.5	4.83	
Hardware	--	.47		--	.47		--	1.33		--	6.92	
Paint and Ship	--	.20		--	.30		--	.25		--	.50	
	35.9 lbs.	$4.61	4.61	47.2 lbs.	$6.02	6.02	140.3 lbs.	$16.05	16.05	401.6 lbs.	$39.35	39.35
3. OVERHEAD												
$.61 per labor hour	--	$ .78	.78	--	$ .97	.97	--	$ 1.39	1.39	--	$ 3.42	3.42
COST		TOTAL	$5.76		TOTAL	$7.45		TOTAL	$18.10		TOTAL	$44.40
PRODUCT DESCRIPTION	*SMALL PUMP SHALLOW WELL (25 per day)			*SMALL PUMP DEEP WELL (25 per day)			*LARGE PUMP SHALLOW WELL (10 per day)			WINDMILL HEAD UNIT (5 per day)		

*Includes Well Point

Well Pipe - Cost per Foot

A. Small Pump - Shallow Well - 1 1/4" inside diameter - 2.9 lbs./ft. -- $ .41 per foot

B. Small Pump - Deep Well - 2 1/2" inside diameter - 6.1 lbs./ft. -- $ .81 per foot
(Pipe plus Piston Rod)

C. Large Pump - Shallow Well - 3" inside diameter - 8.7 lbs./ft. -- $1.25 per foot

Hence, the value of one day's production -- labor, material, and overhead, but not including any profit, is:

($5.76 x 25) + ($7.45 x 25) + ($18.10 x 10) + ($44.10 x 5)
= 144 + 187 + 181 + 222 = $734 per day

Calculation of Profit

Using the figures from Chart "B," we can draw up a blank table for use when calculating values of Sales, Expenses, and Profits. This is shown in Chart "C."

CHART "C" -- SALES, EXPENSES, AND PROFITS

SALES

_____ Small Pumps - Shallow Well at _____ = _____

_____ Small Pumps - Deep Well at _____ = _____

_____ Large Pumps - Shallow Well at _____ = _____

_____ Windmill Head Units at _____ = _____

_____ feet - 1 1/4" Well Pipe at - per foot _____ = _____

_____ feet - 2 1/2" Well Pipe at - per foot _____ = _____

_____ feet - 3" Well Pipe at - per foot _____ = _____

COST OF SALES

Cost of Manufacturing Products

_____ Small Pumps - Shallow Well at $ 5.76 = _____

Labor	.37
Material	4.61
Overhead	.78

_____ Small Pumps - Deep Well at $ 7.45 = _____

Labor	.46
Material	6.02
Overhead	.97

_____ Large Pumps - Shallow Well at $18.10 = _____

Labor	.66
Material	16.05
Overhead	1.39

_____ Windmill Head Units at $44.40 = _____

Labor	1.61
Material	39.35
Overhead	3.42

Well Pipe, described by inside diameter.
(Labor and Overhead small on these items --
95% of total cost is Material.)

_____ feet - 1 1/4" Well Pipe at - per foot $ .41 = _____

_____ feet - 2 1/2" Well Pipe at - per foot $ .81 = _____

_____ feet - 3" Well Pipe at - per foot $1.25 = _____

_____

SALES EXPENSES

Advertising	_____	_____
Freight	_____	_____
Commission	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

_____

_____

PROFIT

_____

Operating Capital

The only remaining factor to be determined is the amount of Operating Capital. The basis for the estimate of this capital is given below:

Raw Inventory -- See page 22 (Pumps and Windmill Units only)	$37,062
In-process Inventory -- 2 days' production	1,468
Finished Goods Inventory -- 30 days' production	22,020
Accounts Receivable -- 30 days' production	22,020
Expenses for one month (22 days)	
Wages -- 35 x 8 x 22 x $.30 = $1,850	
Utilities -- 4 weeks at $125 = 500	2,350
Operating Capital -- excluding Well Pipe	$84,920
(Use a rounded-off figure of	$85,000)

(See note re Well Pipe under RESULTS)

90 days' Raw Inventory -- Well Pipe only	$223,200
(This is also used as Finished Goods Inventory since only a few minutes' work is required to cut and thread the ends)	
Operating Capital -- including Well Pipe	$308,120
(Use a rounded-off figure of	$308,000)

CONCLUSIONS:

We have specified the building and equipment to produce simple pumps and windmill head units in under-developed countries. These units could be redesigned in more complicated and possibly more efficient form and still be produced with the equipment specified, but in reduced quantities per day. The productive capacity can be greatly increased by the addition of a few machines and necessary floor area.

The equipment is well balanced, and other similar items may be produced at some future date, if required. The plan outlined is flexible and easily adapted to changed conditions.

January 4, 1954

Methods Engineering Council
Pittsburgh 21, Pennsylvania

PUMPS AND WINDMILL UNITS

(Not Including Well Pipe)

ASSETS		
Current Assets		
Cash		
Accounts Receivable	$22,020	
Inventories		
Raw Materials	37,062*	
In-Process	1,468	
Finished Goods	22,020	
Fixed Assets		
Building	36,000	
Depreciation per year		2,400
Non-durable Tools	9,320	
Depreciation per year		4,660
Office Equipment	2,000	
Depreciation per year		400
Production Equipment - I	35,300	
Depreciation per year		3,530
Production Equipment - II	9,640	
Depreciation per year		1,928
Land		
OPERATING ACCOUNTS		
Income		
Sales - See Chart C		
Expenses		
Purchases		
Office Supplies	2,600	
Raw Materials	152,000*	
Wages		
35 x 8 x 5 x $.30 x 52	21,840	
Power, light, heat, and water	6,500	
Sales Expenses - See Chart C	_____	
General		
Depreciation	12,918	
Administration (Included in Wages)		
Other	_____	

* If well pipe is included, these figures are replaced by:

Inventories - Raw Materials - $260,000
Purchases - Raw Materials - $772,000