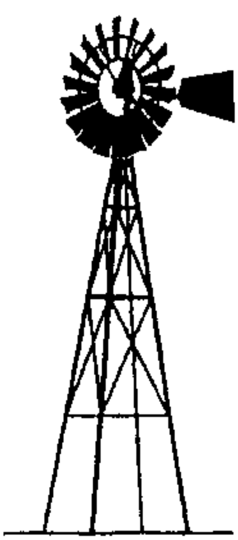
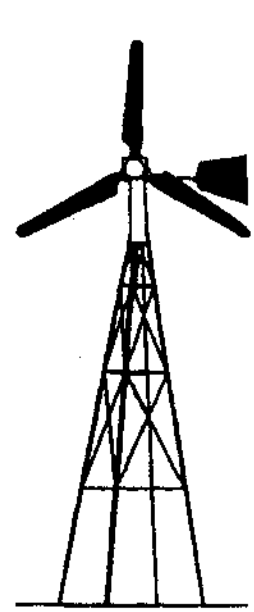
The Penryn Windmill Book





Peterborough,
Ontario, Canada

March 1, 1995

Dear Reader,

Thank you for buying this book. I do hope that it will be of use to you, as it took me six long weary years to write. Actually, I look back on it as six years of great challenge and total fascination!

You will find that we offer some seven principle designs, most of which I actually built and tested myself in North Pakistan, during my two year sojourn there as a "Windmill Expert".

None of these designs are new, by the way. None of them are my own invention. They are all very old types, tried and true. I have simply dug up the necessary material about how to make them from libraries and from old people who were there and who knew what they were talking about.

You can be sure, therefore, that they will all work, as long as you stick to the general principle of each plan. Obviously, though, you are expected to take advantage of the many alternatives within each design idea. Such decisions will be up to yourself and will be made according to what materials you can find locally and what you can afford.

Besides the eighty odd full page plates, or illustrations, which I think cover every single practical aspect of the text, you will find theoretical and factual suggestions on such subjects as background history, model comparatives, pump making, electrical principles, storage battery lore, tower construction, site selection and feasibility guidelines, and many other fascinating subjects as well as mathematical formulas to calculate power and efficiency and some not so mathematical ways of calculating wind speed.

Good luck to you!

Patrick Arnoldi

PENRYN FARM

PENRYN WINDMILLS

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Metric conversion charts

Metric prefixes and abbreviations

The metre is used as an example below. The same prefixes apply to litres (l or lit) and grams (g). The abbreviation lit is used for litre when unqualified to avoid confusion with the numeral 1.

millimetre (mm)	0.001	one thousandth metre
centimetre (cm)	0.01	one hundredth metre
decimetre (dm)	0.1	one tenth metre
metre (m)	1	one metre
decametre (dam)	10	ten metres
hectometre (hm)	100	one hundred metres
kilometre (km)	1000	one thousand metres

Length (linear measure)

Fractions of 1 inch in millimetres

Thirty-seconds, sixteenths, eighths, quarters and one half

in	*mm*
1/32	0.8
1/16	1.6
3/32	2.4
1/8	3.2
5/32	4.0
3/16	4.8
7/32	5.6
1/4	6.3
9/32	7.1
5/16	7.9
11/32	8.7
3/8	9.5
13/32	10.3
7/16	11.1
15/32	11.9
1/2	12.7
17/32	13.5
9/16	14.3
19/32	15.1
5/8	15.9
21/32	16.7
11/16	17.5
23/32	18.3
3/4	19.0
25/32	19.8
13/16	20.6
27/32	21.4
7/8	22.2
29/32	23.0
15/16	23.8
31/32	24.6
1 inch	25.4

Twelfths, sixths and thirds

in	*mm*
1/12	2.1
1/6	4.2
1/4	6.3
1/3	8.5
5/12	10.6
1/2	12.7
7/12	14.8
2/3	16.9
3/4	19.0
5/6	21.2
11/12	23.3
1 inch	25.4

Note

Find the Imperial figure you wish to convert in the **heavy** type central column and read off the metric equivalent in the right-hand column and vice versa.
For example:
10 inches = 254 millimetres and 10mm = 0.39in.

Conversion from inches is only taken up to 40 in the chart below, see next chart for continuation.

Inches/millimetres

in		*mm*
0.04	**1**	25.4
0.08	**2**	50.8
0.12	**3**	76.2
0.16	**4**	101.6
0.20	**5**	127.0
0.24	**6**	152.4
0.28	**7**	177.8
0.31	**8**	203.2
0.35	**9**	228.6
0.39	**10**	254.0
0.43	**11**	279.4
0.47	**12**	304.8
0.51	**13**	330.2
0.55	**14**	355.6
0.59	**15**	381.0
0.63	**16**	406.4
0.67	**17**	431.8
0.71	**18**	457.2
0.75	**19**	482.6
0.79	**20**	508.0
0.83	**21**	533.4
0.87	**22**	558.8
0.91	**23**	584.2
0.94	**24**	609.6
0.98	**25**	635.0
1.02	**26**	660.4
1.06	**27**	685.8
1.10	**28**	711.2
1.14	**29**	736.6
1.18	**30**	762.0
1.22	**31**	787.4
1.26	**32**	812.8
1.30	**33**	838.2
1.34	**34**	863.6
1.38	**35**	889.0
1.42	**36**	914.4
1.46	**37**	939.8
1.50	**38**	965.2
1.54	**39**	990.6
1.57	**40**	1016.0
1.97	**50**	
2.36	**60**	
2.76	**70**	
3.15	**80**	
3.54	**90**	
3.94	**100**	
7.87	**200**	
11.81	**300**	
15.75	**400**	
19.68	**500**	
23.62	**600**	
27.56	**700**	
31.50	**800**	
35.43	**900**	
39.37	**1000**	

Imperial measurements are expressed below in yards, feet and inches rather than in decimals for convenience if converting with rulers or measuring tapes which do not include decimal readings.

Feet/metres

ft	*in*		*m*
3	3	**1**	0.30
6	7	**2**	0.61
9	10	**3**	0.91
13	1	**4**	1.22
16	5	**5**	1.52
19	8	**6**	1.83
23	0	**7**	2.13
26	3	**8**	2.44
29	6	**9**	2.74
32	10	**10**	3.05
65	7	**20**	6.10
98	5	**30**	9.14
131	3	**40**	12.19
164	0	**50**	15.24
196	10	**60**	18.29
229	8	**70**	21.34
262	6	**80**	24.38
295	3	**90**	27.43
328	1	**100**	30.48

Yards/metres

yd	*ft*	*in*		*m*
1	0	3	**1**	0.9
2	0	7	**2**	1.8
3	0	10	**3**	2.7
4	1	1	**4**	3.7
5	1	5	**5**	4.6
6	1	8	**6**	5.5
7	2	0	**7**	6.4
8	2	3	**8**	7.3
9	2	6	**9**	8.2
10	2	10	**10**	9.1
21	2	7	**20**	18.3
32	2	5	**30**	27.4
43	2	3	**40**	36.6
54	2	0	**50**	45.7
65	1	10	**60**	54.9
76	1	8	**70**	64.0
87	1	6	**80**	73.2
98	1	3	**90**	82.3
109	1	1	**100**	91.4

Quick conversion factors – length

Terms are set out in full in the left-hand column except where clarification is necessary.

1 inch (in)	= 25.4mm/2.54cm
1 foot (ft)/12in	= 304.8mm/30.48cm/0.3048m
1 yard (yd)/3ft	= 914.4mm/91.44cm/0.9144m
1 mile (mi)/1760yd	= 1609.344m/1.609km
1 millimetre (mm)	= 0.0394in
1 centimetre (cm)/10mm	= 0.394in
1 metre (m)/100cm	= 39.37in/3.281ft/1.094yd
1 kilometre (km)/1000m	= 1093.6yd/0.6214mi

Quick conversion factors – area

1 square inch (sq in)	= 645.16sq mm/ 6.4516sq cm
1 square foot (sq ft)/144sq in	= 929.03sq cm
1 square yard (sq yd)/9sq ft	= 8361.3sq cm/ 0.8361sq m
1 acre (ac)/4840sq yd	= 4046.9sq m/0.4047ha
1 square mile (sq mi)640ac	= 259ha
1 square centimetre (sq cm)/ 100 square millimetre (sq mm)	= 0.155sq in
1 square metre (sq m)/ 10,000sq cm	= 10.764sq ft/1.196sq yd
1 are (a)/100sq m	= 119.60sq yd/0.0247ac
1 hectare (ha)/100a	= 2.471ac/0.00386sq mi

Quick conversion factors – volume

1 cubic inch (cu in)	= 16.3871cu cm
1 cubic foot (cu ft)/ 1728cu in	= 28.3168cu dm/0.0283cu m
1 cubic yard (cu yd)/ 27cu ft	= 0.7646cu m
1 cubic centimetre (cu cm)/ 1000 cubic millimetres (cu mm)	= 0.0610cu in
1 cubic decimetre (cu dm)/ 1000cu cm	= 61.024cu in/0.0353cu ft
1 cubic metre (cu m)/ 1000cu dm	= 35.3146cu ft/1.308cu yd
1cu cm	= 1 millilitre (ml)
1cu dm	= 1 litre (lit) See **Capacity**

Area (square measure)

As millimetre numbers would be unwieldy for general use, square or cubic inches have been converted to square or cubic centimetres. Conversion from square inches is only taken up to 150 in the first chart below; see next chart for continuation.

Square inches/square centimetres

sq in		*sq cm*
0.2	**1**	6.5
0.3	**2**	12.9
0.5	**3**	19.4
0.6	**4**	25.8
0.8	**5**	32.3
0.9	**6**	38.7
1.1	**7**	45.2
1.2	**8**	51.6
1.4	**9**	58.1
1.6	**10**	64.5
3.1	**20**	129.0
4.7	**30**	193.5
6.2	**40**	258.1
7.8	**50**	322.6
9.3	**60**	387.1
10.9	**70**	451.6
12.4	**80**	516.1
14.0	**90**	580.6
15.5	**100**	645.2
17.1	**110**	709.7
18.6	**120**	774.2
20.2	**130**	838.7
21.7	**140**	903.2
23.3	**150**	967.7
31.0	**200**	
46.5	**300**	
62.0	**400**	
77.5	**500**	
93.0	**600**	
108.5	**700**	
124.0	**800**	
139.5	**900**	
155.0	**1000**	

Square feet/square metres

sq ft		*sq m*
10.8	**1**	0.09
21.5	**2**	0.19
32.3	**3**	0.28
43.1	**4**	0.37
53.8	**5**	0.46
64.6	**6**	0.56
75.3	**7**	0.65
86.1	**8**	0.74
96.9	**9**	0.84
107.6	**10**	0.93
215.3	**20**	1.86
322.9	**30**	2.79
430.6	**40**	3.72
538.2	**50**	4.65
645.8	**60**	5.57
753.5	**70**	6.50
861.1	**80**	7.43
968.8	**90**	8.36
1076.4	**100**	9.29

Square yards/square metres

sq yd		*sq m*
1.2	**1**	0.8
2.4	**2**	1.7
3.6	**3**	2.5
4.8	**4**	3.3
6.0	**5**	4.2
7.2	**6**	5.0
8.4	**7**	5.9
9.6	**8**	6.7
10.8	**9**	7.5
12.0	**10**	8.4
23.9	**20**	16.7
35.9	**30**	25.1
47.8	**40**	33.4
59.8	**50**	41.8
71.8	**60**	50.2
83.7	**70**	58.5
95.7	**80**	66.9
107.6	**90**	75.3
119.6	**100**	83.6

Volume (cubic measure)

Cubic inches/cubic centimetres

cu in		*cu cm*
0.06	**1**	16.4
0.12	**2**	32.8
0.18	**3**	49.2
0.24	**4**	65.5
0.31	**5**	81.9
0.37	**6**	98.3
0.43	**7**	114.7
0.49	**8**	131.1
0.55	**9**	147.5
0.61	**10**	163.9
1.22	**20**	327.7
1.83	**30**	491.6
2.44	**40**	655.5
3.05	**50**	819.4
3.66	**60**	983.2
4.27	**70**	1147.1/1.15cu dm
4.88	**80**	1311.0/1.31cu dm
5.49	**90**	1474.8/1.47cu dm
6.10	**100**	1638.7/1.64cu dm
12.20	**200**	3277.4/3.28cu dm
18.31	**300**	4916.1/4.92cu dm
24.41	**400**	6554.8/6.55cu dm
30.51	**500**	8193.5/8.19cu dm
36.61	**600**	9832.2/9.83cu dm
42.72	**700**	11470.9/11.47cu dm
48.82	**800**	13109.7/13.11cu dm
54.92	**900**	14748.4/14.75cu dm
61.02	**1000**	16387.1/16.39cu dm
122.05	**2000**	32774.1/32.77cu dm

Cubic feet/cubis decimetres

cu ft		*cu dm*
.04	**1**	28.3
0.07	**2**	56.6
0.11	**3**	85.0
0.14	**4**	113.3
0.18	**5**	141.6
0.21	**6**	169.9
0.25	**7**	198.2
0.28	**8**	226.5
0.32	**9**	254.9
0.35	**10**	283.2
0.71	**20**	566.3
1.06	**30**	849.5
1.41	**40**	1132.7/1.13cu m
1.77	**50**	1415.8/1.42cu m
2.12	**60**	1699.0/1.70cu m
2.47	**70**	1982.2/1.98cu m
2.83	**80**	2265.3/2.27cu m
3.18	**90**	2548.5/2.55cu m
3.53	**100**	2831.7/2.83cu m

Cubic yards/cubic metres

cu yd		*cu m*
1.3	**1**	0.8
2.6	**2**	1.5
3.9	**3**	2.3
5.2	**4**	3.1
6.5	**5**	3.8
7.8	**6**	4.6
9.2	**7**	5.4
10.5	**8**	6.1
11.8	**9**	6.9
13.1	**10**	7.6
26.2	**20**	15.3
39.2	**30**	22.9
52.3	**40**	30.6
65.4	**50**	38.2
78.5	**60**	45.9
91.6	**70**	53.5
104.6	**80**	61.2
117.7	**90**	68.8
130.8	**100**	76.5

Capacity

Fluid ounces/millilitres

fl oz		
0.04	**1**	28.4
0.07	**2**	56.8
0.11	**3**	85.2
0.14	**4**	113.6
0.18	**5**	142.1
0.21	**6**	170.5
0.25	**7**	198.9
0.28	**8**	227.3
0.32	**9**	255.7
0.35	**10**	284.1
0.70	**20**	568.2
1.06	**30**	852.4
1.41	**40**	1136.5/1.136 lit
1.76	**50**	1420.6/1.421 lit

Pints/litres

pt		*lit*
1.8	**1**	0.6/568ml
3.5	**2**	1.1
5.3	**3**	1.7
7.0	**4**	2.3
8.8	**5**	2.8
10.6	**6**	3.4
12.3	**7**	4.0
14.1	**8**	4.5
15.8	**9**	5.1
17.6	**10**	5.7

Gallons/litres

gal		*lit*
0.2	**1**	4.5
0.4	**2**	9.1
0.7	**3**	13.6
0.9	**4**	18.2
1.1	**5**	22.7
1.3	**6**	27.3
1.5	**7**	31.8
1.8	**8**	36.4
2.0	**9**	40.9
2.2	**10**	45.5
4.4	**20**	90.9
6.6	**30**	136.4
8.8	**40**	181.8
11.0	**50**	227.3
13.2	**60**	272.8
15.4	**70**	318.2
17.6	**80**	363.7
19.8	**90**	409.1
22.0	**100**	454.6

Weight

Ounces/grams

oz		*g*
0.04	**1**	28.3
0.07	**2**	56.7
0.11	**3**	85.0
0.14	**4**	113.4
0.18	**5**	141.7
0.21	**6**	170.1
0.25	**7**	198.4
0.28	**8**	226.8
0.32	**9**	255.1
0.35	**10**	283.5
0.39	**11**	311.8
0.42	**12**	340.2
0.46	**13**	368.5
0.49	**14**	396.9
0.53	**15**	425.2
0.56	**16**	453.6
0.71	**20**	567.0
1.06	**30**	850.5
1.41	**40**	1134.0
1.76	**50**	1417.5
2.12	**60**	1701.0
2.47	**70**	1984.5
2.82	**80**	2268.0
3.17	**90**	2551.5
3.53	**100**	2835.0

Pounds/kilograms

lb		*kg*
2.2	**1**	0.5
4.4	**2**	0.9
6.6	**3**	1.4
8.8	**4**	1.8
11.0	**5**	2.3
13.2	**6**	2.7
15.4	**7**	3.2
17.6	**8**	3.6
19.8	**9**	4.1
22.0	**10**	4.5
44.1	**20**	9.1
66.1	**30**	13.6
88.2	**40**	18.1
110.2	**50**	22.7
132.3	**60**	27.2
154.3	**70**	31.8
176.4	**80**	36.3
198.4	**90**	40.8
220.5	**100**	45.4

Quick conversion factors – capacity

1 fluid ounce (fl oz)	= 28.4ml
1 gill (gi)/5fl oz	= 142.1ml
1 pint (pt)/4gi	= 568.2ml/0.568 lit
1 quart (qt)/2pt	= 1.136 lit
1 gallon (gal)/4pt	= 4.546 lit
1 millilitre (ml)	= 0.035fl oz
1 litre (lit)	= 1.76pt/0.22gal
1ml	= 1 cubic centimetre (cu cm)
1 lit	= 1 cubic decimetre (cu dm) See **Volume**
1 US pint	= 5/6 Imperial pt/473.2ml/0.473 lit
1 US gallon	= 5/6 Imperial gal/3.785 lit

Quick conversion factors – weight

1 ounce (oz)	= 28.35g
1 pound (lb)/16oz	= 453.59g/0.4536kg
1 stone/14lb	= 6.35kg
1 hundredweight (cwt)/ 8 stone/112lb	= 50.80kg
1 ton/20cwt	= 1016.05kg/1.016t
1 gram (g)	= 0.035oz
1 kilogram (kg)/1000g	= 35.274oz/2.2046lb/ 2lb 3.274oz
1 tonne (t)/1000kg	= 2204.6lb/0.9842 ton

Metric conversion tables

			Millimetres to Inches		Inches to Millimetres	
Inches	Decimals	Millimetres	mm	Inches	Inches	mm
1/64	0.015625	0.3969	0.01	0.00039	0.001	0.0254
1/32	0.03125	0.7937	0.02	0.00079	0.002	0.0508
3/64	0.046875	1.1906	0.03	0.00118	0.003	0.0762
1/16	0.0625	1.5875	0.04	0.00157	0.004	0.1016
5/64	0.078125	1.9844	0.05	0.00197	0.005	0.1270
3/32	0.09375	2.3812	0.06	0.00236	0.006	0.1524
7/64	0.109375	2.7781	0.07	0.00276	0.007	0.1778
1/8	0.125	3.1750	0.08	0.00315	0.008	0.2032
9/64	0.140625	3.5719	0.09	0.00354	0.009	0.2286
5/32	0.15625	3.9687	0.1	0.00394	0.01	0.254
11/64	0.171875	4.3656	0.2	0.00787	0.02	0.508
3/16	0.1875	4.7625	0.3	0.01181	0.03	0.762
13/64	0.203125	5.1594	0.4	0.01575	0.04	1.016
7/32	0.21875	5.5562	0.5	0.01969	0.05	1.270
15/64	0.234375	5.9531	0.6	0.02362	0.06	1.524
1/4	0.25	6.3500	0.7	0.02756	0.07	1.778
17/64	0.265625	6.7469	0.8	0.03150	0.08	2.032
9/32	0.28125	7.1437	0.9	0.03543	0.09	2.286
19/64	0.296875	7.5406	1	0.03937	0.1	2.54
5/16	0.3125	7.9375	2	0.07874	0.2	5.08
21/64	0.328125	8.3344	3	0.11811	0.3	7.62
11/32	0.34375	8.7312	4	0.15748	0.4	10.16
23/64	0.359375	9.1281	5	0.19685	0.5	12.70
3/8	0.375	9.5250	6	0.23622	0.6	15.24
25/64	0.390625	9.9219	7	0.27559	0.7	17.78
13/32	0.40625	10.3187	8	0.31496	0.8	20.32
27/64	0.421875	10.7156	9	0.35433	0.9	22.86
7/16	0.4375	11.1125	10	0.39370	1	25.4
29/64	0.453125	11.5094	11	0.43307	2	50.8
15/32	0.46875	11.9062	12	0.47244	3	76.2
31/64	0.484375	12.3031	13	0.51181	4	101.6
1/2	0.5	12.7000	14	0.55118	5	127.0
33/64	0,515625	13.0969	15	0.59055	6	152.4
17/32	0.53125	13.4937	16	0.62992	7	177.8
35/64	0.546875	13.8906	17	0.66929	8	203.2
9/16	0.5625	14.2875	18	0.70866	9	228.6
37/64	0.578125	14.6844	19	0.74803	10	254.0
19/32	0.59375	15.0812	20	0.78740	11	279.4
39/64	0.609375	15.4781	21	0.82677	12	304.8
5/8	0.625	15.8750	22	0.86614	13	330.2
41/64	0.640625	16.2719	23	0.90551	14	355.6
21/32	0.65625	16.6687	24	0.94488	15	381.0
43/64	0.671875	17.0656	25	0.98425	16	406.4
11/16	0.6875	17.4625	26	1.02362	17	431.8
45/64	0.703125	17.8594	27	1.06299	18	457.2
23/32	0.71875	18.2562	28	1.10236	19	482.6
47/64	0.734375	18.6531	29	1.14173	20	508.0
3/4	0.75	19.0500	30	1.18110	21	533.4
49/64	0.765625	19.4469	31	1.22047	22	558.8
25/32	0.78125	19.8437	32	1.25984	23	584.2
51/64	0.796875	20.2406	33	1.29921	24	609.6
13/16	0.8125	20.6375	34	1.33858	25	635.0
53/64	0.828125	21.0344	35	1.37795	26	660.4
27/32	0.84375	21.4312	36	1.41732	27	685.8
55/64	0.859375	21.8281	37	1.4567	28	711.2
7/8	0.875	22.2250	38	1.4961	29	736.6
57/64	0.890625	22.6219	39	1.5354	30	762.0
29/32	0.90625	23.0187	40	1.5748	31	787.4
59/64	0.921875	23.4156	41	1.6142	32	812.8
15/16	0.9375	23.8125	42	1.6535	33	838.2
61/64	0.953125	24.2094	43	1.6929	34	863.6
31/32	0.96875	24.6062	44	1.7323	35	889.0
63/64	0.984375	25.0031	45	1.7717	36	914.4

CHAPTER ONE

DESIGN RELATIONSHIPS

The Penryn Windmills are designed to be constructed with whatever materials are available in the builder's locality, or with whatever materials the builder can afford.

It may therefore be possible, or even desirable, to replace parts of one design with details or parts from another. As all of the designs have been created with this interchangeability in mind, the following table of relationships is presented.

THE WOODEN MULTIBLADE can be built entirely of wood, with the exception of the gas pipe axle, or it can make use of some, or many metal parts as follows:

(A) THE WOODEN BEARINGS (plate no. 15), can be made from teflon or they can be replaced with metal bearings (plate no. 16).

(B) The WOODEN MAIN HUB (plate no. 6), and wooden back-up hub (plate no. 7), can be replaced with metal hubs (plate no. 17), or with big truck fan blades as in plate no. 54, or steel drum tops as in plate no. 55, (fig. 5).

(C) The WOODEN ECCENTRIC (plates no. 19, 20, 21, 22 and 23), can be made entirely, or in part, from teflon, using the same design, or it can be replaced with one of the metal crank shafts shown in plate no. 25, plate no. 28, (fig. 5 and 6), plate no. 55 (fig. 2), plate no. 59, (fig. 2), or plate no. 60, (fig. 4).

Also, there can be an adaptation made with the LEVER-CRANK shown in plate no. 56. The Lever-Crank can be used in conjunction with the eccentric and placed at the bottom of the tower over the pump.

The eccentric, if it is set directly on the windshaft axle, should be used only with the 35 blade fan (plates 8 and 9), because that fan is slower turning and requires no gear-down, (see introductory principles).

(D) The WOODEN ECCENTRIC (plates no. 19, 20, 21, 22 and 23), can also be replaced with the right angle drives shown in plates no. 26, 28, 29, 30, 31, 32, 57, and 81.

This would be more sensible, however, with the faster turning 18 blade fan illustrated in plates no. 8 and 9. The fast turning metal multiblades illustrated in plates 33 through to 36, will also adapt well to right angle drives.

(E) The 36 Blade WOODEN SAILS (plate no. 8), can be made from vinyl (plastic), or sheet metal using the same design, or they can be made from sections of steel drum as illustrated in plates no. 33 (fig. 3). All of these sail designs can be mounted on either wooden or metal frames. It should be noted that steel drums have a near to perfect aeronautical curve.

As it is slower turning than the 18 blade, (plates 11 and 12), or the 15 blade, (plates 33 and 34), of the same diameter, it is best adapted to eccentrics and cranks, (see "C" above), that are set directly on the windshaft axle. It can, however, be geared down for slower mechanical work as illustrated in plate 22, or geared up for electrical work as illustrated in plates 66 through to 72.

(F) The WOODEN SAIL FRAMES on both the 36 blade and 18 blade wooden multiblade (plates 8, 9, 10, 11, and 12), can be replaced by metal sail frames as illustrated in plates no. 33, 34 and 35. It should be noted, however, that metal hubs should be used with metal frames.

(G) The 18 blade WOODEN SAILS (plates no. 11 and 12), can be made of the same materials as the 36 blade sails, (see "E" above). This design, however, turns too quickly to adapt to eccentrics and cranks mounted directly on the windshaft axle, (see "C" above).

As it has a blade surface area almost equal to that of the 15 blade metal multiblade of the same diameter illustrated in plates no. 33 and 34, it will do about the same amount of work at about the same speed.

It is best adapted to gearing down for mechanical work (plate no. 22), or gearing up for electrical work (plates no. 66 through to 72).

(H) The WOODEN AND METAL MULTIBLADE SAILS AND FRAMES (plates no. 8, 9, 10, 11, 12, 33, 34, 35 and 36), on the wooden locating table (plates no. 3, 4 and 5), can also be replaced with the rotor blades angled by wedges illustrated in plates no. 39, 40, 41, 42, 43 and 44. This, of course, should only be done if the generation of electrical energy, as opposed to mechanical energy, is the singular interest.

(I) The TAIL VANE "SHUT OFF" MECHANISM illustrated in plates no. 13 and 14, is applicable to every multiblade and rotor design in this book.

(J) The WOODEN TAIL VANE illustrated in plate no. 14 (fig. 4, 5, 6, 7 and 8), can be replaced with the metal tail vanes illustrated in plates 5 (fig. 1, 2, 3 and 4), plate no. 14, (fig. 1, 2, and 3), plate no. 32, (fig. 1) and plate no. 36.

(K) The SPROCKETS illustrated in plate no. 24, can be replaced by sprockets mounted on the metal hubs illustrated in plate no. 17, using solid steel axles.

(L) For MECHANICAL WORK, the metal rotating table illustrated in plates no. 31 and 32, is designed to make use of the Multiblade Sails illustrated in plates no. 8, 11, 33 and 35.

For the same purpose, the wooden or metal multiblade sails can be replaced with the sail windmill sails of up to 15 foot diameter, as illustrated in plates no. 8, 11, 33 and 35.

Another alternative is the application of big truck fan blade and steel drum sails illustrated in plate no. 54. See also the right angle drive application illustrated in plate no. 26.

(M) For ELECTRICAL APPLI-CATIONS, the metal rotating table illustrated in plates no. 31 and 32, should be adapted as shown in plate no. 68. It should then be mounted with the rotor blades angled by wedges illustrated in plates no. 39, 40 and 41. This would also require implementation of the electrical connections illustrated in plates no. 66 through to 75.

The sail windmill sails of up to 15 foot diameter as illustrated in plates no. 49, 50 and 51, can also be mounted on the metal rotating table, (plates no. 31 and 32), for the generation of electricity.

For seven foot diameter rotors, use the tail vanes illustrated in plates no. 5 and 14.

For 14 to 15 foot diameter rotors, use the tail vanes illustrated in plate no. 32, (fig. 1), and plate no. 36.

See also the right angle drive application illustrated in plate no. 26.

(N) The SAIL WINDMILLS, illustrated in plates no. 48 through to 53, of up to 30 foot diameter, are designed to be mounted on the wood rotating table illustrated in plates no. 1, 3, 4, 5, (fig. 2), 14, (fig. 5), 21, (fig. 3, 4, 5, 6 and 7, 22, 23 and 30, (fig. 1, and 66).

Sail Windmills of up to 15 foot diameter can be mounted on the metal rotating table illustrated in plates no. 30, 31, 32, 68 and 70, using the hub illustrated in plates no. 52 and 17.

(O) The METAL ROTATING TABLE illustrated in plates no. 31 and 32, is designed to use the eight diameter metal multiblade sails illustrated in plates no. 3, 34, 35 and 36, as well as the 13 foot diameter metal multiblade sails illustrated in plate no. 35.

It can also be powered by the wooden sails and frames illustrated in plates no. 8 through to 12. These can be mounted on the metal hubs illustrated in plate no. 17, or on the wooden hubs illustrated in plates no. 6, 7 and 8, (fig. 3).

It can also be powered by the sail windmill sails of up to 15 foot diameter as illustrated in plates no. 48 to 53. If this is done, the hubs to be used should be those illustrated in plates no. 17 and 53.

(P) The ROTOR BLADES illustrated in plates 37 through to 47, can be replaced by "sock types" constructed in the manner of the sail windmill tail vane illustrated in plate no. 53.

A "sock" is simply a canvas bag of the proper shape stretched over a metal frame, as in plate no. 53, (fig. 1 and 2).

The frame can be made in the same shape as the rotor blades illustrated in plate 42, (fig. 1 or fig. 2). The frame is, of course, set in the Hub at the proper angle (15° or 11°), to give the required pitch.

Once in place, the canvas "socks", or covers, should be given two or three coats of heavy paint to keep them rigid.

This is a very common practice in the construction of windmill sails.

(Q) The TAIL VANE SPRINGS illustrated in plates 13, (fig. 3, 4 and 5), 31, (fig 1), and 68, (fig 1), can be replaced with the Counter Weight illustrated in plate no. 58, (fig. 1 - lower right corner). Care must, of course, be taken that the counter weight does not blow around too wildly in the wind. This can be accomplished by means of a vertical rod, with rings surrounding the rope and counter weight, extending downward from the tail vane bar. The advantage is that the counter weight will not wear out, whereas the spring will.

(R) The LOWER RIGHT ANGLE DRIVE illustrated in plates no. 26 and 30, (fig. 1), can be replaced with the axle and pulley system illustrated in plate no. 59, (fig. 5).

(S) The BIG TRUCK FAN BLADE AND STEEL DRUM SAILS illustrated in plate no. 54, can be used on the wooden rotating table, plates no. 3, 4, 5, 13, 14, 21, 22, 23, 26, 30 and etc.

It can also be used on the metal rotating table illustrated in plates no. 30, 31, 32 etc.

It can also be used on the saw horse windmill as illustrated in plate no. 55.

(T) The SAW HORSE WINDMILL SAILS as illustrated in plate no. 55, can be replaced with:

I - The 36-blade wooden multiblade sails as illustrated in plates no. 8, 9 and 10.

II - The 18-blade wooden multiblade sails as illustrated in plates no. 11 and 12.

III - The 8-foot metal multiblade sails as illustrated in plates no. 33 and 34.

IV - The 13-foot diameter metal multiblade sails as illustrated in plate no. 35.

V - The rotor blades as illustrated in plates no. 37 through to 47. (Note the sock alternative described in "Design Relationships" (P1).

VI - The sail windmill sails up to 15-foot diameter as illustrated in plates no. 48 through to 53.

VII - The big truck fan blade and steel drum sails as illustrated in plate no. 54.

(U) The SAW HORSE WINDMILL CRANK as illustrated in plate no. 55, can be replaced with:

I - The Eccentric as illustrated in plates no. 19, 20 and 21.

II - (By breaking the axle in the centre and reshaping the "saw horse" accordingly), the crankshafts as illustrated in plates no. 25 and 28, (fig. 2 and fig. 3) and 60, (fig. 4).

(V) The SAWHORSE WINDMILL LEVER-CRANK as illustrated in plate no 56, can be used in conjunction with any design in which there is a need to increase the power of vertical, (sucker rod or eccentric) action. It is most highly recommended for use with the 36-blade multiblade (without gear down), as illustrated in plates no. 8 and 9.

(W) The BELL CRANK as illustrated in plate 59, (fig. 2 and fig. 3), can be used with any design where it is necessary to convert horizontal rotary action to vertical up and down action. The bell crank can be used in conjunction with the lever-crank as illustrated in plate no. 56.

(X) The design relationships and possible design component interchanges in the polish windmill section (plates no. 57 through to 60), are contained within the section itself.

(Y) The design relationships and possible design component interchanges in the pump plans (plates no. 61 through to 65), the electrical connections (plates no. 66 through to 75), and the tower construction (plates no. 76 through to 82), sections, speak for themselves.

(Z) The FOUR BLADE rotor of up to 14 foot diameter with a fifteen degree pitch (plates no. 37 through to 47), can be built onto a direct drive shaft connection (plate no. 26 or plate no. 31). If built onto the metal rotating table (plate no. 31), it can be mounted on the post tower (plate no. 81, fig. 3).

This will create a faster rotating water pumper than a multiblade, which can be connected to a pressure pump (plates no. 61 through to 65 - see note attached), for overhead sprinkler irrigation.

It can also be used for electrical production with a generator at ground level. The disadvantage is that the operator must climb the tower to work the shut off pull rope.

A four blade rotor with a fifteen degree pitch will start sooner, develop more bottom end torque, and be less likely to overrun than a three blade rotor with an 11° pitch. It is therefore more amenable to mechanical work.

CHAPTER TWO

INTRODUCTORY PRINCIPLES AND GENERAL DESCRIPTION OF WIND MACHINE TYPES

Most scholars agree that windmills were "invented" by either the Chinese, the Babylonians or the Persians some 2,000 years ago. These were simple canvas-sail powered, vertical axis machines used for the pumping of irrigation water. The principle was, in fact, similar to that of the Polish Windmill illustrated in plates no. 57 through to 60.

Horizontal axis machines seem to have been developed in the South Mediterranean area by about 1,000 A.D. and were introduced to North Europe by the returning crusaders in 1,100 A.D. By the advent of the fourteenth century, windmills had become widely distributed throughout England and neighbouring countries.

They were mostly what were called "post-mills", large cabin like structures, containing the mill house surrounded by the wind shaft, and sails that were manually rotated, or swivelled, on a single upright post. Of course, the post had to be very strong and well supported. In turn, the size of the mill house, and hence the size and work capability of the sails, were restricted by the size and strength of the post. This design changed very little over the next 600 years. Some that were built during the 1800's still survive.

The next, and really the final, development of the European wind machine was the "tower mill" introduced by the Dutch in the early 1400's. It consisted of a tower, which could be of any height and of any number of floors, surmounted by a rotating cap which supported the wind shaft and sails. This was soon augmented by the invention of the "fan tail" which rotated the sails into the wind.

The fan tail was a small multivane wind wheel, set on the axis at 90° to the main wind shaft. When the wind was blowing straight onto the main sails, the fan tail was shielded and did not turn. When the wind shifted, the exposed fan tail rotated, driving a set of wheels geared down by several thousand to one, which caused the cap to turn, facing the sails again into the wind.

The sails consisted of wooden lath frameworks called "stocks", fixed to the radial arms. Canvas covers were adjusted over these stocks according to the speed of the wind and the desired revolutions per minute of the sails.

For nearly 300 years, the Dutch relied upon some 10,000 tower windmills to grind grain, pump water, make paper and saw lumber. The industrial revolution and the advance of steam after 1750, pushed these picturesque landmarks into decline so that by 1900, only 2,500 were left. There are now about 900 at most.

The real boom in American windmills, however, came in the late 1860's with the development of the factory made, almost indestructible farm type multiblade water pumping windmill with its standardized parts that could be erected by almost anyone in a couple of days.

They were called "multiblades" because they had fifteen or more sheet metal blades, all of them curved and all of them pitched at 30° to the plane of rotation, perpendicular, or 90° to the axle or windshaft.

The tail vane, located down wind from the blades, kept the blades facing into the wind, (just as it does on rotor type wind generators). This vane was opened or closed by a person standing on the ground pulling on, or cranking on, a rope. When the blades were turning, the tail vane was held "open" in line with the axle by a spring mechanism. That is to say that the spring held the vane at right angles to the blade's plane of rotation. When shut off, or "closed", the tail vane was pulled in the manner of a hinged gate, to a position 90° to the axle, parallel to the blades. The tail vane then acted as a weather vane and swung the blades 90° to the wind which would stop them turning, (see plate no. 5).

These wonderful, all metal machines, were so durable that once a farmer bought one he might never have to replace it. The old farm multiblades filled water tanks for steam locomotives, watered livestock and irrigated land. They also filled the upstairs water reservoirs of Victorian country houses giving them indoor plumbing and flush toilets for the first time ever.

Sold by mail order companies and itinerant tradesmen, there were 6,000,000 of them in operation by the late 1930's.

As their forbears were destroyed by the advance of steam power, the multiblades were destroyed by the advance of rural electrification and the power of the electric motor.

When American soldiers returned from the first World War, having seen the lights of "Paree", they attempted to convert some of their old water pumpers into makers of electricity, but found that the machines turned too slowly to run generators, and that the necessary "gearing up" was too expensive, (see plate no. 66).

Harking back to their war time experiences and their memories of the airplane, they began the long time love affair with the propeller, which developed into the rotor. It must be remembered, however, that a propeller pulls an airplane through the air, whereas a rotor is pulled around by the wind. Their designs are therefore somewhat different.

It is hoped that some of the suggestions in the pages that follow, will cause the reader to reconsider the multiblade for electrical generation, (see plate no. 66).

Multiblades (plates no. 3 through to 36), do not turn at high speeds because, after a certain point, the many blades begin to steal wind from each other. That is to say that some 80% of the energy developed by each blade is devoted to the fighting of every other blade, with the result that the power transmitted through the axle is greatly reduced. As each blade passes through the air, it leaves behind it a turbulence, creating a negative drag in the path of the blade that follows.

The same principle applies to the rig of a sailing schooner. Each of the four sails will not do as much work as a single sail of the same size and cut, on a similar vessel, in a comparable wind.

The farm multiblades high torque and low R.P.M. potential, nevertheless, related directly to its greatest asset, robustness of performance, (see torque as "twisting power", plate no. 38, fig. 4).

A Multiblade will not overrun in the strongest wind and it will not fly apart or disintegrate from centrifugal force. The only reason to ever shut one down is when it has performed its assigned task; pumped enough water, sawed enough wood, ground enough grain or generated enough electricity. You rarely have to worry about it being hurt by the power of the wind.

Furthermore, its large sail area enables it to catch every little puff of wind that blows and immediately convert its kinetic energy to useful power.

To sum up so far then, the multiblade has high starting torque for when the blades are at rest, but apparently the wrong blade design for when the blades are in motion.

If all but three blades of a multiblade were to be removed, the speed of rotation, and even the power, would increase, but the light weather performance would be sacrificed and the machine would be put at mechanical risk.

The principle is illustrated by the 36 blade fan shown in plate no. 8 which is slower turning than the 18 blade fan shown in plate no. 11, or the 15 blade fan shown in plate no. 33. All of these designs are of the same eight foot diameter.

Similarly, it will be observed that "the Big Truck and Steel Drum" fan illustrated in plate no. 54 will be faster turning if made as shown, with the width at the root, (the part closest to the hub), the same as the width at the tip.

If the width at the tip is increased, the blades will turn at a lower speed, but will have more torque.

Wider tips will cause the blades to start turning sooner in light breezes but will impede their ability to reach higher speeds.

All of the high torque multiblades illustrated in (plates no. 8, 11 and 31), are wider at the tip than at the root.

Conversely, it will be seen that many high speed rotors are wider at the root than at the tip, (see plates no. 42, fig. 1, 43, fig. 3 and plate no. 47).

In engineering terms, it may be stated that the speed varies inversely as the square root of the number of blades, (blade width will be examined later under the heading "solidity").

The old farm multiblades gave a steady output of power when the wind was brisk and the mill speed was high. It was important to utilize light breezes to fill livestock water tanks. It was not important if the wind pump slowed down in winds of over 15 miles an hour when the tank was already full.

High speeds and high numbers of revolutions per minute were not required for pumping water. It was thought better to pump a large amount of water slowly than to pump a small amount of water rapidly. Slow speed reduces the resistance to flow in pipes. Water flows easier in a large pipe. Large diameter, slow moving pumps require high torque windmills.

Water pumping multiblades were in fact geared down, that is to say that their pumping mechanism was made to run at a speed slower than the speed at which the axle turned. This gearing down would decrease the pumping speed and increase the pumping power, (see plate no. 22).

The wind shaft, or axle, was connected to a set of speed reducing gears which motivated a cam that moved a connecting rod up and down. The rod, in turn, operated a piston pump, like a hand pump without its wooden handle, at the base of the 30 foot tower.

Rotor (propeller) type wind machines, on the other hand, are designed for the generation of electricity as opposed to the performance of mechanical work. They are actually geared up to increase the axle speeds delivered to the generators. Gear ratios of 5 to 1 and as high as 10 to 1 are used in most successful designs, (see plates no. 38 through to 47, and plates no. 68 through to 75).

High torque had to be available from the outset as the water pumper had to start in light breezes under heavy load. There was always water in the line from the pump up to a water tank unless, of course, the pump had lost its prime. This entire column of water, or load, had to be immediately lifted. There was no free wheeling run before the load cut in, as there is with a rotor generator.

The trick, therefore, in converting a multiblade from the pumping of water to the generation of electricity is to overcome the disadvantage of low tip speed and to take the greatest possible advantage of the high "bottom end" torque. The axle, or windshaft speed, must therefore, be geared up so that the generator takes on its full load almost immediately in winds of about five miles an hour. The increasing load will then slow the machines down so that the period of performance is prolonged, (see plates no. 66 and 67).

It will be seen that the same principle applies to electrical generation with Sail Windmills, (see plates no. 48 through 53).

There is considerable engineering evidence to suggest that a sail windmill, properly geared up, using modern air foil cut sails, can be the most efficient electrical generator of all. It combines the best features of both the multiblade and the rotor. A principle problem is the necessity to furl the sails in foul weather.

Conversely, it may be seen that air foil propeller driven rotor windmills are high speed machines with low starting torques. They turn five to ten times as fast as multiblades but they do not take on any generator load at all until considerable speed has been developed. Some high speed rotors experience considerable difficulty in getting started at all.

Dovarik reports that a 12 foot multiblade could pump 35 gallons of water a minute to a height of 25 feet in a 15 mile and hour wind.

Bossel reports that a 13 foot diameter, home made, 16 blade direct drive shaft multiblade could put out 1/3 h.p. in a 10 m.p.h. wind and 2.5 h.p. in a 20 m.p.h. wind. This, of course, means power transmitted to the bottom of the tower or power delivered to the generator. From these figures, 30% must be deducted for normal mechanical loss. One horsepower = 746 watts, so, 2.5 h.p.= 1865 watts. Bossel does not say how this machine was geared up, (see plate no. 26 through to 32 and plates no. 71 and 72).

An Australian source reports that a 10 foot diameter, direct drive, wooden frame multiblade, should develop about one eighth horsepower in a 10 m.p.h. wind, while a 22 foot diameter machine of similar design should develop about one h.p. in a similar wind.

A direct drive shaft wind machine is one on which the blades turn a right angle drive off the axle at the top, which turns a drive shaft that runs down the tower and turns a second right angle drive at the bottom. Various power pulleys are connected to the horizontal axle off the bottom right angle drive, (see plates no. 26 through to 32).

Various kinds of machines (like saws, grinders and even generators), can be run off shafts connected to the lower pulleys.

Marcellus Jacobs, the great American manufacture of rotor type wind generators, once said that a 15 foot diameter, three bladed rotor, will develop between 6 and 8 horsepower in a fifteen mile hour wind, while a multiblade of the same diameter, at the same time and in the same place, will develop only two horsepower. As the wind increases to 20 m.p.h., the multiblade requires all the power it can generate just to run itself.

As has already been pointed out, multiblades operate in winds of 5 miles an hour but are not very effective in winds of over 15 miles an hour - unless they are held back by the load. It is their built-in safety factor.

It is a very big plus for the multiblade, however, that over most of North America, the 5 to 15 miles an hour are a "bonus".

The overall wind regime in Canada is better than it is in most countries, including the United States. Parts of Labrador, Newfoundland and the St. Lawrence Valley have average wind speeds of 15 to 20 miles an hour, which is very high. Most of Northern Canada, including Northern Ontario, Quebec, all of the Maritimes, the Prairie Provinces and Northern Vancouver Island have average wind speeds of more than 10 miles an hour.

Long ago, in Oak Settlement, where the writer grew up, thirteen foot diameter direct drive shaft multiblades were used to buzz-saw fire wood. Many times my uncles have seen a saw blade stick fast in a 10 inch diameter piece of green elm. The windmill not only didn't stop, but it had the strength to throw the belt off the saw pulley. We have always thought that it would take a 10 horsepower gas engine to generate that much power today.

Furthermore, a present day builder using the plans in plates no. 32 through to 34, should be able to create an ever more powerful multiblade wind machine, considering the availability of much more efficient bearings (plates no. 16 and 27), hubs (plate no. 7), and right angle drive gear boxes for direct drives (plates no. 26 through to 31).

The same, of course, applies to the electrical power generating rotors illustrated in plates no. 37 through to 47 and plates no. 67 through to 75. There is no reason why a careful person using these plans should not be able to duplicate the famous Jacobs machines previously discussed.

The reader should consider these facts when examining the formulas that follow. The reader should also be aware that he can proceed without benefit of the formulas. Just select the plans or combination of plans that suit your purpose and measure the power of the completed machines with the dynameter illustrated in plate no. 83.

To sum up, multiblades (plates no. 3 through to 36), having high torque and low R.P.M., start sooner in low winds but do not attain the high speed of which rotors are capable. They are, therefore, more suited to mechanical work, but can be converted to perform electrical generation. Multiblades have a built-in safety factor in that they will not over run. A multiblade generating electricity could, therefore, be left permanently "on" converting all available wind to electrical power and never hurting itself, (see plates no. 66 through to 72).

Rotors, (plates no. 37 through to 47 and no. 66 through to 72), have less bottom end torque (twisting power), but attain five to ten times the rotational speeds attained by multiblades. Rotors are, therefore, generally thought of as being the best suited to the generation of electricity.

Plates no. 39 through to 42 show a method of making rotors using wedges to angle the blades which, if anything, make them easier to construct than multiblades.

Sail Windmills, (plates no. 48 through to 53) are, perhaps, the most efficient wind machines of all, if modern air foil cut sails are selected. Using direct drive shafts (plates no. 26 through to 32), they can be geared down for mechanical work or geared up for the generation of electricity. The biggest problem is the necessity of furling or taking down the sails in foul weather.

Polish windmills, (plates no. 57 through to 60), operate on vertical axles and are easy to construct using very simple and often very crude materials. Though their efficiency can be greatly improved by sheltering the returning sail from the wind, (plate no. 58, fig. 2, 3, 4, 5 and 6), their great advantage is that they are multidirectional and require no tail vane. They are best suited to the performance of light mechanical tasks such as the pumping of water for livestock, which does not require a high power input.

The Saw Horse Windmill, (plate no. 55), is also multidirectional in that it has no tail vane mechanism. Though it is used mainly where wind directions are constant, such as in coastal areas with daily on shore off shore breezes, it is a simple matter just to pick the sawhorse up by hand and turn it around to face the wind. It is usually employed to perform very light mechanical tasks such as the washing of clothes and the churning of butter, but it can be rigged with any kind of sail or rotor to perform any task that any other wind machine can perform. Its "pumping" power can be doubled by using the lever-crank shown in plate no. 56. This device will also decrease the length of the pump stroke by 50%.

CHAPTER THREE

SCIENTIFIC AND ENGINEERING INFORMATION

FUNDAMENTAL RULES OF WIND POWER:

I) Wind velocity increases with tower height. On clear and open ground, the wind speed is always 20 to 50% greater at an elevation of 30 feet than it is on the earth's surface, (see plate no. 76).

II) When the blade diameter is doubled, the power is increased by the square of two (2) or 2 X 2 = 4 times. If a 6 foot diameter windmill produces 0.12 h.p. in a 10 m.p.h. wind, a 12 foot diameter windmill will produce 0.48 h.p. in the same 10 mile an hour wind.

III) When the wind speed is doubled, the power is increased by the cube of two (2), which is eight, as in 2 X 2 X 2 = 8. If a wind machine is generating 0.48 X 8 = 3.84 H. P. in a 10 mile an hour wind, it will generate 0.48 X 8 = 3.84 H. P. in a 20 mile an hour wind.

This would indicate that it could be cheaper to find a better location than to build a higher tower or a larger wind wheel.

Towers of more than 60 feet are dangerous as are wind wheels with a diameter of more than 15 feet.

POWER

Power	=	Torque X rate or rotation
	=	Force X velocity (or speed)
	=	The rate of work done
Force	=	Pressure X area,
		(see plate no. 83, fig. 3).

Torque may be defined as not really a force but more precisely the result of a force which is applied to a certain radius from the centre of rotation or axle. If it is a twisting force, the hand is applied to the end of the wrench.

Torque causes blade bending (mostly at the root end), and tries to shear the blade hub off at the axle.

It is torque that causes the windmill axle to turn when the blades are facing into the wind.

Force is a push or a pull, a repulsion or an attraction. Force produces work only if it results in motion. Work, then, is a force moving through a distance.

Energy is the capacity to do work.

Centrifugal force may be likened to a person swinging a stone around his head on a string. The stone wants to fly away like the one with which David struck Goliath but the string holds the stone back and retains it on its circular path. The outward pressure exerted by the stone on the string is the centrifugal force. It is a force directed away from the centre of rotation - the persons' hand holding the string. In terms of a windmill, it is the tendency for parts near the centre of rotation to stretch and move towards the tip, while the tip tries to part company entirely.

Centrifugal force increases with the square of rotational speed, which means that a windmill that is just structurally strong enough at say, 100 revolutions per minute, has to be four times as structurally strong at 200 revolutions per minute or it will fly apart.

With slow turning multiblades, centrifugal force, which tries to make the blades fly away is not a factor of overpowering significance, but with high speed rotors it is a very serious consideration.

Great care must be taken to prevent a rotor from "overrunning", that is to say, running at more than its optimum speed, (see the "Pilot Vane", plate no. 65, fig. 1).

EFFICIENCY

Though it is not efficient to build a wind machine that costs a lot of money to generate power that is worth very little money, the concept of efficiency does not have the same significance with wind machines as it has with other mechanical devices because the wind is free.

Nevertheless, some concepts should be born in mind:

I) If the wind could be stopped entirely by a rotating device, then 100% of the wind power could be extracted and a person standing behind the rotating device would feel no wind at all. This does not happen.

II) The theoretical maximum power available to a wind machine is 59% of the total available wind.

III) The multiblade has an efficiency of about 30%, while the high speed rotor has an efficiency of 42%, though some rotors may have more. It should be noted, however, that this is 30% and 42% of the theoretical maximum of 59% of the available wind.

IV) In terms of electrical generation, gear, power train and generation losses account for a further 30%. A multiblade working as a wind generator can, therefore, obtain 70% of 42% of 59%.

V) In terms of water pumping and other mechanical work, empirical factors are available to account for the wind machine's mechanical losses. These, however, are only estimates. A factor like half again or even twice the pump's, or other machine's calculated requirements, is not unreasonable. One can assume a pump efficiency of 70%.

VI) A low efficiency wind machine will have to be larger than a high efficiency wind machine to generate a comparable amount of either mechanical or electrical power.

EFFICIENCY IN TERMS OF TIP SPEED RATIO AND SOLIDITY

To calculate the power and work potential of a wind machine, it is first necessary to comprehend two concepts; tip speed ratio and solidity.

I) Tip speed ratio: Wind machines generate power by rotating around a central axis. Components near the centre of rotation will be moving relatively slowly while portions near the outer edges, or tips, will be moving faster because they have to travel further to make the same revolution.

If the axle has a circumference of three inches and the circle made by the revolving blade tips has a circumference of 300 inches and, being attached to each other, they both make the same number of revolutions per minute, a point on a blade tip will have to travel faster than a point on the axle because the point on the blade tip has to travel 100 times as far in the same length of time.

This is the reason race horses like to run on the "inside track", close to the inner rail. They have a shorter distance to travel than horses running on the outside, hence they have a better chance of winning a race.

The tip speed ratio of a wind machine is the ratio of the speed of a blade tip to the speed of the wind. It is the speed of a blade tip divided by the wind speed.

Tip speed ratios are lower for multiblades than they are for rotors. This is directly related to the solidity factor.

Efficiency is related to both tip speed ratio and starting torque.

II) Solidity: If one looks directly at the front of a multiblade, one gets the impression of a solid circular area of blades. There appears to be little or no space between the blades.

What one is looking at is the "frontal area" or "disc". It is the area of a circle of which the blade length, from blade tip to axle centre, forms the radius.

The blade length itself may be shorter than the radius. The actual blade length is measured in terms of "root to tip", the root being the extremity closest to the axle and the tip being the extremity farthest from the axle.

"Solidity" is the ratio of blade surface area to total disc or frontal area. It is the blade area divided by the frontal area.

As the blade surface area of a multiblade is almost equal to the frontal area, the solidity of a multiblade is rated as one. This is a high solidity. (When blade area equals frontal area, the solidity equals one).

As propeller type rotors have much more space between their blades, they are said to have a low solidity. A two or three blade rotor has a solidity to about 0.2.

Solidity effects design appearance.

High solidity wind machines have many blades; low solidity machines have very few blades, usually between two and ten.

High solidity machines turn slower than low solidity machines.

High solidity machines have greater starting torque than low solidity machines.

Multiblades blades are often wider at the tip than at the root whereas the contrary is often the case with rotor blades. The wider tip increases early wind catching ability but causes greater losses at working speed. In other words, it increases starting torque but hinders speed.

The wider tip also fills up the outer section of the frontal area and contributes to increased solidity.

Frontal area is a factor in the calculation of any wind machine's power.

The term "frontal area" has no reference to solidity.

CALCULATIONS OF SOLIDITY, TIP SPEED RATIO AND R.P.M.

Frontal Area:

- formula = π r2
- π (or pie) = 22/7 or 3.147

- r = the radius measured in feet (6.5 feet, not 6 feet 6 inches).

Therefore the frontal areas of a 13 foot diameter multiblade

- π r2 = 3.147 X (6.5 feet X 6.5 feet)
- 3.147 X 42.25 square feet

= 132.96 sq. ft.

Solidity = blade surface area divided by the windswept (frontal) area = The blade surface area = 132.96 square feet = the frontal area = 132.96 square feet. Therefore, as the blade surface area is equal to the frontal area, the solidity = 132.96 divided by 132.96 = 1.

Tip Speed Ratio = The speed of the wind wheel perimeter divided by the wind speed = The speed of one blade tip divided by the wind speed.

Any wind speed with a solidity of one has a tip speed ratio of one.

If the tip speed ratio is one, the tip travels the same speed as the wind.

If the axle is attached to the blade, and the tip is the outer end of the blade, the tip travels at the same speed as the axle. Therefore, the axle also travels at the same speed as the wind. If the tip revolves at 10 miles an hour in a 10 mile an hour wind, so does the axle. The R.P.M. of the axle will be the same as the R.P.M. of the tip. The tip and the axle rotate at the same speed.

Therefore, to calculate the R.P.M. of the axle you must first calculate the R.P.M. of the tip.

It is important to calculate the R.P.M. of the axle in order to learn how to "gear up" or "gear down" for power transmission, whether it be mechanical or electrical.

R.P.M. CALCULATION

Axle R.P.M. may be calculated by:

I) Translating the wind speed from miles per hour to feet per minute.

II) Dividing the circumference of the windwheel in feet into the number of feet the wind will travel in one minute as calculated in (I).

Problem - Calculate the axle R.P.M. of a 13 foot diameter multiblade in a 10 m.p.h. wind.

Solution - i) Calculate the distance travelled by a blade tip

1 mile = 5,280 feet

1 hour = 60 minutes

Therefore, 10 m.p.h. calculated in feet per minute = 5,280 X 10 divided by 60 = 880 feet per minute. Therefore, each blade tip travels 880 feet in one minute when the wind is blowing at 10 miles per hour.

To calculate the number of times a single blade tip has to travel its circular path to cover a distance of 880 feet in one minute, you simply divide 880 (feet) by the number of feet, (circumference), a single blade tip travels in one revolution of the wind wheel. In other words, you divide 880 by the circumference of the wind wheel measured in feet. This will give you the R.P.M.

The path travelled by the blade tip, (one of the blade tips), is the circumference of the circle with a diameter of 13 feet.

Use the formula - circumference = 2 π r or π d, where r = radius = 6.5 feet, (not 6 feet 6 inches), d = 13 and π (pie) = 3.147.

Therefore, π d = 3.147 X 13 = 40.91 feet = the distance travelled by one blade tip in one revolution.

ii) Calculate the number of revolutions required for the blade tip to travel the same distance the wind travels in one minute with is 880 feet.

Simply divide the distance travelled by the wind in one minute by the distance travelled by the blade tip in one revolution. This will give the number of revolutions per minute, 880 divided by 40.91 = 21.5106 = 21.51 or 21 1/2.

Therefore the blade tip, and hence, the axle, has an R.P.M. of 21.5 in a 10 mile an hour wind.

This is slow but safe. Propeller type rotors have tip speed ratios of 4 up to 10 to one and axle speeds of 100 to 300 R.P.M.

It will be seen or easily calculated, that a multiblade of half the diameter (6.5 feet), will have twice the R.P.M. (43.02 R.P.M.), but its power will be reduced by the square root of two (1.4142). It will also have less torque, as the "wrench handle" will be shorter

CALCULATION OF POWER AND THE GEAR-UP RATIO

Horsepower available in the wind may be calculated with the formula: - h.p. = 0.0000022 X V X A

Where: - h.p. = Horsepower

- 0.0000022 is an empirical factor, just use it and don't ask questions.
- V = the wind speed measured in feet per second
- V = V X V X V

- A = the windmill frontal area in square feet

Problem: Calculate the horsepower available to a 13 foot diameter multiblade in a 10 mile an hour wind.

Solution: - A = Frontal area
= π r2
= 3.147 X (6.5 X 6.5)
= 3.147 X 42.25
= 132.96 sq. ft.

- V = 10 m.p.h.
- 5,280 X 10 - feet per hour
= 52,800
- feet per hour (5,280 X 10 m.p.h.), divided by 60 divided by 60
= feet per second.

Therefore,

V = 14.67 X 14.67 X 14.67
= 3157.1145 feet per second.

Therefore,

h.p. = 0.0000022 X V X A
= 0.0000022 X 3157.1145 X 132.96 = 0.92 = 0.92

The theoretical maximum
= 59% of 0.92
= 0.5428
= 0.54 Horsepower,

Therefore: multiblade efficiency = 30% of 59% (the theoretical maximum)
= 30% of 0.54 = 0.162 or 0.16 Horsepower

One horsepower is equal to 746 watts, so 0.16 horsepower
= 0.16 X 746
= 119.36 watts.

Remember that 30% of these watts will get lost in the transmission and generator so the delivered power will be: 119,.36 - (30% of 119.36)
= 119.36 - 35.8
= 83.56 watts

The same 30% should be deducted for mechanical transmission to pumps, saws, etc.

Remember also that horsepower, (even after it has been translated into watts), is a per second measurement of work done. One horsepower is equal to 550 pounds lifted one foot in one second.

If the above multiblade does the work of 0.16 horses in one second, it does the work of 60 X 0.16 = 9.6 horses in one minute and 60 X 9.6 = 576 horses in one hour.

If these horsepower figures depress you, bear in mind that a man alone can contribute only about one horsepower hour of work in a given day.

NOTE: There are other, seemingly simpler formulas, but it is difficult to determine what figures they are working with, available horsepower, theoretical maximum etc. It is better to stick with the above formulas.

NOTE: For rotating machinery, mechanical power is calculated from shaft torque times R.P.M. Torque is measured in foot pounds.

Torque - may be calculated from either of the following formulas:

I)Horsepower, (as put out by the blades, not by the generator being driven by the blades):
= 1000 X h.p. divided by 0.190 X R.P.M.

where: - 1000 and 0.190 are empirical factors
- h.p. = the horsepower = 0.16
- R.P.M. = the revolutions per minute of the axle and wind wheel
= 21.5
= 1000 X 0.16 divided by 0.190 X 21.5
= 160 divided by 4.085
= 39.167686
= 39.17 foot pounds

II) Torque = 330 X (d) X h.p.
- tip speed ratio X wind speed X 1.47 where: - 330 and 1.47 are empirical factors
- D = the diameter of the (multiblade) wind wheel in feet = 13 feet
- h.p. = horsepower of the given wind machine
= 0.16
- tip speed ratio - this being a multiblade, though these formulas work for rotors as well,
= (see discussion under "Calculations of solidity, tip speed, ratio and R.P.M.)
= 3300 X 13 X 0.16 divided by 1 X 10 X 1.47
= 6864 divided by 14.7
= 466.93877 inch pounds
= 466.93877 divided by 12
= 38.911564 foot pounds

You will notice that the results from formulas (I) and (11) are similar but not the same.

Personally, I have more faith in my uncle's wind driven buzz saw than I have in most formulas. Here is a method of calculating the horsepower, and hence the torque, of your own wind machine that, at least, has a practical basis.

The idea is that you wrap a piece of rope around the axle two or three times, attach a container of water at the long end of the rope, and measure the time it takes to raise the container of water by winding the rope up on the axle, all the while keeping hand tension on the short end of the rope.

METHOD - (as illustrated in plate 83)

1) Determine the wind speed. Ten miles an hour is suggested.

11) Make two marks on the tower, one above the other, say 3, 5, 10 or 20 feet apart. Call the top mark B and the bottom mark A.

111) Find a light fibre rope, (not any other kind), about 50 feet long. Tie one end to a plastic container of water. Keep adding water to the container until it is so heavy that the windmill lifts it fairly slowly. If it runs up too fast it will be too hard to time. Weigh the container and water. Record the combined weight.

IV) Wrap the other end of the rope loosely around the windmill axle (windshaft), so that it hangs in festoons. When you are ready to start, you just have to tug on the tag end of the rope and keep a tension on it. The rope will tighten on the axle and wind up the water container.

V) When the container has passed the upper mark, loose the tag end of the rope and the container should slide down to the ground.

VI) In case it does not, a set up sheers should be kept handy to cut the rope so that the container does not reach the top and wrap around the axle, (see the "brake board" illustrated in plate no. 83).

VII) Repeat the test several times within half an hour in the same wind speed. Each time, measure the time it takes the container to pass from the lower mark "A" to the high mark "B". Take an average.

Make your calculation according to the following formula:

- Power (in foot pounds)

$$= \frac{MGZ}{T} = M \times G \times Z \text{ divided by } T$$

Where: M = The weight of the plastic container of water that is to be pulled up by the axle.

G = The force of gravity which is 32.2, a constant that never changes.

Z = The distance in feet between the marks A and B on the tower.

T = The time, measured in seconds, that it takes the weight (M) to rise between the points "A" and "B" on the tower.

To be truly accurate, this time will have to be taken by two people with stop watches, one at A and one at B.

A third person will have to be at the top keeping the tension on the line and making sure that the weight does not wrap around the axle.

A fourth person will have to be at the bottom, making sure the weight does not get tangled in the lines. The weight would be allowed a "speed run" at operation speed before the weight reaches the lower mark A.

NOTE: The answer will be in foot pounds. This figure will have to be divided by 550 to get horsepower.

GEAR-UP

"Gear Up" means the increasing of an axle speed or R.P.M. by the use of gears. It is accomplished by running a small gear off a larger gear. If the larger gear is twice the size of the smaller gear, the smaller gear will have to turn twice every time the larger gear turns once. This would be a gear ratio or "gear up" of 2:1.

If the large gear was ten times the size of the smaller gear, it would constitute a gear ratio or "gear up" of 10:1, (see plates no. 66 through to 72).

1) Problem - to calculate the required gear up ratio for a 14 foot diameter rotor if it is to match a generator which puts out its maximum power at 2,500 R.P.M. This calculation must be based on an average wind speed of 10 m.p.h.

Note, that whereas the 13 foot diameter multiblade, used as an example in previous calculations, has a tip speed ratio of one, (see "calculations of solidity tip speed ratio and R.P.M." in this section), it can be assumed that the three blade rotors illustrated in plates no. 38 through to 48, have a tip speed ratio of at least four, that is the say four times the speed of the wind or four times the tip speed ratio of a multiblade wind wheel of equal diameter.

Therefore, the easy way to calculate the tip speed or axle R.P.M. of a three blade rotor is to first calculate the tip speed of a multiblade of equal diameter and then multiply the result by four. This will be a conservative calculation.

The following formula, however, provides a more precise method for calculating the axle R.P.M. of high speed rotors at given wind speeds.

The axle R.P.M. has then to be divided into the required R.P.M. to get the "gear up" or gear ratio.

SOLUTION: (to problem 1)

Formula - N

= V X Tip Speed Ratio - 2 π r

Where: N

= The windshaft axle R.P.M. at the given (10 m.p.h.) wind speed.

V = The wind speed measured in m.p.h.

= 10 m.p.h.Tip Speed Ratio

= 4, meaning four times the speed of the wind.

π (pie) = 3.147

r = the radius

= 14 feet - 2 = 7 feet

Therefore:

N = 10 (m.p.h.) X 5,280 (feet per mile) X 4 (tip speed) 60 minutes p.h. X 2 X 3.147 (pie) X 7 (radius)

= 211200 m - 2643.48

= 79.894684 = rotor R.P.M. at a wind speed of 10 m.p.h.

To find the gear up ratio just divide the required generator R.P.M. by the wind shaft axle R.P.M.

= 2,500 divided by 79.9

= 31.289111

Therefore:

the required gear up ratio

= (about) 30.1

Note: If the rotor is required to match a generator which commences the generating of electricity at 2,000 R.P.M., the wind speed being the same 10 m.p.h., simply adjust the above formula result in the following way: just divide the required generator R.P.M. by the windshaft R.P.M. at the stipulated wind speed, (10 m.p.h.) - 2,000 divided by 79.9 = 25.031289. Therefore, the required gear up ratio = (about) 25:1.

11) Problem - to calculate the required gear up ratio for the same 14 foot diameter rotor if it is to match an alternator which puts out its maximum power at 1,000 R.P.M. in the same 10 m.p.h. wind.

Solution: use the same formulas in (1)

N = V X Tip speed ratio divided by 2 π r

= 10 X 5,280 X 4 divided by 60 X 2 X 3.147 X 7

= 211,200 divided by 2643.48

= (about) 79.9

= 1,000 (alternator speed) - 79.9

= 12.515644

= a gear up ratio of 12.5:1

Note: If the rotor is required to match an alternator which commences making electricity at about 750 R.P.M. with the wind speed being the same 10 m.p.h., simply adjust the above formula in the following way: 750 (alternative R.P.M.) divided by 79.9 (windshaft R.P.M.) = 9.3867334

= a gear up ratio of 9.39 to 1

= 9:1 or 10:1

11) Problem: To calculate the required gear up ratio for a 13 foot diameter multiblade if it is to match a generator which commences the generation of electricity at 2,000 (generator) R.P.M.

Solution: use the same formulas in (1) and (11):

N = V X Tip speed ratio X π r

Where: N = R.P.M. of windshaft if the wind speed = 10 m.p.h.

V = 10 (m.p.h. wind speed)

Tip speed ratio = 1

π (pie)

= 3.147

r = radius = 13 divided by 2

= 6.5 feet = 52,800 divided by 2454.66

= 21.510107

= 2,000 divided by 21.5 = 93.023

- a gear up ratio of 93.1 or to be safe, say 100:1

IV) Problem: Adapt the same multiblade to an alternator which commences making electricity at 750 alternator R.P.M.

Solution: Adapt the same result as in (111).

= 750 (alternator R.P.M.) divided by 21.5 (windshaft axle R.P.M.)

= 34.88372

35.1 = the gear ratio.

CHAPTER FOUR

LOCATION

IV - WHERE TO BUILD:

Wind speeds are greatest at locations surrounded by water or by flat unbroken plains. They are less over rural areas with buildings and trees, and even less over metropolitan areas where tall buildings seriously change the normal wind patterns. An ideal location, therefore, would be on a barge or small island in the centre of a lake.

When wind near the ground flows over anomalies, such as large buildings or steep sided hills, the wind profile is distorted into a complicated pattern of reverse flow, eddy current and irregular air movements, broadly classified as "turbulence". This obviously reduces the wind speed delivered to the wind machine. Such swirling, erratic wind current also buffet the wind machine causing premature mechanical failure.

Sometimes, however, objects on the ground, hills, trees, etc., actually "funnel" the wind, thereby increasing the wind speed in certain locations.

Nevertheless, if it is necessary to locate near a building, the tower should be at least three times the height of the building, or the wind machine should be placed on a post passing through the roof of the building to a point fifteen feet above it, (see plate No. 81, fig. 1).

For most installations, the type of terrain is the most important factor in deciding whether the increased cost of a very high tower is justified.

As a general rule, the tower top should be fifteen to twenty feet above any trees or buildings within a radius of 400 feet.

Of course, the greater the distance between the wind machine and the building, the greater will be the power loss when transmitting between the two. It may be necessary to compromise.

The same principle applies to hills and the turbulence they cause. The wind machine should either be on the top of the hill, or be as far away from it as possible. If it has to be on a side of a hill, cuts should be on the side towards which the wind blows most constantly.

This, of course, means that the installation must be strategically placed in terms of the prevailing wind, which is the direction of wind that blows most frequently in your area. Such information can be obtained from government meteorological records and from your own records using your own weather vane. Bear in mind that wind patterns often change with the seasons. They are usually stronger in the winter.

V - TOWER HEIGHT - HOW HIGH TO BUILD:

It must be remembered that the perfect wind machine can only extract 59.3% of the wind energy available. In other words, it can extract only 59.3% of the wind power striking the blades.

If the wind could be completely stopped by a rotating device, then 100% of the wind power could be extracted. But, as the wind can only be slowed down by such a device, by about a third of its original speed, we get the theoretical maximum of 59.3%.

Furthermore, there is an additional mechanical loss of 30% before the power can be delivered by the machine. This means that only 70% of the 59.3% is typically available as an end product of a very efficient machine

The multiblade water pumping wind machine has an efficiency of about 30%. The high speed propeller type (rotor), has an efficiency of about 42%, though some have had 50%.

It is therefore important to maximise the portion of the available wind striking the blades on a consistent basis; we can often do this by raising the height of the tower. This is because we know that wind speeds increase considerably with height.

It has already been pointed out that obstacles on the ground near a wind generator can significantly alter the flow of wind blowing against the blades.

There is, however, another factor known as "surface friction", which is the friction caused by the wind passing over (or rubbing over), the earth's surface. This friction causes the wind to slow down at two levels. Obviously then, surface friction increases as one approaches the earth's surface from a great height. Therefore, wind close to the ground moves slower than wind higher up, and conversely, the higher you go, the faster the wind, or the greater the wind speed, and hence, the greater the power to be extracted.

Also, even without obstructions in the form of trees, hills or buildings, the wind closest to the ground may not only slow down because of surface friction, it may also tumble like a tumble weed, causing eddy current to develop. These current will interfere with normal wind flow and further reduce the amount of useful wind reaching the blades, and hence, the amount of power available at a typical wind speed.

Therefore, we can see that greater tower heights produce higher wind speeds and higher wind speeds, on a consistent basis, mean more operational hours per year.

We are going to see that higher wind speeds also mean greater power.

A machine on a high tower may be working well while the same size machine on a lower tower may be becalmed by surface friction.

At thirty feet, a wind machine receives three times the wind power available at five feet, even though the actual wind speed is only 1.4 times as great.

At sixty feet, it receives 4.25 times the power it does at five feet.

At eighty feet, it receives 5.3 times the power it does at five feet.

At 100 feet, the wind speed may be half as much again as it measures on the ground surface.

The wind speed at 33 feet can be expected to be 20% greater than at 13 feet. Using the Cube Root Law, this would double the power.

By the same law, a tower, 57 feet high, would have three times the power of a 13 foot tower.

As noted in Section III of chapter three above, the cube law states that when the wind speed is multiplied by two, the power that can be extracted from it is multiplied by eight.

Again, though the power at 30 feet is three times the power at 5 feet, at 80 feet, the power is 5.3 times the power at 5 feet. Hence, by going from 30 to 80 feet, we gain by a factor of 1.8, but as we have already said (chapter 3, sec. 111), any tower over 60 feet is dangerous, not to mention expensive and difficult to erect.

The greater power is certainly higher up, but the financial and engineering problems of getting there may be prohibitive.

It would seem therefore, that the 30-33 foot tower is the best compromise providing the location is conducive. The cost and other difficulties involved with extra footage beyond that point may not be compensated for by proportionate returns.

Perhaps we could look at the Cube Root Law introduced in Section 111 and repeated above just one more time because of its extreme importance.

As we have seen in the "Power" section of Chapter Three, power is equal to force times wind speed or velocity. (P = F X V).

This also applies to wind power which is proportional to the square of the velocity, (i.e. V2 or V X V), which is the same as S2 or S X S. So, if the wind force is equal to the velocity squared, which means, velocity times velocity, the wind force is also proportional to the cube of the wind speed, which means the wind speed times the wind speed times the wind speed, (S to the power 3 = S X S X S). In other words, if the wind speed, or the velocity, doubles, (S X 2), the wind power goes up by a factor of eight, (2 X 2 X 2 = 8).

By the same law, it will be seen that when the wind speed triples, the power that can be extracted is 27 (3 X 3 X 3), times greater!

It is therefore essential to determine the wind speed and hence the available power at various sites and elevations in order to decide on the best location and tower structure for your installation.

Vi - MEASURING THE WIND SPEED WITHOUT INSTRUMENTS:

As power is so closely related to wind speed, it is essential to measure the speed of the wind at certain locations and at certain heights in order to determine the feasibility of erecting a wind machine, and to be sure that it is being erected at the best possible site.

Whereas a farm type water pumping multiblade wind machine will take on its full load and deliver water in winds of five miles an hour, it will slow down and virtually stop producing in winds of fifteen miles an hour.

A two or three blade rotor, or wind charger, making electricity, delivers almost no power at wind speeds below 6 to 8 miles per hour and puts out its full power at wind speeds of about 25 m.p.h.

Most wind generators require consistent winds in excess of 12 m.p.h. in order to produce significant power. Twenty m.p.h. is perhaps the ideal, though average wind speeds at a good site will rarely exceed 15 - 18 m.p.h.

When wind speeds approach 32 m.p.h., they are becoming dangerous to the machine and some braking device should be put into effect to either stop the machine or turn it out of the wind.

In measuring wind speeds, it is important to realize that it is the average wind speeds that count so you must take several readings a day to get your daily averages and these daily averages should be averaged out for a period of at least three months.

Wind almost never blows at a steady speed for long periods of time in most places, though some places may have somewhat predictable weekly patterns. The prevalent winds (5 out of 7 days), blow most of the time at about 5 to 15 m.p.h. The energy winds blow less often (2 out of 7 days), but at the higher speeds of 10 to 25 m.p.h. you should have at least two or three days a week averaging over 10 m.p.h. to establish an adequate site.

The logical first step then, is to check out the nearest airport for the mean annual wind speed, short-term wind speed patterns on a weekly basis and the seasonal variations, bearing in mind that wind speeds are usually higher in winter than in summer. This last should not be a problem as lighting demands tend to be higher in winter.

Weather Bureaus should also be consulted for local wind speed patterns and for the direction and reliability of prevailing winds.

Beyond that, in the absence of proper measuring instruments, one can only depend on natural phenomena to tell the story. Here are some of "nature's ways" of measuring wind speed:

	WIND SPEED (m.p.h.)	WIND EFFECT
i	0 - 1	Calm; smoke rises vertically.
ii	2 - 3	Direction of wind shown by smoke drift but not by wind vanes (weather vanes).
iii	4 - 7	Wind felt on face; leaves rustle; ordinary vane moved by wind.
iv	8 - 12	Leaves and twigs in constant motion. Wind extends light flag.
v	13 - 18	Raises dust, loose paper; small branches are moved.
vi	19 - 24	Small trees in leaf begin to sway; crested wavelets form on inland waters.
vii	25 - 31	Large branches in motion; whistling heard in telegraph wires, umbrellas used with difficulty.
viii	32 - 38	Whole trees in motion; inconvenience felt in walking against the wind.

It will be seen therefore, that multiblade water pumping wind machines function between the wind speeds shown in No. iii and No. v above.

Wind chargers or rotors function between No. iv and No. viii.

The 8 - 12 m.p.h. winds shown in No. iv, indicated by the extension of a light flag, may be seen as a good medium for both kinds of machines.

Therefore, light flags flown from poles at prospective sites would be a good idea, as they are easy to see and to record.

Thirty foot poles for such flags would be perfect, but 10, 15 or 20 foot poles would be useful.

If you are planning to spend a lot of money on your installation however, such crude estimates may not be enough. You may want some more precise figures which you can only get from proper measuring instruments.

Vii - MEASURING WIND SPEED WITH COMMERCIALLY AVAILABLE INSTRUMENTS - FACTORY MADE:

The easiest solution is to buy a simple

hand held wind gauge. The best known of these is the "Dwyer Windmeter" made by the F. W. Dwyer Instrument Company of Michigan City, Indiana, U.S.A., 46360. It measures about 6 or 8 inches by about 1 1/2 or 2 inches, and should cost less than 10 dollars. It is available at "The Whole Earth Truck Store", and through merchants who cater to the sports of hand gliding and sailing, as well as through a number of scientific supply houses, "Edmund Scientific" being one of them.

The most common type of hand held anemometer just picks up the pitot-static pressure of the wind. This displaces a disk which can rise up and down inside a tapered and transparent container of circular cross section. The position of the disk corresponds to the wind speed.

All you have to do is to hold this device into the wind and read the wind speed directly from the scale on the face of the instrument. Unfortunately though, it has no counter or other means of recording its readings.

Of course, you should take several readings a day at your chosen location, or your many prospective locations, and always at the same times of day. Failing this, you should take at least one a day, preferably in the afternoon.

As we have seen in Section V, such readings should be taken at various heights above the ground, which may involve climbing a 50 foot tree every afternoon at 3 p.m. This will no doubt give you a good appetite for your dinner. A more practical solution might be some kind of an arrangement with a tall step ladder, well secured of course.

You should have at least two or three days a week with winds averaging more than 10 m.p.h. to establish an adequate site.

Dwyer also makes an instrument called "The Dwyer Wind Speed Indicator" which is classified as a "Remote Reading Pneumatic Wind Speed Indicator" This means that, as it comes with 50 feet of flexible tubing, it can be mounted on a pole as high as 50 feet, and read from the ground. No more climbing, but you still have to go at your regular times and write down your recordings.

At one time, it was selling for about $30 dollars. Though, it may have gone up in price a bit by the time you read this, I am sure it will still be a good buy.

More sophisticated commercially available instruments that can be mounted on poles and can record, as well as convert their findings to average wind speeds, cost as much as $1500.

Perhaps the best known commercially available wind speed measuring device is the revolving cup anemometer, because of its use on sailing vessels and around air fields, (see plate No. 84).

It consists of a 5/16 inch vertical axle, about 15 inches long, which has been fitted with a 6 digit mechanical counter equipped with a reset button on its bottom end.

The mid point of the axle passes through a set of low friction bearings encased in a 6 inch tube. The tube is "U" bolted to a 3 inch by 12 inch by 1 inch board. The board is "U" bolted to the top of a pole.

At the top end of the axle, a 2 inch piece of square brass tubing is fitted over the axle and braced on. At a point one inch below the top of the square tubing, four horizontal, 1/4 inch diameter metal arms extend at right angles to each other from each of the four flat surfaces of the square tubing.

At the outer end of each arm, there is a 2 3/4 inch diameter cup, looking something like a soup bowl or a round back rice bowl. To give strength, each of the four arms pass directly through the lip side of its cup, from side to side, and is of course brazed, welded or soldered on. The four cups are all set on their sides so that their lip sides are vertical in order to catch the wind and turn the device on its axle.

Each cup must, of course, face the same way, so, looking down at the arms, the mouth of each cup faces to the right, which of course, allows the wind to drive the cup to the left, that is to say, in a counter clockwise direction. Looking up from the ground, of course, the cups revolve in a clockwise direction.

The distance from the mid point of the axle, along each arm, to the centre point of each cup lip is 6 inches.

In this case, a mechanical gear on the axle works the counter directly, so one has to climb up the mast, or whatever, at regular intervals to take the readings.

The same mechanical gear can also trip an electrical switch which in turn operates a distant solenoid drive counter so that no climbing is necessary.

Sometimes the revolving vertical axle of the anemometer itself generates the power to operate the switch.

The number of revolutions are therefore counted over a period of time, say a minute, an hour, a day or a week. This figure should be proportional to the amount of moving air, or wind, passing that point at that time. It is thus calibrated by the manufacturer to reveal the wind speed in miles per hour. An electric meter can record this information on its own remote dial, so that no calculations and no climbing are necessary.

In the case of a mechanical counter, such calibration must be achieved by consulting a chart provided by the manufacturer.

Viii - MEASURING WIND SPEEDS WITH HOME MADE INSTRUMENTS:

The easiest wind speed measuring instrument to make is hand held and very simple.

It consists mainly of a large wooden "school size" protractor held vertically with its flat side up and its round side down. Of course, a large size plastic protractor will do almost as well.

With the calibrated angle sizes, or the side with the written numbers on it, facing you, bolt one end of a 16 inch piece of one inch by 1/4 inch wood or metal to the left or 180° top corner.

The other end of this piece of wood or metal should angle up by about 45° and be directly over the centre of the protractor, that is to say that it should be directly on a projection of the 90° angle line. It thus can be used as a handle to enable you to hold the instrument level and also to hold it as far as possible from yourself to minimise disturbance.

To double ensure that the instrument is held parallel to the ground, you should horizontally cement a small spirit level, like a brick layer's line level, to the top side of the protractor at the right hand or 0° corner.

At the top centre point of the flat side, still facing you with the numbers evident, you must now attach, with glue or cement, one end of a 2 foot piece of monofilament nylon line or thread.

The bottom end of this line should pass through two opposing holes drilled into a ping pong ball. The line should be held fast to the bottom end of the ping pong ball with a water proof glue or cement.

The length of monofilament nylon, from the point of attachment, on the top of the flat side of the protractor to the top side of the ping pong ball, should measure exactly 30 centimetres. Clip off the extra piece.

If the protractor is held as far from the body as possible, with the 180° mark facing into the wind, the ping pong ball will be blown back from the 90° point towards the 0° point.

The angle formed by the nylon line can then be read on the protractor. This angle can be translated into wind speeds in terms of miles per hour

Here is the calibration data:

ANGLE	M.P.H.
90	0
85	5.8
80	8.2
75	10.1
70	11.8
65	13.4
60	14.9
55	16.4
50	18.0
45	19.6
40	21.4
35	23.4
30	25.8
25	28.7
20	32.5

The alternative is to make a revolving cup anemometer as described in section vii, (see plate no. 84).

The cups can be made from "L'EGGS" pantyhose containers while bearings and shafts can be found in hobby shops; you should be able to pick up a counter at a surplus store. If you get the six digit variety, it should be able to hold several days of pretty good winds. Don't forget the reset button at the bottom so that you can send it back to zero after you have taken your reading.

The viability of such an instrument will depend on the low friction bearings not becoming stiff after working in foul weather.

The big trick, however, is to calibrate it, because your home made one can never by the same as a manufactured one.

One way is to set it up near to a commercially made anemometer and compare your daily count to the wind speed calibrated on the factory made device.

You can also compare your home made anemometer to a hand held device like the Dwyer Windmeter which, as you will remember, has no counter.

First you use the hand held device, or Windmeter, to establish a 15 minute average by taking many readings over a 15 minute period and then working out the average.

Then compare this average to a 15 minute count on your home made device and scale that figure up to one day.

The more often you repeat this procedure, the more accurate your calibration will become.

Finally, you can place your device on a pole over your car roof and calibrate it with the help of a stop watch and the car's oedometer, which counts the miles or kilometres the vehicle has travelled. Oedometers have a reset switch which will send them back to zero before commencing the next reading.

It is also possible to use the car's speedometer if a steady speed is maintained. The distance is recorded on the oedometer and the time is recorded by the stop watch. All of this information is calculated in terms of the number or revolutions per hour recorded on the anemometer's counter.

Whatever may be the method of calculation or calibration, if the anemometer is mounted on a pole above a moving motor car, the height of the pole, over the car's roof, must be at least as high again as the vehicle itself, to avoid the distortion caused by the streamline of moving air passing over the vehicle's top.

The anemometer's reading should then be at least as accurate as that of the car's speedometer. All you then need is a private road, a windless day and a uniform speed!

CHAPTER FIVE

AERODYNAMICS and the AIR FOIL ROTOR BLADE - FOR THE GENERATION OF ELECTRICITY

The old Dutch windmills were built on the principle of the water wheel. Moving air, in the form of wind, was utilized to "push" the sail blades around, just as moving water in a river, or mill stream, is utilized to "push" a water wheel around.

This was changed when the science of aerodynamics developed the principle of the air foil airplane wing which utilizes "lift" to keep the craft airborne.

The same "lift" force is utilized to "pull" the rotor blade around.

It will be seen that the wind can "pull" a lot faster than it can "push".

Aerodynamics deals with the subject of forces created by bodies moved, (as opposed to moving), through the air. The body's actions are predictable, therefore, the flying characteristics of a rotor blade can be determined with great accuracy.

The air foil airplane wing has a wide rounded leading edge and a narrow, pointed trailing edge. The top side is shaped in the form of an upward or symmetrical curve. The bottom side is flat, (see plate no, 37, fig. 1).

The moving air, air flow, or wind, is created by the airplane propeller pulling the craft, and hence the wing, forward in a horizontal direction.

Therefore, the wind, or air stream, is moving in the direction of the air foil wing's trailing (back), edge while the wing is moving in the direction of its own leading (front), edge.

The air stream is thereby split by the leading edge of the wing. Equal amounts of air will pass over the curved top and pass under the flat bottom.

The portion passing over the curved top, or upper side, has a longer distance to travel, much like the race horse running on the outside of the race track.

As the race horse on the outside has to run faster to keep up with the horse running on the inside rail, the air passing over the top has to travel faster if it is to reach the trailing edge at the same time as the air travelling under the flat bottom.

As the amount of air, in cubic units of measurement, does not change, it not only has to travel faster, it has to "stretch out" to cover the greater distance.

Because it has to stretch out, it contains less air particles per cubic unit of measurement. It is, in fact, thinner.

Because it is thinner, it creates a cold pressure area, a vacuum or upward suction above the wing top which, in fact, pulls the wing upward in a direction perpendicular to the air stream, no matter what may be the direction of the air stream. It has no connection with the force of gravity. It works equally well if the craft is flying horizontally or straight up or straight down.

This upward force or suction is called "lift". It is the force which keeps the craft airborne by actually pulling or sucking it upwards. That is to say, it pulls the wing in a direction perpendicular to the air stream of the direction of air flow. It actually lifts the aircraft.

"Lift" is derived from the very small deflection of a very large volume of air.

It will also be apparent that air passing over the curved wing top and down over the pointed trailing edge has a downward thrust that also contributes to lift.

It is travelling faster than it was when it first contacted the leading edge. Not only because it has to "catch up" but because it is passing into, or being drawn into, the area left by the advancing air foil.

The force of this air being accelerated downward and to the rear can be compared to a fish bending its tail to force itself ahead and the water back. It can also be compared to a swimmer wearing fins on his feet to increase his speed through the water.

Both lift and thrust are, therefore, generated by the curved upper side of the air foil wing.

Conversely, the portion of the air passing beneath the flat lower side of the wing moves in a straight line. It, therefore, travels the shortest possible distance between the two points, the front of the wing's leading edge and the back of the wing's trailing edge.

It, therefore, creates an area of high pressure beneath the wing which tends to push the wing upwards or in the same direction as the lift. This "push" is similar to the push exerted by the wind on the blade of an old Dutch windmill.

Lift is the force which pulls or sucks the wing upward from the high pressure area beneath to the low pressure area above.

At the same time, the wing is being driven upward and forward by the thrust angling downward and backward from the trailing edge.

There is also a force being exerted from below, pushing the wing upward from the high pressure area beneath to the low pressure area above the wing.

In the case of the airplane wing, this upward pressure, or "push", is of little significance.

It will be seen, however, that in the case of the rotor, "push" is the force that starts the blade turning.

Nevertheless, lift is the most significant factor in all air foils.

As the leading edge moves into the air flow, a turbulence is created behind the wing directly following the trailing edge. As this turbulence has to be pulled through the air behind the air foil, it has the effect of slowing the air foil down, retarding its progress through the air, dragging it back.

The force created by turbulence is, therefore, called "drag".

Drag is the retarding force experienced by the wing in a direction parallel to the air stream.

Drag is similar to the turbulent wake that follows an ocean vessel as it moves through the water. It is the force exerted by a canoe paddle, a paddle wheel or a person's foot in the water. It is also the force that tries to push down a windmill tower.

Lift, aided by thrust, pulls the air foil upward or in a direction perpendicular to the air flow.

Drag pulls the air foil back in a direction parallel to the air flow.

Lift is measured perpendicular to the air flow, not to the air foil.

Drag is measured parallel to the air flow.

Air foil designers, therefore, strive for high lift and low drag.

The science of aerodynamics is performing at its best when the air flow is being deflected off the air foil with the least possible amount of turbulence or drag.

It has been found that the radius of the leading edge curve can be calculated to give maximum toleration to changes in the angle of the approaching air flow.

The exact curve of the upper surface controls separation of the air flow, and hence, the degree of lift.

Chord length (plate no. 37, fig. 2, 3 and 4), or air foil width, influences drag because it influences the distance travelled over the air foil and, hence, the amount of friction caused. Increased friction causes increased drag. It is, therefore, of tremendous importance that the air foil surface be as smooth as a baby's back side.

A sharp angled trailing edge allows the parted air stream to come together easily and so diminishes the turbulent wake or drag.

Lift and drag also depend significantly on the square of the normal air flow velocity and the density of the air.

Vertical thickness of the wing, on the other hand, has no bearing on the wing's performance as an air foil. It is of structural value only.

There is no reason why a wing shaped like a section of a steel drum (plate no. 33), or even like a flat plate (plate no. 8), should not make a perfectly good air foil. They do not, however, make the best air foils.

A flat plate, like a piece of plywood, sheet metal, plastic or cardboard, will generate considerable lift at low angles of attack. Furthermore, it will do so with minimal amounts of turbulence following the trailing edge.

As the angle of attack is increased by raising the leading edge in terms of the angle of the approaching air stream, air particles have more and more trouble changing direction fast enough to prevent pockets of turbulent air forming on the upper surface of the plate. As this turbulence has to be pulled along behind the trailing edge like a horse pulling a cart, it has the effect of slowing the air foil down.

Lift, therefore, increases with higher angles of attack, but so does turbulence and drag.

At this point, the difference between angle of incidence and angle of attack should be made clear.

An aircraft wing's angle of incidence corresponds to the pitch angle of a wind machine blade. It is the angle at which the wing is set in the fuselage. It is the angle formed by the chord line of the wing and the axis line of the motor.

Angle of attack is the angle at which the wing approaches the air stream. It is influenced by both the angle of incidence and the angle at which the craft is flying, in terms of the earth's surface.

Later, it will be seen that a rotor blade's angle of attack is influenced by both the angle of blade pitch and the angle of the relative wind.

Nevertheless, the principles involved in angle of attack apply equally to both rotor blades and airplane wings.

As aeronautical engineers discovered that lift, as well as turbulence and drag, increased with increased angles of attack, they also found that it took more power to fly an airplane at low angles of attack, just as it took more power to overcome higher angles of attack. The optimum had to be somewhere in between.

An airplane must travel at a certain speed for each angle of attack to lift a certain weight. The minimum speed possible is the stalling or landing speed.

The early airplanes flew with low power, low speed, and low angles of attack.

In recent times, however, some air foils have been successfully designed to have lifts fifty times greater than their drag.

The science of aerodynamics has become so developed, in fact, that some small aircraft have to be tied down to the ground when not in use. Otherwise, the lift, caused by wind blowing on the leading edges of the wings will raise the craft almost straight up in the air. They remain airborne until the leading edges move out of the air flow. The lift then diminishes and the craft fall to the ground and are damaged.

Air foil principles have all been very painstakingly worked out by scientists and engineers using terribly expensive wind tunnels and the many, many mathematical formulas which they so dearly love.

The reader, however, can conduct similar experiments involving lift and drag by simply holding a piece of cardboard at arms length out a car window while the vehicle is moving at thirty miles an hour.

Aim the leading edge of the cardboard slightly upwards and you will notice a slight upward lift. Your arm will also be slightly lifted.

Aim the cardboard slightly downward and you will notice a slight downward lift and your arm will be pressured downward.

Somewhere between the upward and downward lift you can find a point or angle of the cardboard where you will experience no lift at all. This is the angle of "zero lift". It should be at an angle where the breadth of the cardboard is nearly parallel to the ground.

At this point of "zero lift" you will notice some drag, a pressure pushing your arm backwards in the direction of the rear of the motor car.

As you slowly raise the leading edge of the cardboard from the zero lift position, upward lift will increase but so will backwards drag. The pressure pushing your arm back will become stronger than the pressure pushing your arm up.

The angle you are now forming between the present angle of the cardboard and the previously discovered "angle of zero lift" is "the angle of attack". It is the angle of the cardboard actually being struck by the air flow.

As the angle of attack continues to be increased by your raising the leading edge of the cardboard, drag will become increasingly stronger than lift.

This is illustrated in plate no. 30, fig. 2, where the cardboard is represented by the chord line of the air foil.

At some point in the raising of the cardboard's leading edge, your arm will experience little or no upward force of lift but only backward force or drag.

The exact point where drag supersedes lift is called "the stalling point". Depending on the design of the air foil, it occurs when the angle of attack is somewhere between 15° and 20° above or below the point of zero lift.

The point of air foil "stall" is the point, or angle of attack, where the air flow breaks up, separates from the air foil and stops producing lift. The separated air flow, however, still continues to produce drag.

Birds angle their wings to the stall point when they are slowing down to land on a branch.

Wind machine rotor blades must be seen as two or more air foil wings rotating around an axis, the windshaft axle.

Lift then must be translated as the wind generated lateral thrust that turns the blades by actually pulling them around.

Angle of attack, at this point, must be seen as angle of incidence which, it will be remembered, is the angle at which the wing is set into any airplane body or fuselage.

In the case of the rotor, angle of incidence must be translated as "pitch" which is the angle at which all of the blades are set to the plane of rotation.

The plane of rotation is the path followed by the blades. It is perpendicular to, or at right angles to the axle, or axis of rotation. It is the plane of the circular path followed by the blades. It is the plane in which the hub turns.

Pitch, like angle of incidence, is the angle at which the blades are set in the hub. It is the angle formed by the plane of rotation and the chord of the air foil, (see plate no. 37, fig. 2, 3 and 4).

The traditional Dutch four bladed windmills were pitched at 20°, but this was arrived at by trial and error rather than by aerodynamic theory. It is interesting to notice, however, that the angle of maximum push was found to be just short of the aerodynamic "stalling point".

Rotors are usually pitched between 2°, which is considered "fine", and 15°, which is considered "course".

As the flat side of the rotor blade corresponding to the underside of the airplane wing is the side that faces into the wind, it will be seen that the value of the push is to start the blade moving through the air so that the lift can commence. It will also be seen that the faster the blade turns, the greater the volume of air passing over the leading edge; the greater the volume of air passing over the leading edge, the greater will be the lift, which, in turn, will cause the blade to rotate faster, which will again increase the volume of the air moving over the leading edge etc., etc., ad infinitum. This is the stuff from which a dangerous "overrun" can be made, (see "pilot vane", plate no. 68, fig. 1).

Remember centrifugal force increases with rotational speed and centrifugal force's one interest in life is to make the blade fly off and kill somebody, (see plate no. 38, fig. 1).

Overrun should be born in mind when examining plates no. 39 through to 47 which illustrate a comparison between rotor blades of 11° and 15° pitch angles.

The following points should be of help in making a decision between the two.

Increasing the pitch (angle of attack), to 15°, will increase the push which will increase the rotor blade's ability to start in light winds.

It will also bring the angle of attack

further from the angle of zero lift and closer to the angle of the stalling point.

We have established that an air foil stalling point is between 15° and 20° to the angle of zero lift, and we can assume that the angle of zero lift is almost parallel to the axle. The angle of maximum drag would be parallel to the hub at right angles to the axle.

Beyond the 15° to 20° pitch, lift will decrease and push will increase so that the rotor acts less and less like an air foil and more and more like a water wheel. Eventually it will act like the bird's wing when it is approaching a branch and just plain stop.

This is the principle of "feathering" by which sophisticated (and expensive), wind machines are able to employ intricate machinery to change blade angles which slow down the rotors and prevent overrun.

This "feathering" is usually in full effect when winds reach a velocity of 25 m.p.h.

The 11° pitch, on the other hand, will have more difficulty starting because it will have less push on its flat front side, but it will have more lift from its curved backside which will make it turn faster. This lift will be constantly increased by the increasing volume of air passing around, (that is to say over), the air foil. The faster it turns, the faster the increasing lift will make it turn.

At the same time, drag will be reduced by the lesser amount of turbulence following the sharper or flatter angle.

As the problem of overrun may be solved by adjusting the pilot vane already mentioned, the decision of whether or not to select the 11° pitch over the 15° pitch will be based on the builder's preference for higher speed and lower starting ability over lower speed and higher starting ability.

Higher speed of rotation means greater electrical generation with less gear up, but that won't help much if the machine won't start in the prevailing winds of your area.

Remember that most rotors do not cut in until the winds exceed 8 m.p.h. because there is not much energy in winds below that speed.

Very fast rotors have been pitched at around 7°. No doubt, someone had to climb up the towers and nudge them into reluctant action.

Nevertheless, Calvert has calculated, with the best of scientific equipment, that a 7° pitch provides the optimum lift-drag ratio for a rotor blade.

The builder can, however, make the decision easier for himself by conducting a number of simple experiments.

From three pieces of six foot 2" X 4" pine, use rip saw or table saw cuts to make three blades of 7°, 11° and 15° pitches.

Sand down the saw cuts a little bit.

Rough plane the back sides a little so that they are a bit rounded and somewhat resemble air foils.

Give them each a coat of outdoor paint to smooth them off a bit more and protect them from weather.

There should be a six inch section in the middle of each 2" X 4" piece that is not angled or pitched in any direction.

Drill a small central "axle hole" through the broad side of each six inch flat middle section of each piece.

The three pieces of 2 X 4 will then somewhat resemble the blade illustrated in plate no. 43, fig 3, except that they will have the same pitch angle throughout each side and they will not be tapered.

Mount the three rotors on three pieces of 4" X 4" lumber by driving 6" or 8" spikes through the axle holes into the 4" X 4" pieces.

Wire the three 4" X 4" pieces to fence posts, a reasonable distance apart, and watch how each "rotor" works.

Note how soon each one starts and how fast it goes.

Take the one you like best as the pitch for your wind machine.

It is expected that the 15° pitch will be chosen because of its early starting ability.

Nevertheless, one very successful American builder has recommended an 11° pitch. He suggests 15° only for winds that exceed 23 m.p.h. This is based on his own experience and there is no known substitute for that.

Starting ability is, of course, an important consideration and, as we have noted in an earlier section, the farm type multiblade has the greatest starting ability of all. This is not only because it has a large number of blades, but because each of its blades is a cambered air foil.

A cambered air foil is one in which the chord line has an upward curve or convex shape.

It you can imagine the chord line in plate no. 37, fig. 2, as having an upward curving convex shape, you will see that it resembles the symmetrically curved blade of a multiblade as illustrated in plate no. 33, fig. 3, that has been cut from a steel drum.

Cambered air foils are also used on Darius, (egg beater), vertical axis type wind machines.

The same principle is applied to the air foil type designs of ships rudders and keels.

Cambered air foils bend the air flow, thus increasing the thrust and giving good starting torque. Their curved surfaces also allow air particles to move up more easily around the leading edge. Greater angles of attack are, therefore, possible with less danger of turbulence and drag.

It will be remembered that multiblades are pitched at an angle of 30° to the plane of rotation.

The cambered air foil, however, is not the best design for when the blades are in motion because the sharp leading edge is not tolerant of the changes in angles of incidence and attack which occur with changes of speed and direction of wind.

The cambered, or curved multiblade sail, nevertheless, allows for inexpensive and rugged construction so that its very imperfections may be seen as aids to control.

Galvanized metal sails of this kind have been known to last for more than forty years with no signs of wear or deterioration.

At the same time, it should be remembered that the early multiblades in both America and Australia were made with flat plate sails as illustrated in plates no. 8 and 35. These machines pumped an awful lot of water for an awful lot of cows and saved an awful lot of blistered hands.

Since then, of course, scientists in their wind tunnels have proven beyond doubt that a rotor type air foil will consistently and greatly out perform a flat board or piece of plywood of the same dimensions and shape.

The flat board, or plate type air foil, whether it be made of wood, plywood, galvanized iron or plastic, has two great advantages; it is cheap to make and it works.

If you decide on this type of air foil, you should give it every possible advantage by rounding the leading edge and painting the trailing edge to a thickness not exceeding 1/8".

It is the usual custom on a multiblade to pitch the flat plate blade at 30° as you would the camber or steel drum section.

After reading the foregoing, however, you might decide that without the camber you cannot justify the 30° pitch or greater angle of attack, as you do not have the curve to bend the air flow and increase the thrust.

You might, therefore, prefer a 15° pitch like the sawhorse windmill (plate no. 55, fig 2), or the 20° pitch of the old dutch four bladers, for your flat blade, plate type air foil, as illustrated in plate no. 8. There can be no doubt that these pitch angles have worked and worked well on flat blades in the past. Somewhere between 15° and 20° might, therefore, seem to be the ideal.

Calvert, on the other hand, has calculated that an air foil will work sufficiently well over a range of angles of attack up to 15°. If, as we shall see, the real angle of attack is the angle formed by the angle of the relative wind and the plane of rotation, and the angle of the relative wind bisects the angle of the real wind and the plane of rotation, then a 30° pitch would represent a real angle of attack equal to 30° divided by 2 = 15°, which would be the maximum acceptable angle.

Remember, that the smaller the angle of attack, the faster the wind machine will turn. Increasing the angle of attack toward the 15° theoretical maximum slows the machine down, just as changing the position of the sail on a vessel changes the vessel's speed.

A 36 blade fan with blades pitched at 30° will be very slow turning. This could be exactly what you want for a fan that has an eccentric mounted on its wind shaft axle and is thus directly connected to a water pump without benefit of gear down.

It will certainly start quickly in a light breeze and get the water out to your cows.

There is, nevertheless, an obvious difference between the airplane wing flying into a self created air stream and a rotor blade turning in the face of the real wind, though both are air foils designed on the same set of principles.

The difference is the difference between the real wind and relative wind as illustrated in plate no. 37, fig. 3 and 4 and in plate no. 38, fig. 2 and 3.

If you can visualize a cross section of any air foil rotor blade as a human eye, the relative wind is the real wind as the air foil "sees" it from the view point of its leading edge.

The real angle of attack, then, should be the angle formed by the relative velocity line, that is to say, the relative wind direction line and the line formed by the chord of the air foil.

The relative wind line must be seen as the result of two motions combined, as illustrated in plate no. 38, fig. 3;

1) The real wind line, moving up from the bottom to the top of the page parallel to the windshaft or axis of rotation: The real wind, in other words, is the wind blowing into the "face" of the wind machine.

11) The blade motion rotating in the plane of rotation: This is shown as a movement to the left in the illustration.

It will be observed that (1), the real wind direction and (11) the direction of blade motion are at 90° to each other.

In an oversimplification, the relative wind direction would equally split direction (1) and (11), and be at 45° to both the real wind direction and the direction of blade retaught.

The rotor blade must be pitched at an angle relative to the direction of motion in a way that adjusts the angle of attack to the relative wind.

The blade angle, or pitch, must be equal to the relative wind angle less the angle of attack plus the zero lift angle of the air foil.

The zero lift angle of;

A) A symmetrical (rotor type) air foil = 0°
B) A cambered (Multiblade type) air foil = 2°
C) A highly cambered air foil = 4° - 6°

Example;
Relative wind angle = 20°
Angle of attack = 6°
Zero lift angle = 2°
Blade angle = 20 - 6 + 2 = 16°

This calculation may be likened to one made by a boat's pilot striving to reach a given point in terms of;

D) The set of the tide.
E) The direction of the wind.
F) The lateral drift of the boat.
G) The boat's forward speed through the water.

- Draw a right angle triangle A - B - C, in which "A" is the apex (high point), and A - B is the upright line. "B" is the right angle and "C" is the other point off to the left hand side. Make A - C twice the length of A - B.

The line B - corresponds to the linear speed or velocity of the blade.

- "B", (the right angle), is a point on the plane of rotation, or, as the boat's pilot would see it, a point on the surface of the sea.

- The length on the (upright), line A - B, represents, to some scale, the speed of the wind relative to the speed at which the earth is rotating.

- The direction of A - B, corresponds to the direction of the rear wind.

- The line C - A, corresponds to the direction of the relative wind and also to the velocity of the wind relative to the velocity of the blade.

- The angle formed at the point "C" is the angle of the relative wind to the plane of rotation.

Such calculations are beyond the scope and interest of the average wind machine builder.

What is significant, however, is that the relative wind angle is roughly 45° to the plane of rotation, and the real angle of attack is formed by the relative wind angle and the chord of the air foil.

CHAPTER SIX

ROTOR BLADE CONSTRUCTION SELECTION AND TESTING

Wood is the best material for rotor construction because the wind can repeatedly apply loads to it and, theoretically, it will not crack. It might crack or split from environmental causes, but there are many ways to protect it from this.

Wood is stronger for its weight than metal. Jacobs found that even aluminum was too heavy and would create too much centrifugal force.

The best woods are soft woods and the best soft wood is aircraft grade Sitka Spruce, properly selected and dried. This, however, may be hard to find, as it all comes from a relatively small area in Western North America.

A good second choice would be the comparable quality of Douglas Fir, because it is readily available and comparatively cheap. Red Pine would be a third choice with the other pines following.

Properly dried, Sitka Spruce weighs 28 pounds per cubic foot and has a strength in bending of 9,400 pounds per square inch.

Douglas Fir is, therefore, able to withstand more stress per cubic inch, or linear inch than Sitka Spruce at a very small increase in weight.

The light coloured layer of any log that is found next to the bark is called "sapwood". The darker central portion is called "heartwood". Heartwood is usually more resistant to decay, stain and mould, but sapwood is not only more porous and pliable, it is fundamentally more strong. Sapwood is, therefore, preferable where severe bending pressures are encountered, such as in the operation of a rotor blade. Make your rotors from sapwood.

It is also of great importance to select properly grained lumber. Bear in mind that wood always shrinks more across the grain than it does along the grain. A board will, therefore, shrink more from the sides than it will from the ends. It will also shrink one half to two thirds as much in a tangential direction than it will in a radial direction to the annual (growth) rings. Such shrinking causes the wood to twist, cup, sliver and check.

If you can visualize the long arm of a clock pointing at the number nine indicating that the time is 15 minutes to the hour, the best board for rotor construction will be in the sapwood section along the direction of that arm. The same, of course, applies to sections along the clock arms pointing to the three and six portions. The point is, that the boards should have vertical grains so they could be selected from positions along radial lines from the centre of the log, (see plate no. 42, fig. 1 under "good" and "not good").

Marcellus Jacobs personally selected his own 2" X 8" pieces of Sitka Spruce. When he got them home, he rough cut his 7' 6" blades, (for 15' diameter blades), then kiln dried them for several weeks before giving them their final shape and polish.

There are many records of his blades being fully operational after 25 years of continuous service.

There is no doubt that the strength of wood increases as it is dried out.

Some living trees have a moisture content of 115% expressed in terms of completely dried wood.

If an average size house were to be built of very green wood, it has been estimated that it would contain about 500 gallons of water.

When water leaves the cell walls, it causes the cells to contract, harden and stiffen so the wood gains strength.

Once the wood is dried, in other words, once the cells stiffen and cell walls loose their moisture and enter their closed state, they develop a resistance to the reabsorption of moisture.

When normal building lumber has been dried to an average moisture content of 19%, its bending strength increases by 22%, the strength of horizontal sheer increases by 10%, the stiffness increases by 9% and the crushing strength increases by 32%.

The structural lumber in aircraft usually has a moisture content of 12%. They try not to let it fall below 8%. Propellers are often dried to between 5% and 7%.

Between 8% and 12% is about right for a wind machine rotor blade. Above 12% moisture content, there are problems of glue adhesion and glue line fractures as well as weight and dimensional changes. In all events, try to stay within the 10% - 15% levels.

Wood can be dried in the open, or even in an unheated barn or loft, as long as it is piled in such a way that the air circulates evenly through it and it is held fast so that it can not change its shape. This is called "seasoning" and usually takes a year or two. Timbers for the old wooden navies were seasoned for seven years. Seasoning increases the hardness and stiffness of lumber but reduces its toughness and resistance to shock. There is also a variation throughout in terms of the final moisture content. For instance, the boards can dry more on the ends which causes splitting, or they can dry more on the outside than the inside (case hardening), which causes them to warp when cut. The results of seasoning, in other words, tend to be uneven, but it may be the only method at hand.

Kiln drying is faster and more uniform, but it must be done at a controlled rate. Too rapid drying can cause splitting, cell collapse and case hardening.

Once the blade pieces are dried, they should be shaped and painted as quickly as possible so they will not reabsorb moisture.

Be sure that the heavy end of the board is to be at the hub end of the blade, so you can minimize centrifugal force. Use the broom handle method illustrated in plate no. 46, fig. 1.

All of the blades illustrated are about two inches thick, similar to the thickness of the 7' 6" Jacobs blades. Though Jacobs used single pieces of wood, with obvious success, you will greatly increase strength and avoid problems of splitting if you use lamination. Lamination will also make the blades easier to balance.

First select three pieces of 1" grade one Douglas Fir for each of the blades you intend to make. Be sure that they are absolutely straight and that they meet all of the above criteria.

Rough the joining sides a bit to give them grip; glue them together with a good weather proof plastic resin glue; clamp them carefully in such a way that the wood does not bruise and let them properly dry.

One inch dressed lumber should be about 3/4" thick, so the overall thickness of the three pieces should be about 2 1/4". The 6" unshapen part that fits into the hub should be left at 2 1/4" to give extra strength. You will then be left with a choice of two almost perfectly smooth (dressed), sides, which is very important, as we shall see.

Plates no. 39 through to 42, show how to angle rotor blades with the use of wedges glued onto the but ends of the blades where they fit into the hub and are bolted between two pieces of steel.

This is by far the easiest and best method because each of the two, three, or four blades is then shaped in exactly the same way. Even the wedges are the same; the only difference is that wedge sides are reversed on each side of the hub.

Only the rounded back side is hand shaped, and this is easily done with the use of the metal template in the illustrations.

The flat front side is the untouched side of the original dressed lumber. You do not have to shape it at all.

To sum up: No work is done on the flat front side, except smoothing and sanding, and the pitch angles are created by the wedges only. There is no loss of strength.

The point is that it is much easier to cut 6" wedges, with an ordinary hand saw, than it is to attempt accuracy when cutting and hand shaping both sides of an opposing angle blade like the one illustrated in plate no. 43, fig. 3, and plate no. 46, fig. 2, 3 and 4.

Marcellus Jacobs had a power operated duplicating lathe or copy machine for shaping his blades. You, presumably, do not.

Once the blades are shaped, they should be carefully weighed, sanded and painted with three coats of aluminum asphalt paint, with careful sanding after each coat. This was the Jacobs method.

Each blade must weigh the same or vibrations will occur which will tear the machine apart.

Before painting, a seven foot blade should weigh between 5 1/2 and 6 pounds.

If you have to lighten one or two blades, be sure you do it by evenly sanding the curved back side in such a way as not to alter the air foil shape.

All of the blades should be weighed again before they are set in the hub.

The paint will effectively seal out moisture. The blades will appear black at first, but will have a bright aluminum finish when they dry.

If aluminum asphalt is not available, three sanded coats of a good marine spar varnish will do almost as well.

Wood and fibreglass also make an excellent combination and are especially useful in cases where the blade length may somewhat exceed scientific recommendations or stipulations. Wood can produce a combination of bending strength, toughness and stiffness unsurpassed by other materials, while glass fibres are among the strongest materials known to man. Glass fibres, however, must be put onto a shape that is as perfect as that intended for the final product. Remember, an error or blemish of even 1/64 of an inch, especially on the curved back side, can throw an air foil out of kilter, though good air foils can adjust a significant amount to both sides of their optimum.

Wood under fibreglass will be stronger, and it will be protected from the elements so that it cannot split, crack, or warp.

If the blade is not to be fibreglass

covered, something like a strip of brass, copper, or aluminum should be tacked on and glued down along the leading edge to protect it from wear and tear caused by particles carried in the wind.

This is always a necessity if the blades rotate at close to 300 R.P.M., as some do, even if dust or sand are not noticeable in the air. These strips sometimes had to be replaced on the Jacobs blades after they had been battered by hail stones for a number of years. Obviously it is cheaper to replace a strip of tin than it is to replace whole blades.

When the blades are finished and painted, weigh them carefully, glue on the wedges, and set them in the hub, (see plate no. 41).

Glue the wedged blades, if you are using wedges, onto wood or plywood circles and glue the hardwood, "pie pieces", in between the blades, (see plate no. 41, fig. 4 and 5).

Glue a second wood or plywood circle over the top of the blade ends, pie pieces, and wedges.

These wood circles are not shown in plate no. 41, fig. 4, but they are necessary because they strengthen the blade's grip in the hub. They should be of 3/4" plywood, and two pieces glued together on each side won't hurt.

If you don't use plywood, you will have to use two one inch layers of hardwood glued together on each side. Be sure the hardwood is kiln dried and that the two pieces of each side are glued together with their grains going in opposite directions so they won't split under the strain.

These circular pieces of wood, the blade ends and the pie pieces, are sandwiched between two circular pieces of 1/2" steel plate which are bolted together with the strongest 5/16" bolts you can get. Aircraft quality bolts are suggested.

The steel pieces are of the same diameter as the circular pieces of wood.

There should be two bolts through each blade end and one bolt through each blade end. Hardware store bolts will have to be thicker, say 1/2" or so.

One of the steel plates is welded to the hub, as shown in plate no. 17.

The hub should be mounted onto a solid steel axle of not less than 1" diameter.

Hub (steel plate), diameter should be 12" for blades of six to seven and a half feet, that is to say for rotor diameters of 12 to 15 feet. This will allow a six inch grip for each rotor blade.

Blades of three foot six inches, for seven foot diameter rotors, can be mounted on 8 inch diameter hubs.

Jacobs had hubs of about 10 inch diameter on his 15 foot diameter rotors.

These should be a cone shaped piece of wood or metal fixed to the windward side of the hub (steel piece), to minimize drag.

When the blades have been fixed to the hub, the rotor should be balanced. Do this by mounting the rotor on an axle that has been set up with proper ball bearings.

Number each blade.

Gently spin the rotor by hand and take note if one blade, as indicated by its number, continually stops with its tip pointed to the ground. This will be the heavy blade.

You can also use a "bubble" balancer, as professional mechanics do when they balance automobile wheels.

It will be necessary to increase the weight of the lighter blades. Do this by adding pieces of lead to the outer hub bolts behind each blade. Do not tamper with the air foil at this time.

Now that the construction methods have been established, we should consider the measurements of the blades and what we want them to do.

Generally speaking, a seven foot diameter rotor with three foot 6 inch blades will satisfy the needs of a small cabin; a 14 or 15 foot diameter rotor with seven foot or seven foot six inch blades, will satisfy the needs of an average house.

These rules apply only in the light of certain modifications. Once such modifications would be that "heat up" appliances, such as electric stoves could not be used. More attention will be given to this aspect in the electrical section which follows.

The 15 foot diameter Jacobs direct drive machines had 32 or 110 volt generators running off the axle in their "heads". These would kick in at about 125 R.P.M. and reached their full power of 3,000 watts at about 225 R.P.M. They achieved a tip speed ratio of 6:1 at about 175 R.P.M. and would rotate at about 150 m.p.h. in a 25 m.p.h. wind. They could develop between six and eight horsepower in an 18 m.p.h. wind.

Remember that the power of a rotor increases by the square of its diameter. This means that a seven foot rotor produces 100 units of energy. A 14 foot rotor will produce 400 units of energy, rather than the 200 units that might be expected.

Remember also that the tip speed increases as the diameter of the rotor increases. A 14 foot diameter rotor, therefore, requires less gearing up than a seven foot diameter rotor. To use an extreme example, a good 15 foot diameter rotor will achieve a 6:1 tip speed ratio at only 47 R.P.M.

Also, it should be noted, most of the work is done by the extreme 20 or 30% of each blade. You can relate this to torque. It is the strong hand on the handle of the wrench.

The builder should, at the same time, bear in mind the significance of the increased wind velocity that will be exerted on the longer blades with their increased energy production and increased tip speed.

When the wind speed doubles, the power that can be extracted from it is eight times as great.

In other words, if a 14 foot diameter rotor is extracting 0.47 horsepower in a 10 m.p.h. wind, it will extract 0.47 X 8 = 3.76 horsepower in a 20 m.p.h. wind.

When the wind speed triples, the power that can be extracted is 27 times as great.

Therefore, the 14 foot diameter rotor, which extracted 0.47 horsepower in a 10 m.p.h. wind, would extract 0.47 X 27 = 12.69 horsepower in a 30 m.p.h. wind.

The seven foot diameter rotor which extracts 0.125 horsepower in a 10 m.p.h. wind would extract 0.125 X 27 = 3.75 horsepower in a 30 m.p.h. wind.

This is the principle of "cubing the velocity".

Rotors are designed to operate in winds of seven to 25 m.p.h. Winds of 30 m.p.h., therefore, must be considered dangerous.

Home built rotors of more than 15 foot diameter must also be considered dangerous.

The larger diameter, therefore, produces many times more than twice the power and it does so with less gear up. (See "Gear Up" under "Scientific and Engineering Information").

So, if you want full output at low wind speeds, you will need a large rotor, whereas, if you are satisfied with full output only at high wind velocities, a small rotor will suffice.

Once having decided on the length of the blade, the next consideration is the width.

The standard length to width ratio is 10:1. That is to say that length should be ten times width. Therefore, a blade 5 1/2" wide (plates no. 39 through to 43), should be no longer than 10 X 5.5" = 55" = 4' 6". Yet 5 1/2" blades have been successfully built to a length of six feet giving a total diameter of 12 feet.

As the seven foot 6 inch Jacobs blades were just under eight inches in width, it would be best to use the seven inch wide blade illustrated in plate no. 45, for blades over six feet in length. The seven inch blade could even be extended another 3/4" to the trailing edge side on the right side of the drawing, as long as the contour is not changed and the trailing edge remains at 1/8". Seven inches, however, should be wide enough. Many successful 15 foot diameter rotors have been 6 1/2" wide.

A 1/8" trailing edge is the rule for all blades.

If the blade width is extended to seven inches, the width of the Butt, or Root end should be kept at six inches so that it fits well into the hub. The one inch should be taken off the trailing edge side, so as not to reduce strength.

To sum up then: Blades of up to six feet (12 foot diameter), should be 5 1/2" wide and blades of over six feet to seven feet 6 inches, giving 14 or 15 foot diameters, should be seven inches wide. All of these blades should be 1 3/4" to 2" thick.

Plates no. 42, 46 and 47 show tapered blades, which are narrower at the tip than they are at the root. This is the traditional rotor blade shape. It observes the principle that by making the tip narrower, you increase the potential rotational speed, just as you reduce the speed and increase the bottom end torque of the multiblade by widening its tip.

Also, by making the tip narrower and thinner, you reduce its tip end weight, and hence the power of its centrifugal force. In other words, you reduce the weight of the stone on the end of the spring. You will also reduce the "flywood effect", or momentum build up.

The English engineer, N.G. Calvert, has calculated that a hypothetical 6.5 foot diameter rotor turning at 1,200 R.P.M. would produce a centrifugal force of 3 tons or 6,000 pounds. This situation, however, is somewhat unlikely when even the Jacobs 15 footer rotates at no more than 300 R.P.M.

More realistic calculation, by the American engineer, Jack Park, has shown that a five pound, six foot blade on a three blade rotor will have a centrifugal force of about 100 pounds when rotating in a 10 m.p.h. wind. The centrifugal force on the same blade would be 226 pounds in a 15 m.p.h. wind, 401 pounds in a 20 m.p.h. wind and 628 pounds in a 25 m.p.h. wind.

Bear in mind that centrifugal force is the force that tries to rip a blade away from the hub, but these hubs are of a very strong design. Park has also proven, for instance, that two 5/16" aircraft quality bolts can handle a centrifugal force of 10,000 pounds.

If you wish to be especially careful, you can also consider the resistance to centrifugal force of the blade itself.

Tensile strength is end to end pulling strength. That is to say, it is resistant to breaking from stress in relation to length. It is, therefore, the blade strength that combats centrifugal force.

The tensile strength of wood, varies between 7,000 and 12,000 pounds per square inch.

To calculate the tensile strength of a rotor blade, multiply its cross section in square inches by 7,000 pounds, (though in the case of properly dried Sitka Spruce or Douglas Fir, 8,000 pounds might be more realistic).

A 7' 6" rotor blade with a width of 7" and a thickness of two inches would have a cross section area of 2 X 7 divided by 2 = 7 square inches.

Therefore, its minimal tensile strength would be 7 (square inches) X 8,000 (pounds) = 56,000 pounds, considerably more than Mr. Calvert's 6,000 pounds for a much faster turning rotor. It is, therefore, not necessary to taper either the width or the thickness of the blade to reduce centrifugal force.

A non-tapered blade is also much easier to accurately construct. Remember that each blade must be exactly the same in terms of shape and weight. You can, however, taper the rounded back side down to 3/4" at the tip if you really want to.

Do this by cutting one long wedge, which you can use on all blades by fixing it to the flat front side while you are working. Make it sharp where the blade joins the hub, six inches from the but end, and 1 1/4" thick where it rests against the tip end. Then, place the blade round side up on a table and use your template to shape the back side evenly throughout, always maintaining a constant 1/8" on the trailing edge.

The width can taper to 3" on a 3' 6" blade, 3 1/2" on a six foot blade and 4" on a seven foot or a 7' 6" blade.

All of this tapering, let me emphasize, is optional.

Just the same, you should always round the tip to minimize drag. Do this by making a perfect semi circle, the diameter of which is the breadth of the blade tip. You should also taper the last 6" of the tip down to 3/4" for the same reason. Do this with a straight cut before you shape the blade with the template. Be sure that, that edge also is perfectly rounded. The tip, in fact, should resemble the tip of an airplane wing.

You can also angle the blade tip back for about three inches from the trailing edge to the leading edge. Again, be sure the edge of this straight angle is well rounded, (see plate no. 38, fig. 1).

Something else you will notice in the illustrations of plates 46 and 47 is a "twist", the pitch angle progressively reduces towards the tip. This idea was first introduced by an Englishman named John Smeaton in 1759 on the English version of the Old Dutch Four Bladers. He reduced the pitch from 18° at the root to 7° at the tip. Somehow this became a standard practice right up to the present day.

Smeaton's reason could have been to maintain torque by a long blade length, while at the same time restraining the rotational speed by gradually reducing the speed by reducing the pitch angle as the tip was approached. In those days, they believed that windmills were run by push, rather than lift, so by reducing the pitch, they believed they were reducing the push.

Remember, the blades could be 20 feet or more in length, giving diameters that could exceed 40 feet. This could create a lot of torque as well as a lot of momentum built up.

The Dutch liked their windmills to turn at about 15 R.P.M.

Overrun was a major problem, as the brakes could heat up to the point that the mill could actually catch on fire.

You will also notice the same reducing pitch or "twist" in the design of airplane propellers. For this, the supposed reason is that the strain on the blade and axle will be reduced by keeping the largest angle close to the hub where the blade is thicker and the leverage is less.

Calvert's experiments have found no more justification for this twist on a wind machine blade than they have for taper. He points out that, as the tip extremity does most of the work, it should have the same angle to work with. It will also be obvious that on a wind machine you want to increase the strain on the axle, not minimize it.

Commercially manufactured machines, including the modern wind charger, make a straight cut blade without taper or twist. It is assumed that they have done this to keep down labour costs. Nevertheless, it has proven to be a reasonably reliable rotor for general use. It is suggested that the home builder do the same.

The blade, then, should be of the same thickness and pitch throughout, except that the thickness of the last 6" should be tapered down to 3/4" at the rounded tip.

Having decided on the number and shape of the blades, there remains only the decision as to how many blades you require.

The early rotors were two bladers like the one illustrated in plate no. 43, fig. 3. This was because they resembled airplane propellers and people thought they were easier to make. Neither of these facts are true. As we have seen, though the two blade is certainly faster turning than the three or the four blade rotor because its solidity is less, there are, however, attendant problems which give the two blade a "choppy" performance that strains the machine.

When the wind changes direction, the tail vane moves the rotor, weather vane fashion, so that it faces the wind head on. When the two blades are straight up and down, they are parallel to the vane and so have little resistance to the vane's orienting motion. When the blades are parallel to the horizon, the blades act as a gyroscope, which causes an actual resistance to turning into the wind. This causes the series of jerky motions known as "yawning".

The Curtis Write Corporation discovered a similar problem during the early days of the Second World War. When they started making really big engines and mounted them on two blade airplanes, they found that the power plants tore themselves right out of their mounts when the airplanes were put into an abrupt turn. Many aircraft were wrecked before it was discovered that the problem could be solved by doubling the number of propeller blades from two to four. Later it was found that the same effect could be achieved even if the fourth blade was left off, in fact, the air speed actually increased, so they settled for the three blade propeller.

Jacobs had made the same discovery with his rotors some years before.

Adding a third blade to a wind machine then, is something like adding another cylinder to an engine. The engine runs smoother and so does the wind machine. It also "steers" better.

Adding a fourth blade will cause it to start sooner and run slower with less danger of overrun.

A four blader will rotate at 72% of the speed of a two blader. A six blader will run at 58%, and an eight blader will run at 50%.

The rule is that the rotational speed varies inversely as the square root of the number of blades.

The first wind chargers were four bladers, but the most recent models are straight non-tapered, non-twisted, two bladers with air brakes. Air brakes are, however, a bit too complicated for the home builder to construct. For this reason, the pilot vane is recommended, (see plate no. 68, fig. 1).

The United States, (War Production Board), in the Second World War, concluded from their studies that the two blader was superior, but they were concerned with very large generators designed for the commercial production of electricity.

On the other hand, one home builder has stated that he operated a 12 foot diameter two blade for 18 months with total success. The blades were 6" wide.

Jacobs, however, estimated that if his three blade, 15 foot diameter machine, had two blades instead of three, 1,100 pounds of gyroscopic resistance force were consistently applied and then removed to the movement of the tail vane twice during every revolution of the rotor.

To sum up: At the instant when the two blade is vertical, it offers no centrifugal force resistance to the horizontal movement of the tail vane as it conforms to changes in wind direction. On the other hand, at the instant when the blades are horizontal, their centrifugal force, then at its maximum, offers a considerable resistance to the horizontal movement of the tail vane. The two blade, therefore, produces a high level of dangerous vibration in the machine.

The three blade cures this problem by creating a steady centrifugal force against which the tail vane moves smoothly as it horizontally shifts.

One of the Marcellus Jacobs three bladers was operated in Minnesota for more than a quarter century. During that period, two tornados passed through the area. No damage was done to the machine in either case, even though, during the second tornado, a tree was uprooted and fell onto a nearby multiblade tower and knocked it down.

No further proof is required for the superiority of the three blade rotor as an electrical generator. The case rests.

A four blade rotor, pitched at 11°, will make an especially safe wind generator because of its slower rotational speed and resistance to overrun. Jacobs did not object to a fourth blade, he just could not see what purpose it would serve on his own machines.

It is really as a water pumper that a four blader comes into its own. Pitched at 15°, with direct drive axle (plates no. 31 and 32), it can be geared down to run a lift or pressure pump with considerably more power than could be derived from a multiblade, though it might not start as soon.

The four blader can also be geared up to run a high speed pressure pump for overhead spray irrigation, (see "Design Relationships" (Z)).

Before making the final decision, however, the builder should consider the "sock type" rotor blade suggested in "Design Relationships" (P). This design is especially applicable to four blade rotors, particularly to those of smaller diameter, say, 12 feet or less.

It is hard to believe, however, that a "sock type" can create the same quality of air foil shape to be obtained from a wooden blade. Nevertheless, "sock types" have consistently worked well in the field.

Now that the blades have been selected, finished and set in the hub, you will want to test their bending strength to make sure that they will be able to stand up and not break against the force of the wind.

First you must set the hub, with blades attached, on some kind of a stool whose diameter corresponds to the diameter of the hub. The blades will then be horizontally supported by the hub only, so equal weights can be suspended from each blade tip. These weights will equal the strongest expected wind force of, say, 30 m.p.h. If the blades do not break from the pull of the weights, it will be proof that they will stand up safely in a 30 mile an hour wind.

What you are going to measure is drag. This drag, among other things, is the force that causes windmill blades to bend when the rotor is facing directly into the wind. It is the force which tries to bend the blade in the direction in which the wind is blowing, (see plate no. 38, fig. 1). It should not be confused with the aerodynamic drag that follows the trailing edge of each blade and tries to slow down the windmill rotation, (see plate no. 37, fig. 2).

Drag is measured by multiplying the frontal area (A), measured in square feet, by an empirical wind speed factor (F). The result, then, has to be divided by the number of rotor blades, (2, 3 or 4), to determine the weight to be hung from each blade tip. This method, of course, will also apply to multiblades.

EMPIRICAL WIND SPEED FACTORS

WIND SPEED IN M.P.H.	EMPIRICAL FACTOR (F)
5	.065
10	.259
15	.583
20	1.04
25	1.62
30	2.33
35	3.18
40	4.15
50	6.48
60	9.34

Problem: Determine the drag force per blade applied to a 15 foot diameter, three blade rotor, in a 30 mile an hour wind.

Solution: Apply the formula - Drag (in pounds) = A X F divided by 3 (blades)

Where: A = Frontal Area = π r2

π = 22/7

r2 = 7.5 X 7.5

F = The Empirical Wind speed Factor

for a 30 m.p.h. wind (see table) = 2.33

Therefore:

Drag per blade =

(22/7 X 7.5 X 7.5) X 2.33 divided by 3

= 177 (sq. ft.) X 2.33 divided by 3

= 412 divided by 3 = 137 pounds

= 137 pounds per blade

Now suspend a 137 pound weight to the tip of each of the three blades. If the blades do not break, they will stand up safely in a 30 mile an hour wind.

This means that the rotor will never break at all because no rotor would operate in a 30 mile an hour wind; the pilot vane would steer it out.

CHAPTER SEVEN

ELECTRICAL GENERATION - ONE PRINCIPALS

ELECTRICITY AND HOW IT WORKS

Electrical charges are measured in units of electrons, protons and neutrons, which together form atoms.

Atoms are very small. Nearly 250 billion of them could form a single layer over the period at the end of this sentence.

An electron is a negative or minus (-) charge of electricity.

A proton is a positive, or plus (+) charge of electricity.

A neutron has no electrical charge; it is effectively neutral.

The smallest electrical charge is either a single electron or a single proton. An electrical charge can be made up of any number of electrons and protons.

The Law of Magnetic Poles states that like poles repel, and unlike poles attract.

The Law of Electrical Charges is similar. It states that like charges repel, and unlike charges attract each other.

In other words, two positive (+) charges placed in proximity to one another will create forces that will drive each other apart.

Two negative charges (-) placed in proximity to one another will do the same thing. They will repel each other.

If, however, two dissimilar charges, a positive (+) and a negative (-), are placed in proximity to one another, they will create a force that will try to pull them together. They will, in other words, attract each other.

These forces of attraction and repulsion are harnessed to form the power base of all electrical generators, alternators and motors.

The power is taken to and from such devices by means of an electrical current.

A current, by definition, is a continuous onward flow of a flue, such as water, along a stream bed or through a pipe. Electrical current is much the same. It is the flow, or rate of flow of an electrical charge through a wire.

An electrical current is a great number of free electrons moving in the same direction through the confined space of the wire.

Vast numbers of free electrons move in the spaces between the atoms (which themselves contain electrons), near the surface of the metal that forms the wire.

Wires are made from materials that are "good conductors", materials that have large numbers of free electrons among their atoms. Metals are good conductors. The best conducting materials are copper, aluminum, brass, wet wood and iron or steel.

Materials which have few free electrons do not conduct electricity well. They are, therefore, known as "poor conductors". Glass, rubber, plastic and even dry wood are poor conductors.

Some materials have so few free electrons that they actually block the flow of electric current. Some extremely poor conductors, through which electricity cannot flow under ordinary circumstances, are called "insulators".

Insulators are used to wrap wires and prevent "short circuits". They are used to protect people and things from dangerous electrical contact. Glass, porcelain, rubber and some plastics are very poor conductors, and hence, good insulators.

The path that an electrical current follows in the wire as it flows through any electrical machine or device is called a "circuit". The path of the circuit is a circle though, not necessarily, a perfect one in shape. The path, therefore, is endless, so the current travels continuously and endlessly around and around the circuit. The wire from the battery to the light bulb, and the wire returning to the battery, all make up the circuit.

A "short circuit" is an interruption of some kind, say between the battery and the light bulb, which "shorts out" or drains power from the circuit towards the ground, the direction in which all power wants to go.

The wire, then, is the "pipe" through which the electrical current flows in the circular path, providing it does not find a short cut or short circuit to the ground.

There are, however, two kinds of current; alternating current of A-C, and direct current or D-C.

Alternating current is electrical current that rapidly, continuously and periodically reverses its direction of flow. In other words, it pulsates back and forth. Sixty cycle A-C pulsates back and forth in the wire 60 times each and every second. This is the kind of current you probably use in your home. Utility companies prefer 60 cycle A-C because it travels easier and further by wire with less loss. In other words, it is easier to transmit along power lines and the line losses are less.

As it is the only standard power available, nearly all home appliances are designed to operate on this type of steadily pulsating electrical current.

Alternating current, however, can not be stored in batteries because it would charge them half the time and discharge them the other half. It is, therefore, not good for wind generating systems, because energy must be stored against the times when the wind does not blow.

Furthermore, the A-C that could be produced by a home built machine could not be used on normal 60 cycle household appliances because of its variable frequency resulting from the variable frequency of the wind turning the generator.

Directly usable 60 cycle A-C, can only be produced by a generator turning at a constant speed, usually 60 revolutions per second. Frequency varies as the rotor speed varies. Only very large and expensive wind machines can control their R.P.M. enough to do this.

Direct current (D-C), on the other hand, is electrical current that flows in one direction only. For this reason, it can be stored in batteries, though it cannot travel as far in a transmission wire as can A-C. Direct current can, also, run all of the 12 volt systems and appliances on a motor vehicle, a boat or a wind system. Likewise, it can run a number of "normal" household appliances of the kind that must immediately achieve their maximum R.P.M. Electric drills and some food mixers would fall into this group. Such appliances are equipped with "universal motors" which have brushes that run on both A-C and D-C.

The builder should examine the long list of 12 volt appliances that have been developed as a result of space age technology's impact on the recreational vehicle revolution. If a rich man has a beer cooler on his yacht, it will be a 12 volt direct current beer cooler.

Everything from coffee pots and refrigerators to electric razors and television sets can now be plugged into the cigarette lighter of an automobile.

All of the light bulbs, radios, electric can openers and air conditioners that have been developed for use on motor vehicles, yachts, houseboats and house trailers can be plugged into a 12 volt D-C system or run off a car battery, (see plate no. 74, fig. 1).

There are, also, 12 or 120 volt electric motors that can be used to power pressure pumps, freezers, clothes dryers and refrigerators.

Furthermore, D-C can be converted to usable 60 cycle A-C by a instrument called an "inverter" (see plate no. 74, fig. 2), which is quite expensive to buy.

It is also quite expensive to operate because it wastes a lot of power. Eighty per cent efficiency is the best that can be expected from an electronic solid state inverter.

A cheaper alternative is the "mechanical rotary inverter" which is really a 60 cycle A-C alternator running off a battery powered 12 volt D-C motor. It is about 60% efficient.

To sum up; A-C can travel further in a wire, but only D-C can be stored in a battery. Alternating current can only be produced by a wind electric system if an inverter is employed.

The builder is advised to carefully

consider the purely 12 volt system that is illustrated in plate 74, fig. 1.

There are, however, some adjustments that can be made as illustrated in plate no. 74, fig. 1.

The first is a 12 volt system to operate the D-C light bulbs, radios, etc., plus the introduction of a smaller, (say 550 watt), and hence cheaper, inverter to run a small number of appliances that operate only on A-C. This list would include "normal" A-C appliances like electric typewriters, television sets, washing machines and medium powered audio systems.

The second alternative would be the introduction of a gasoline powered A-C generator. This can be connected to a battery charger to charge the 12 volt batteries if the wind has proven to be insufficient. At the same time, it can directly run such A-C appliances as vacuum cleaners or washing machines for the small number of hours its services will be required each day or week.

CHAPTER EIGHT

ELECTRICAL GENERATION - TWO

ELECTRICAL MEASUREMENT - VOLTS, WATTS ETC.

Neither water nor electricity will move without a force from behind that pushes it along. Water is pushed through a pipe by a pump. The greater the amount or volume of water forced into the pipe from the pump, the greater will be the force of the water at the outlet.

Likewise, the greater the amount of electricity, or free electrons, forced into the wire, the greater must be the force in the wire and at the outlet.

This force is called "electromotive force", "E.M.F" or voltage. The unit with which it is measured is called a "volt". A volt, then, is a unit by which the force of a current is measured.

An automotive lead acid battery forces electrons through the system with an E.M.F. of 12 volts, so the voltage of the battery is 12.

To measure electricity flowing through a wire, you measure the amount of current flowing past any given point in the wire in one second. This amount of current is the unit of flow and is called an "ampere". One ampere is equal to 6,281,000,000,000 electrons per second passing any one point in a conductor along the circuit. Amperage is, therefore, an electrical term that refers to the amount of current, measured in amperes, flowing through a wire. An ampere is a measurement of current.

A 50 amp. lead acid automotive battery would put out 50 volume units of electricity, called amperes, every second that it operates.

It is more difficult to send water through a pipe that has rough interior walls, than it is to send it through a pipe with smooth interior walls. Rough walls hold back or resist the passage of water.

Similarly, electrons in the atoms of a wire resist the passage of electrons that make up the current. The unit with which resistance is measured is called an "ohm". If an E.M.F. of one volt is required to push a current of one ampere through a conductor, then the conductor has a resistance of one "ohm".

To sum up so far then; amps are volume, volts are pressure and ohms are resistance. Watts, however, are the key.

The purpose of forcing electrons through a wire, in the face of resistance, is to make energy available at the other end to do work.

Energy is the ability to do work. Energy is equal to power multiplied by time.

Mechanical power is the rate at which work is performed. To raise 500 pounds one foot, requires 550 foot pounds of work. One horsepower is equal to 550 foot pounds of work being performed in one second.

Electrical power, however, is measured in "watts", Kilowatts" (1,000 watts) and megawatts (10,000 watts). One horsepower is equal to 746 watts of electrical power. One watt will raise 1 1/3 pounds to a height of one foot in one second.

One kilowatt hour is equal to 1,000 watts of electrical power used for one hour.

Rules: Watts = voltage2 X ohms
= voltage X voltage X ohms
Watts = volts X amps
Amps = Watts divided by volts
1 Watt = 1 horsepower divided by 746
1 horsepower = 746 watts
1 watt = 1 1/3 foot pounds

CHAPTER NINE

ELECTRICAL GENERATION - THREE NEEDS

POWER NEEDS

- How do you measure the amount of power you need from your wind system?
- How much power does your wind system have to produce?

According to the rules referred to above, a 50 amp generator in a 12 volt system produces 50 (amps) X 12 (volts) = 600 watts at a specified number of generator R.P.M.

As has already been stated, batteries are usually rated in amp hour capacity. This tells you how many amps they will deliver and for how long. A 100 amp battery will deliver one amp for 100 hours or ten amps for ten hours etc.

So: amps X hours
= amp hours
100 (amps) X 1 (hour)
= 100 amp hours
10 (amps) X 10 (hours)
= 100 amp hours

The amp. hour rating, however, only tells you how much power the battery can put out in a given time. It does not tell you how much power can be stored in the battery.

To determine storage capacity, you must first know the voltage, since amps X volts = watt hours. For example, if the battery is rated at "100 amp hours at 12 volts", you can calculate;

100 (amp hours) X 12 (volts)
= 1,200 watt hours
= 1.2 kilowatt hours

so; amps X volts = watt divided by 1,000 = kilowatts.

Therefore, a 60 amp, 12 volt battery implies; - 60 (amp hours) X 12 (volts)
= 720 hours of electrical energy, (.720 kilowatt hours).

Therefore, a 60 amp generator will put out 720 watt hours when it is turning at a specified number of R.P.M. Also, a 60 amp - 12 volt battery will store that much as a complete charge.

Obviously then, to put all of this energy to use, you must first be able to calculate the amount of electrical energy you are going to need in order to perform the work you require.

One method is to simply check the kilowatt - hour meter that the utility company has so thoughtfully placed in your own or your neighbour's home. This may, at first, frighten you, because no wind system can support such a demand. You will just have to cut down on your electrical habits and make use of wood or propane wherever possible.

Once you have decided upon your load requirement, you must then decide how many days or hours your batteries will have to support this load when no charging power is available.

The first thing you must realize is that the rate you see, in rating lists for appliances are the amounts used by each specific appliance for one hour. A good example is the 200 watt, 12 volt light bulb, which takes 200 watts to keep it lit for one hour.

One kilowatt hour, as we know, is equal to 1,000 watts or electrical power put to use for one hour.

So, if one 200 watt, 12 volt electric (incandescent) light bulb is lit continuously for five hours, it will use 200 (watts) X 5 (hours) = 1,000 watt hours or one kilowatt of power.

The same bulb lit for the same five hours will use 1,000 (watts) divided by 12 (volts) = 83.33 amp hours of power.

The same 200 watt, 12 volt light bulb lit for half an hour will use 200 (watts) divided by 12 (volts) X 0.05 (hours) = 8.33 amp hours of power.

Your power requirement is, therefore, a question of how many watts you are going to need and for how long. Again, this is because all appliances, like the light bulb, are measured, and so designated, in terms of how many watts they will require per hour of use.

Your expected load system or total load requirement, must, therefore, be reduced from their initial watt hour rating to an amp hour rating because generators and alternators are measured in terms of the 12 amp hour output; batteries are measured in terms of their amp hour storage capacity and output.

Once you have decided on your load requirement, in terms of a generator that can handle that load, and you have made sure that your wind machine can handle a generator of that size, the next thing you must do is decide on a battery system that can support that load for the expected number of consecutive windless days, when the generator will not be running.

Bear in mind that all appliances are like the light bulb, they do not operate for 24 hours a day.

For instance, if you were to operate the following from your wind system:

(A) One 100 watt kitchen light for four hours each day = 100 (watts) X 4 (hours) = 400 watt hours.

(B) One 60 watt bedroom light, for one hour each day
= 60 (watts) X 1 (hour) = 60 watt hours.

(C) One 60 watt bathroom light for one hour per day = 60 (watts) X 1 (hour) = 60 watt hours.

(D) One 30 watt television set (12 volt portable) for six hours each day = 30 (watts) X 6 (hours) = 180 watt hours. The total load would be 400 + 60 + 60 + 180 = 700 (watts) divided by 12 (volt) = 58.3 amp generator in a 12 volt system.

The same 700 watt load requirement could be stored by one 12 volt battery, rated at 60 amps for one windless day.

The 60 amp generator (alternator) would keep the 60 amp battery well topped up so that the system would have no trouble carrying the load through a few windless hours in any given day. Neither the generator nor the battery would be over stressed.

Rules: - a 200 watt generator will handle two 100 watt bulbs (200 divided by 100 = 2).

- a 3,000 watt generator will handle thirty 100 watt bulbs (3,000 divided by 100 = 30).

But what if the wind should stop blowing for more than one day? What if it should, in fact, stop blowing for several days?

You must then calculate the number of successive windless days you can reasonably expect in your area on a year round basis, multiply your battery needs by this number. Let us suppose that this number, is found. In other words, never at any time of the year, will the wind stop flowing for more than four days.

Then multiply 4 (windless days) X 700 (watt hour load per day) = 2,800 watt hours.

This then, would equal the number of watt hours the batteries would have to produce during the four windless days when the generator is not producing power.

It would equal 2,800 (amp hours) divided by 12 (volts) = 233.3 amp hours and would indicate a need for 233.3 (amp hours requirement) divided by 60 (amp hour capability per battery) = 3.89 or four 60 amp batteries.

You can also work out your battery needs in terms of windless hours instead of days. For instance, if you have ten 200 watt bulbs burning for 24 hours a day, and you expect repetition of four day windless periods, you can make the following calculation:

- Windless hours X household load per hour divided by watt hours per battery = 4 X 24 (hours) X 10 (bulbs) X 200 (watts) divided by 720 (watt hours per 50 amp battery) = 96 (hours) X 2,000 (watts) divided by 720 =266.66 = three, 12 volt batteries.

Both of these calculations are, nevertheless, theoretical. In real life, you would require twice that many batteries. In other words, eight in the first case and six in the second. This is because batteries rarely reach the standards of manufacturers' promises, especially if the batteries are second hand. Furthermore, it is not good for automotive lead-acid batteries (batteries from cars or trucks), to ever be completely discharged. Complete discharging will shorten the battery's life.

If the windless hour or day calculations are especially high, in terms of battery requirement, you might decide to install a gasoline powered battery generator, which could well be cheaper than 267 batteries at $50.00 a crack!

If you like neither the calculations nor the back-up, you might simply plan your storage system for 100 or 150 hours. This should get you through in most places.

All of these figures have been given for a 700 - 800 watt system, whereas, the Jacobs machines produce 3,000 watts.

To sum up then, these are the steps you should follow.

1) Decide on the number of appliances you really want to use.

11) Check the label on each appliance to determine its wattage. As was the case with the 200 watt light bulb, this will tell you the number of watts that will be used per hour.

111) Determine the approximate amount of time each appliance will be used each day, week or month. Add these totals up in terms of watts per hour or fractions thereof.

IV) Translate these figures into a daily average of watts or watts per hour.

V) If it is a 12 volt system, divide this average total by 12 (volts) to get the amp hour requirement.

VI) The amp hour requirement will tell you the size of the generator (alternator), or battery you will need. On the other hand, it will tell you how much you must cut down on your appliances if you intend to use automotive alternators and batteries.

VII) Do not forget that the battery bank will build up during the night when appliances are not being used.

VIII) Bear in mind also, the heaviest and most consistent winds occur during the winter months when the appliances place the heaviest demand on the system.

CHAPTER TEN

ELECTRICAL GENERATION - FOUR STORAGE

POWER STORAGE - AND THE BATTERY SYSTEM

A car battery is designed to motivate the starter motor to start the car's engine. Once the engine is running, it is operated by the generator or alternator, not by the battery. The generator then tops up the battery. In other words, after it has been about 30% depleted by starting the car.

The battery system on a wind machine should not be asked to do a great deal more, especially if it is using lead acid batteries. As we have seen, continuous deep discharging will shorten the battery's life.

The lead acid automotive (car) battery is really a group of six electrochemical (wet) cells, each producing two volts. As the cells are connected to one another in series (positive to positive and negative to negative poles, see plate no. 75, fig. 1), the battery then produces one single outflow of current which is: 6 (cells) X 2 (volts) = 12 volts.

The six electrochemical cells convert chemical energy into electrical energy.

The six cells are contained in water tight acid proof vessels, surmounted by small screw-on caps. The caps have small holes in their tops to allow for the escape of sulphuric acid and hydrogen fumes.

These gases are dangerous, so the battery bank must be kept in a clean, dry, preferable warm, well ventilated place, equipped with highly visible "no smoking" signs.

The temperature for optimum battery performance is around 75 to 80° fahrenheit. The battery room may, therefore, have to be warmed up occasionally. Just be sure that it is not warmed up with an open flame or a red hot element.

Each two volt battery cell has two electrodes, an anode (+) and a cathode (-), which are of dissimilar metals, lead peroxide and sponge lead.

The electrodes are immersed in liquid electrolyte made up of water and sulphuric acid.

An electrolyte is a chemical solution in which electrons (or ions) can move freely or be exchanged.

As each cell gives up its accumulation of electrical current, through the positive (+) poles, the ions move in the electrolyte from the (-) anode to the (+) cathode: the electrodes change to, or become, coated with lead sulphate; the electrolyte becomes such a weak sulphur acid solution as to be almost pure water. This almost "pure water solution" then produces little or no electrical current. The battery is said to be "run down" or "discharged".

By passing an electrical current into the battery, through the positive (+) poles, the ions in the cells are caused to move in a direction opposite to the direction of discharge. They move, in other words, from positive to negative, from the (+) anode to the (-) cathode. A reverse chemical reaction takes place. The (+) anode reverts to lead peroxide and the (-) cathode reverts to sponge lead, while the electrolyte reverts to dilute sulphuric acid, so the cell can again produce electrical current. The battery is, then, said to be "charged up" or "recharged".

This reverse current is, of course, sent into the battery through the (+) positive poles by the generator or alternator, mechanically powered by the wind machine.

In both cases, of discharge and charge, the electrolyte compensates by a process called "ion diffusion" for the loss of electrons at one electrode (plus or minus), or the gain of electrons at the other (plus or minus).

It is, therefore, of great importance to keep the electrolyte in good working condition. Do this by making sure the electrolyte is always at the proper level by adding pure water, (never acid), through the holes covered by the cell caps.

The state of charge can be tested with a simple instrument called a "hydrometer", which measures the specific gravity of the electrolyte.

Specific gravity is a state of comparison between the weight of one substance and the weight of another substance. In this case it is the comparison between sulphuric acid and water, the density of sulphuric acid and the density of water, in other words, how much sulphuric acid is in the water. The more the sulphuric acid, the more the charge.

The heavier battery electrolyte (sulphuric acid in the water), will cause the float in the hydrometer to sink further than it would in pure water. The readings will vary between 1.100 (discharged) to 1.280 (charged).

The state of charge can also be tested with a "voltmeter" which obviously measures volts. The black prod is connected to the negative terminal and the red prod is connected to the positive terminal of each cell.

As we have seen, a battery's storage capacity is measured in terms of amp hours at a given discharge rate. Therefore, two of the most important factors governing a wind system's continuous output are the storage capacity of the battery and its rate of discharge.

For example, a 240 amp hour battery with an eight hour discharge rate is supposed to deliver 30 amps over a period of eight hours. (240 amp hours divided by 8 amp hours = 30 amps).

At slower discharge rates of more than eight hours, the storage capacity is increased. It will deliver something like 20 amps for more than 12 hours. (240 amp hours divided by 12 hours = 20 amps).

At faster discharge rates of less than eight hours, the storage capacity is decreased. It will deliver less than 40 amps for six hours. (240 amp hours divided by 6 hours = 40 amps).

It will be observed that the 240 amp hour rating is a constant. Only the time element is a variant, while the eight hour rating remains the optimum. You can only count on the 240 amp hour output at the eight hour optimum.

The same conditions of fast and slow discharge apply to lead acid truck batteries and golf cart batteries, as well as to car batteries.

An automotive battery usually has a 20 hour discharge rate at 80° fahrenheit.

A 180 amp golf cart battery with a six hour discharge rate will deliver 30 amps for six hours. (180 amp hours divided by 6 hours = 30 amps). It may, for instance, deliver 15 amps for 12 hours (15 X 12 = 180), but it will not deliver 60 amps for three hours. (60 X 3 = 180).

The rule, then, is that the higher the discharge rate (in amps), the lower the amp hour capacity in relation to the stated delivery rate. This is because faster than stated discharge rates create heat build up and consequent loss of energy.

Another rule is that a prolonged charge or discharge should not exceed 15% of the amp hour rating.

It will be obvious that, given a specified task, fewer batteries will have to work harder than many batteries. Increasing the number of batteries will, therefore, reduce the possibility of battery damage resulting from fast or complete discharge. As we have seen, the lead acid battery is capable of a very limited number of complete discharges.

To increase the storage capacity of the battery bank, the batteries must be connected in parallel, (see plate no. 75, fig. 1 and 2), that is to say, all of the positive poles are connected to each other and all of the negative poles are connected to each other. There will then be one loose positive cable at one end and one loose negative cable at the other end, just as there would be on a single battery. It can, if fact, be hooked up just as a single battery would be.

Plate no. 75, fig. 1, shows how this can be done with cables.

Fig. 2 shows how it can be done with busses, which is perhaps the most efficient system, because batteries can always be added to, or taken away, from the right hand side. The busses can be simple pieces of bed iron or they can be brass or copper strips tacked onto dry pieces of wood set on chunks of rubber.

When batteries are connected in parallel, the total voltage of the battery bank remains the same as that of every single battery in the bank, in this case 12 volts. The amp hour rating, or storage capacity, however, does increase to the total amount of amp hours in the total number of batteries.

A battery bank of ten 50 amp hour, 12 volt batteries would have an amp hour rating of 10 (batteries) X 50 amp hour rating per battery = 500 amp hours at 12 volts.

All batteries in the bank should have the same voltage rating because the power is to remain the same. It is only the storage capacity you wish to increase.

It is not necessary, but it does help if all of the amp hour ratings are the same.. This is especially true of six volt batteries. Otherwise the lower capacity batteries may restrict the charge and discharge rates of the higher capacity batteries.

A disadvantage of parallel wiring is that if cell shorting should occur, the resulting very high current in the good batteries will continue until their total discharge.

An advantage of the system is that any number of batteries can be added or taken away to adjust the storage capacity to current requirements. It is just a matter of bolting to, or un-bolting from the "bus".

There is no set limit as to the number of batteries that can be supported by an alternator, though some authorities have warned against a battery bank with a total amp hour rating of more than five times the alternator's maximum output capacity. In this case, a 60 amp alternator could handle no more than 5 X 60 (amps) = 300 amp hours = five 60 amp batteries or four 75 amp batteries or two 150 amp batteries.

It is, perhaps, a better idea that the battery bank should be, at least, seven times the current which the alternator can supply. This can be increased within reason if the storage system is not up to demand. A 60 amp alternator should then have a battery bank of 7 X 60 amps = 420 amp hours.

The rules to remember are that too many batteries may stop any single battery from being fully charged, while too few batteries will not make proper use of the wind's energy and will also run the dangerous and expensive risk of repeated complete discharge.

Again, with the parallel system, batteries can be removed to be charged up in a motor car or truck as it drives along. You should, however, protect your vehicle's own battery system by installing a "battery isolator", which can be purchased from an auto supply store for about $60.00. The vehicle will burn slightly more gasoline as it performs this extra task.

Then, of course, the other alternative is the gasoline driven A-C generator, which you might have to start up four times a month to get you through those extra windless days.

The best type has a plug-in for a special type of high powered battery charger, which can operate on a wire of any desired length. (A-C travels, don't forget!) This will take about 15 amps of 110 - 120 volt A-C power and deliver up to 80 amps D-C to your battery system. As was pointed out earlier, you can, at the same time, use the A-C current to perform tasks beyond the capability of your 12 volt, D-C system, such as vacuuming and clothes washing. You just have to plan and organize these extra chores accordingly. This will obviate the need for an inverter.

The auxiliary should be able to deliver 80 amps of continuous output, and be equipped with a booster and a timer. This will give it 100 amps of continuous capability and a maximum of 300 amps with the booster.

Be sure to use the battery charger, equipped with automatic overload protection, as illustrated in plate no. 74, fig. 2, so the batteries won't be destroyed by overcharge.

Remember the alternator, (plate no. 74, fig. 1 and 2), protects against overcharge in the regular system, 120 volts, etc. The batteries must be connected in series, (see plate no. 75, fig. 3). This means that each negative pole must be connected to a positive pole, just as is the case between the two volt cells in a 12 volt battery. There will then, be one disconnected negative pole at one end and one disconnected positive pole at the other.

By connecting in series, you have, in fact, created one larger battery, which can be connected to the other "larger" batteries in parallel, (see plate no. 75, fig. 3).

The 120 volt "batteries" that can be thus created, can form what is called the 125 volt system, (nominal voltage), that is so often employed in commercial systems or central schemes.

It can power a remarkable number of appliances capable of resistance heating such as heating irons, toasters, electric blankets, coffee makers, fry pans, hot plates, waffle irons and curling irons.

There are many more that use universal motors such as: electric drills, sanders, hedge trimmers, saber saws, and a host of other portable tools, as well as blenders, food mixers, shavers, vacuum cleaners and sewing machines.

It is still a D-C system, so it is somewhat restricted, but, it can be used for incandescent lights (ie. light bulbs), heating systems, and existing A-C lighting systems. Such lighting systems must not include working wall plugs and dimmer switches.

The 125 volt D-C system will not, however, work with some appliances which are designed specifically for A-C. This list will include anything that requires a transformer such as Stereo, T.V. and high intensity lights. It also includes anything that requires a synchronous motor, such as, electric clocks and record players. It also includes anything that requires a split phase or a capacitor start motor with heavier loads such as refrigerators, washing machines, air conditioners and compressors. In addition, there are such devices as fans, blowers and fluorescent lights.

Fluorescent lights, however, can be adapted to D-C, and many of the above can have their A-C motors exchanged for the equivalent 12 or 120 volts D-C motor.

Fluorescent lights, by the way, put out something like three times as much light per watt as do incandescent bulbs.

No wind electric system with a battery bank of any kind can support electric cook stoves or electric home heaters, but it can power the heat blower fans if the heat itself is created by wood or propane.

The same can be said of a clothes dryer. Batteries can turn the cylinder, but the heat must come from another source. There are many propane heated clothes dryers on the market, and with some ingenuity, they could be converted to fan blown wood heat.

Another tremendous advantage of the 125 (120) volt D-C system is that it drastically reduces the in-use power loss to less than 1/3 of 1% as compared to a 20% power loss in a 12 volt system. The principle involved here is that, for a similar amount of power, higher voltage results in lower line losses. Higher voltage systems, therefore, tend to be more efficient.

A disadvantage of the 24 and 120 volt systems is that the wind speed required to begin charging them is greater than the wind speed required to begin charging a 12 volt system.

Remember, the 120 volt battery is made up of ten 12 volt batteries wired in series. This 120 volt battery can be wired in parallel to other 120 volt batteries to increase the storage capacity. Your total voltage (power) and your amp hour (storage) capacity.

When wired in series, batteries do not have to be of the same voltage, but they do have to be of the same battery type, age and amp hour capacity. You can, in other words, serially connect a four volt, a six volt and a two volt to get a twelve volt if all three have the same amp hour rating.

The 120 volt system, the 24 volt system and the 12 volt system, all have to have their own special voltage regulators.

To sum up then, batteries connected in parallel (positive to positive and negative to negative), must have the same voltage rating, but amp hour ratings can be cumulative; batteries connected in series (positive to negative), must have the same amperage rating but the voltage can be cumulative.

It has been pointed out that the primary purpose of the lead acid automotive storage battery is to start the car, after which the generator (alternator) takes over and runs the engine as well as all of the other electricity users, such as, head lights, radios, etc. It was not designed to cope with the special conditions under which a wind system operates.

Nevertheless, and in spite of many recent, and not so recent, developments in the field of electrical energy storage, the automotive lead acid cell remains the most cost effective and viable mechanism for a wind machine. The economics of scale have made their contribution, and America alone, manufactures more than ten million such batteries per year. This has an obvious effect on cost.

During its four years of guaranteed life, the lead acid is capable of tremendous strength, of sustaining tremendous overloads and of storing its energy for weeks, even months without quantitative loss.

A 100% effective battery operated hoist would be able to lift its battery 75 miles in the air on its own stored energy.

When in good condition, the same battery could put out as much as 150 amps to start a 350 cubic inch car engine in the morning, when it has sat in sub zero weather all night. Just to crank such an engine over would require a two to four horsepower effort.

Auto batteries are, therefore, designed for high amperage initial starts. To create this immediate high current capability, more plates are employed and they are thinner. When deep discharges occur, such plates can warp or develop the habit of shedding their active materials too easily.

Incidentally, the same warping reaction will occur when the car battery is overcharged. That is why a voltage regulator is absolutely necessary.

The function of the voltage regulator is to prevent overcharge.

The voltage regulator and the alternator (generator) should come from the same automobile or truck.

The term "good condition" implies that the battery is of an age within the life span specified by the warranty and that it has been maintained according to conditions handed down by the warranty.

The warranty, or guarantee, also assumes that the battery is to be used in a motor vehicle. It further assumes that there will be no deep discharges. So, if you run it to death in a wind system, you may not be able to collect.

The wind machine must, therefore, accomplish the nearly impossible by keeping the battery at full charge or near full charge. If a battery with a six year warranty is discharged 40 times in a single year, it may only last for three years instead of the guaranteed six, in other words, 50% of the guaranteed life span. If discharged only 50%, it may last 100% of the guaranteed time.

It is, therefore, advisable that the number of batteries in the bank be such that their maximum possible discharge is 50%.

The more and the larger the batteries, the longer and safer will be your energy storage bank, and the more continuous will be your power supply through periods of zero or fluctuating wind.

You may then decide that automobile batteries, not having been designed for the purpose, are among the least efficient of storage units and that they retain only about 50% of the energy sent to them by the wind machine.

In that case, you should look to the larger truck batteries or to the deep discharge type of battery that is used in a golf cart.

Truck batteries are larger and more powerful, but, like auto batteries, they are designed to be maintained by an alternator, or generator and voltage regulator at near to full charge. Their capacity of deep discharges or repeated recycling is, therefore, comparable to that of an auto battery. They can be obtained at amp hour ratings of up to 200, but their discharge rates remain at about 20 hours at 80° fahrenheit. Such a truck battery would, therefore, deliver 200 (amp hours) divided by 20 (hours) = 10 amps X 12 (volts) = 120 watts, constantly over a period of 20 hours at 80° fahrenheit.

Deep discharge batteries, on the other hand, have fewer and thicker plates than auto or truck batteries. They can not support the same high current initial power surge required to start a large vehicle with a stone cold engine, but they are much less prone to damage from constant recycling.

Their warranty periods are shorter, often no more than two years, but assume, perhaps, 100 recyclings a year. If the above does not occur, they will last several years beyond their warranty. A local golf course gets an average three years of life out of a golf cart battery, but they probably live a harsher life than they would in a wind machine.

As a matter of fact, all batteries should outlast their warranties by 50%. Nevertheless, you can expect failure at any time in the post warranty period.

Golf cart batteries will lose about 20% of their original capacity after some 250 to 300 discharges. This actually amounts to a bit less than one recycling every two days over the two year warranty period. It is considerably more than would be required in a well managed wind system.

Auto batteries can handle one half that many total discharges or recycles over the six year period of their warranty.

Deep discharge golf cart batteries usually come in six volt units, rated at 200 amp hours, with a 20 hour discharge rate. As with the heavier truck batteries, this works out at 200 (amp hours) divided by 20 (hours) = 10 amps X 6 (volts) = 60 watts. When they are wired in series in groups of two to make 12 volt units, the wattage will equal 2 X 60 (watts) = 120 watts. These 12 volt units can then, of course, be wired together in parallel to create any desired size of battery bank.

Though golf cart batteries may seem to have been designed with wind systems in mind, they are considerably more expensive than the comparative lead acid.

Finally, there is the nickel cadmium aircraft battery which is the most expensive of all. Apparently compensating for the high cost, however, is the fact that some mechanics consider it to be the only true life-time battery. It thereby, has some merit as a second hand or army surplus purchase.

Since it was first thought of by a Swede named Jung in 1899, Ni-cad Development has been greatly stimulated by the aircraft industry so that it now enjoys a wide range of uses, which includes military back-up operations and civilian high rise apartment elevators. Its variety of uses is in fact so wide that it ranges in size from 2,000 amp hours down to less than one amp hour.

It operates in an alkali electrolyte solution between two plated steel electrodes, nickel plates for positive and cadmium plates for negative. Oxidation at the negative cadmium electrode converts cadmium to cadmium peroxide, thus discharging electrodes to the external load. Hydroxide ions, in other words, diffuse between the two electrodes, as do sulphide ions in the lead acid cell.

It is the cost of the nickel and the cadmium which makes the ni-cad four or five times as expensive as the lead acid.

The ni-cad also differs in that each cell is 1.42 volts when fully charged as opposed to two volts per cell for a lead acid. It, therefore, takes ten cells to make the equivalent of a motor vehicle 12 volt battery, (10 cells X 1.42 volts = 14.20 volts).

Also the ni-cad's life expectancy is from ten to twenty years, though some experts believe that it is closer to thirty years. Compare this to three to six years for an automobile lead acid and two years for a golf cart battery. It then becomes a question of whether or not it is cheaper to buy one ni-cad, five auto or fifteen golf cart batteries over a thirty year period.

Some further advantages of a ni-cad are:

A) Ni-cads produce no acid fumes because their electrolyte is an alkali. Hydrogen peroxide, however, is highly corrosive.

B) Ni-cads are smaller and lighter than lead acids.

C) Ni-cads are not effected by temperature. They hold 100% of their charge in cold weather. They do not freeze.

D) Ni-cads can not be over charged, so there is no need for a voltage regulator.

E) Ni-cads recycle well. High current can be drawn from them without fear of internal damage.

F) Ni-cads are practically indestructible. Broken cells can be repaired with epoxy.

To sum up then, you can do almost anything you want with a wind powered, battery operated wind electric system.

CHAPTER ELEVEN

ELECTRICAL GENERATION - FIVE POWER GENERATION

POWER GENERATION AND THE DYNAMO

- The generator, the alternator, the voltage regulator, the wind switch and the slip rings.

The dynamo is the heart of the wind electric system because it is the machine that converts mechanical energy from the wind to electrical energy for either immediate practical use or for temporary storage in the battery bank.

The dynamo has usually been referred to as the "generator" because it is generally a more familiar term, but the alternator is often a more suitable device for a wind machine.

Generators work on the previously described laws of "magnetic poles" and "electrical charges" which state that like poles and like charges repel, while unlike poles and charges attract.

Mechanical energy from the wind, translated through the wind shaft and pulleys, causes a coil of copper wire, called an "armature", to rotate in a magnetic field. The magnetic field is created by two electromagnetic poles called "pole shoes", which, like the armature, consist of wire coils. The rotating armature coil thus cuts the lines of magnetic force which exists between the north and south pole shoes of the magnet. The space between the magnetic poles, through which the coil rotates, is called the "magnetic field" or "field". The cutting of the lines of magnetic force in the magnetic field by the rotating coil is what produces electricity.

The armature coil, therefore, produces all of the power that is all of the current, by repeatedly cutting through the magnetic field force lines as it rotates the two magnetic pole shoes.

The power produced by the armature, however, is totally controlled by two factors; the speed at which it rotates and by the strength of the force lines through which it rotates. The strength of the magnetic force lines are, of course, determined by the strength (number of coil windings) of the magnet.

The power of a generator is, therefore, determined by the strength of its magnet, or by the strength of the (magnetic) field between the north and south poles of its magnet.

Therefore, to build a more powerful generator, you build one with a bigger, and hence, a stronger magnet, so the bigger the generator, the stronger the magnet, and the stronger the magnet, the more powerful the generator will be. Generator power, therefore, increases with generator size, and hence, with generator weight, the more powerful the generator, the more it will weigh.

No matter what their size or weight, all generators have a "V" belt pulley on one external side, which connects to a similar pulley on the crank shaft axle of the engine or on the windshaft axle of the wind machine.

The armature coil rotates on the same axle as the external pulley. This axle passes end to end right through the generator housing.

The protruding part of the coil axle on the end opposite to the pulley, is split lengthwise in half, so that there is a space between the two halves. This split portion of the protruding axle is called the "commutator".

Two carbon "brushes" are placed, one on each side of the axle end, so that one of them is always in contact with the commutator as the axle's split end revolves. The function of the brushes is to collect electrical energy from the commutator and feed it into the "load" (appliance system) or the battery storage system. The brushes, of course, match the magnetic poles, the right hand one is positive and the left hand one is negative.

A wire connected to the positive brush is run to the appliance load and then back to the negative brush. This is the circuit.

To properly understand this, you must visualize a cross section of the generator. The outer casing forms a circle with a flat bottom to which the support base is bolted. On the inside of the casing, the positive or north magnetic pole is on the left hand side and the negative or south magnetic pole is on the right hand side. The axle is represented by a smaller circle in the centre. The armature is seen as wrappings of copper wire forming a larger circle around the axle circle. The commutator split is seen as a wide dark line across the axle circle. The brushes are seen as two small black squares on each side of the axle circle or commutator split. A positive (+) wire runs from the left hand (+) (positive) brush and a negative wire runs from the right hand negative brush. It is important to comprehend that the positive magnetic shoe is on the left and the negative magnetic shoe is on the right.

Because of the split in the axle (commutator), one brush is always in contact with the side of the rotating (armature) coil going up the left side of the field by the positive, north magnetic pole. In the same way, the other brush is always in contact with the side of the rotating armature coil going down the right hand side by the negative south magnetic pole.

The current in the circuit, then, moves continuously from commutator to brush to wire to light bulb (load) to wire to brush to commutator.

As positive electrons are repelled by other positive electrons on the left hand side, they are drawn or attracted through the load to the negative brush on the right hand side because like charges repel and unlike charges attract. By making this passage through the circuit, the electrons cause the bulb to light up.

One positive wire from the left hand, positive, north pole brush, is also connected through the voltage regulator to the positive pole on the battery. The negative pole on the battery is connected by a wire to the negative south pole brush.

Again, the positive electrons are drawn from the generator, through the battery and back to the negative brush on the generator. By making this passage, they cause the battery to be charged.

The electric current created by the generator is direct current which can go directly to the battery for storage. The proper name for this device, then, is "direct current generator".

At one time, all cars and trucks were equipped with generators. Then as the vehicles got bigger and their accessories, like heaters, radios and power windows got more numerous, the generators had to increase in size to perform the additional work. As the generators got bigger, their magnets had to get bigger and the generators got heavier. At some point, they became so big and so heavy that their further use became impractical on motor vehicles because of design restrictions. A smaller and lighter type of dynamo was required. Enter the alternator.

The big difference between an alternator and a generator is the relative position of the armature and field, though the principle is exactly the same.

As we have seen in the case of the generator, the armature rotates on the axle, through the field, between the two magnetic sides.

The alternator is the opposite. The armature, called the "stator", is stationary and divided into two parts and placed on the inside casing walls like the magnetic shoes of the generator. Again, like the generator, the left hand (armature) stator shoe is positive while the right hand (armature) stator shoe is negative.

The magnetic field shoes rotate on the axle inside (between) the left (+) and right hand (-) stator shoes. The field is shaped like a capital letter "I" with the axle through the centre, the magnetic shoes being represented by the top and bottom horizontal marks of the "I".

It will then be obvious that the magnetic shoes of the field contact the left and right hand stator shoes only when the letter "I" of the stator is in a horizontal position.

To sum up so far then; with a generator, the armature spins freely and the field remains stationary, whereas, with an alternator, the field spins freely while the (armature) stator remains stationary.

In both cases, however, the armature, or stator, produces the current or power while the field controls that power by the strength of its magnetic force lines.

In a generator, if no voltage is applied to the field windings, some current will flow because the magnets are permanent. Therefore, the load, to a degree, is taken on immediately so the shaft will never spin freely. For this reason there is always some drag, or friction, so the generator will tend to heat up at high R.P.M.

The generator, therefore, does not require battery voltage to commence work and will not draw battery voltage when it stops work because the wind has stopped blowing. The generator is, therefore, not dependant on an ignition (car) key to energize its magnets.

An alternator, on the other hand, can produce no power unless the battery sends voltage to the field (by the field wire) to initially activate the magnets. The (armature) stator will, therefore, spin freely until the load is applied, thereby reducing the problem of drag.

Here then, is the secret of the alternator. To increase its power, you simply increase the strength of its magnets by supplying more voltage. You do not have to increase the magnets size and, hence, the alternator's weight, and as you do with a generator. An alternator can, therefore, be much smaller and lighter than a generator in terms of the comparable power it puts out.

With an alternator, you do, however, have to have a means of shutting off the battery voltage connection to the field or the field will continue to draw from the battery after the alternator has stopped or when the machine is shut off, or the wind has died down. The alternator is, therefore, totally dependant on the ignition (car) key to initially energize field and will continue to draw from the battery until the battery charge is no more. The ignition key is on the "field" wire.

Also, the generator must, somehow, connect the revolving, power creating armature with the stationary wires leading to the load and battery. This is accomplished, as we have seen, by means of commutator brushes, which obviously take a lot of wear. They, therefore, have to be well designed and tend to be expensive.

In an alternator, these connections are

direct from the stationary stator. This simplifies the problem and reduces the expense. There are, of course, brush connections to the revolving field, but, these do not have to carry so much power as they only "start" the magnets.

Though alternators that can maintain automobile D-C systems are relatively new, alternators themselves are not. They have been used by many cities to generate municipal power for over fifty years, but they were impractical for passenger vehicles because they produced only A-C. The alternator is, therefore, properly called an "alternating power generator".

High output alternators on police, fire and other heavy electricity using emergency vehicles, carried banks of bulky and expensive selenium rectifiers to convert A-C to D-C. But such devices were always beyond the price range of the general public.

The break through came in the 1960's with the development of "silicone rectifier diodes" which were light, small and comparatively inexpensive, yet could convert the alternator's A-C output to D-C. At the same time, they could handle the tremendous current loads of today's automobile while weighing less and taking up less space than a generator of comparable power. Because of the development of these diodes, alternators have replaced generators in passenger cars since the mid 1960's.

Furthermore, alternators are now made in such vast numbers that the economics of scale have reduced their price to below that of an other comparable machine.

The junk yards, in other words, are full of them. Just be sure that you get one that works and that has been stored in a clean, dry place. It is usually cheaper to remove it from the (junk yard) car yourself.

Another reason for their popularity is that alternators have proven to be more efficient convectors of mechanical energy. They produce more power per unit of weight and per unit of time. Most commonly available alternators put out between 40 and 52 amps, whereas most generators put out between 25 and 30 amps.

Alternators not only produce the extra power required for the new accessory systems, such as power seats, power brakes, power windows, electromagnetic clutches, air conditioners, large heaters and more lights. They produce that power at low engine speeds, even when the vehicle is stopped and the engine is at idle, at the curb, at a traffic light or in a traffic jam.

An alternator can put out, at least, 60 watts at engine idle. With all of the accessories turned on, this means a heavy load off the battery which could shorten the battery's life.

An alternator, therefore, starts to produce voltage at relatively lower R.P.M., say about 400 - 900 R.P.M., as compared to a generator, which starts at about 1,000 R.P.M. The alternator also reaches peak output quickly, still at relatively low R.P.M., and, thereafter, increases output more slowly. It thus requires less gearing up when used on a wind machine. Allowances, of course, still have to be made for slippage and mechanical loss.

The recommended test speeds for most automotive systems lies between 1,250 and 2,000 R.P.M. In a typical installation, the alternator rotates at twice the speed of the engine's crankshaft, that is to say, at about 1,200 R.P.M. when idling, and about 6,500 R.P.M. at 60 m.p.h. At maximum engine speeds, it can be run at speeds of up to 10,000 R.P.M. It is, therefore, not possible to overrun an alternator on a wind machine.

At axle speeds of 1,200 R.P.M. or better, a typical automotive alternator will generate 14.2 volts at 60 amps or (volts X amps) 852 watts with no danger of overheating. At this rating, it will absorb something like 0.8 horsepower from the wind machine axle. Therefore, the most you can expect from a run of the mill automotive alternator is 850 watts.

Most of these are in the 30 to 70 amp range, the majority being between 50 and 60 amps. There are, however, larger units designed for trucks, ambulances, police cars and construction vehicles like bulldozers.

Neither an alternator nor a generator will begin to charge a battery until the R.P.M. reaches a point where its output voltage is higher than the battery voltage. The pressure from the dynamo, in other words, has to be greater than the back pressure from the battery in order for the electrons to pass from the dynamo to the battery. The point at which the dynamo pressure begins to exceed the battery back pressure is called the "cut in speed". It is indicated by the turning on of the red light or "idiot light" on the motor vehicle's dash board. The light goes off when the equilibrium point is reached or surpassed.

Below the cut in speed, an alternator actually draws power from the battery by the "field" wire, as we have seen. It will eventually run the battery down to complete discharge. To be more specific, the brushes continue to carry current to the rotor (field) windings through the field wire, thus creating the electromagnetic field necessary for the generation of current, even at times when the "V" belt R.P.M. are too low to produce that current. In a motor car, this reverse current to the battery is stopped by the turning of the ignition key. The key, then, acts as a manually operated valve.

When the key is turned on again, the field wire from the battery supplies the necessary initial power to the field by energizing the field relay through the voltage regulator assembly. The field wire current, then establishes the magnetic flux surrounding the rotor, which gives rise to (armature) stator current when the (fuels) rotor revolves at sufficient speed, as driven by the "V" belt system. Once this "sufficient" or cut-in speed has been attained, the current flow from the battery to the revolving alternator field goes into reverse. It begins to run back from the (armature) stator to the battery, through the positive wire, commences to charge it, and the idiot light on the field wire goes off.

To sum up and simplify then, all alternators and some generators, get their initial field current from the battery, without which, they cannot themselves produce electrical current. This current draw from the battery continues until the dynamo turns fast enough to produce more current than it is drawing from the battery. This point is called the "cut in speed". After this point, in terms of dynamo R.P.M., the dynamo not only stops drawing from the battery, it sends current to the battery and charges it.

When the key is turned off, the field relay opens up so that the battery does not remain loaded with the rotor (field) winding once the engine stops running. The silicone rectifier diodes then, and only then, act as check valves by blocking the reverse current from the positive pole on the battery, through the field wire, through the voltage regulator, to the field (F) terminal on the alternator. The diodes, then, take the place of the cut out relay on the alternator but only when the ignition key is turned off.

The alternator, in other words, draws from the battery at all times, below cut-in speed, while the ignition key is turned on.

Most generators, as we have noted, have permanent, as opposed to electro magnets; they do not require so much initial energizing, if in fact they require any at all. They, therefore, are equipped with what are called "cut out relays" which prevent battery draw beneath cut-in speed. On a wind system, this means that you never have to worry about the generator drawing from the battery when the wind is not blowing at all, or when it is not flowing fast enough to drive the dynamo above cut-in speed.

If a generator does not have a field terminal (F), it does not require battery power to energize its magnet.

On an alternator based wind system, however, initial energizing presents a considerable problem because the field will always draw from the battery as long as the dynamo turns below cut-in speed and the ignition key is turned on. This means that the field terminal, through the field wire, will draw from the battery and continue to draw from the battery when the machine is shut off, when the wind is not blowing, and even when the wind is blowing, but not blowing fast enough to drive the dynamo above cut-in speed. On a rotor, this would mean any time the wind is blowing below eight miles an hour.

The problem, therefore, is to find something to replace the ignition key or to find some means of turning the ignition key on and off at the proper times.

The most simple solution is to replace the ignition key with a breaker switch at the base of the tower. In other words, you run the field wire, from the field terminal on the voltage regulator down to the switch and from there to the positive pole of the battery. All you have to do then, is run out and turn the switch on or off as wind conditions or electrical requirements dictate. Many people do this, but it has obvious disadvantages.

A second solution is to use a generator instead of an alternator in designs where size and weight of the dynamo is not a criteria.

Plates 26 and 30 show metal rotating table systems using direct shaft right angle drives, in which the dynamo is located either somewhere on the tower or at the base of the tower. In these cases, the size and weight of the generator makes no difference whatever. No ignition key replacement is required because battery draw is taken care of by the generator's cut-out relay.

The same can be done with the wooden rotating table design illustrated in plate 66. Here the generator can actually be placed on the rotating table itself because there is lots of space and the eight castors it turns on are all of 100 pound test. Again, size and weight of the dynamo are of no significance in this case.

A third solution is to find an alternator that does not require an ignition key. The most obvious example of this is the "Delco self energizer", (part no. 1100080 or 110008), which sells for about $330.00. Like a generator, it has only two wires, a positive (hot) wire and a negative wire. It has no field wire. The disadvantage, of course, is its expense, but it can be placed on the metal rotating table as shown in plate no. 72, fig. 1, 2, 3 and 4.

The fourth solution is the "windswitch" as illustrated in plate no. 73, which will replace either the ignition key or the breaker switch at the base of the tower. Like the breaker switch, it connects on the field wire between the field terminal on the voltage regulator and the positive pole of the battery.

It is simply a vertical wooden or metal bar about 24" long, balanced somewhere near its centre on a horizontal axis. On the upper half, there is an 8" X 8" paddle facing into the wind. The bottom half is weighed in such a way that it causes the paddle to blow over when the wind reaches the proper "cut-in speed" velocity. When the paddle blows over, it causes two metal plates to make contact and "turn on". When the wind drops below the proper velocity for dynamo cut-in speed, the paddle falls back to a vertical position, causing the metal plates to break contact and "turn off". Both of the metal plates are connected to the field wire, so the field wire then, stops drawing from the battery.

The windswitch must be placed on the tail vane bar in such a way that it catches the same amount of wind as is blowing on the sails or rotor blades or as close to that amount as possible.

The illustration in plate no. 73, explains how to set the weights on the lower half of the windswitch by testing it out on the back of a truck moving down a flat, straight road at seven to eight miles an hour on a windless day. Just be sure that the windswitch is held high enough so that it is not affected by the slip stream from the back of the truck cab.

This is a very uncomplicated, easy to make design, but it can be developed into a more sophisticated wind sensor by reducing its size and introducing micro switches, or by the use of springs instead of weights. Springs, however, have a way of wearing out, especially if they are stretched beyond their design limits.

The windswitch is a very simple device which enables you to make use of the best and least expensive junk yard alternator you can find. Remember, the field wire is smaller and is usually white in colour. It connects the field windings of the alternator to the positive pole of the battery. The positive wire is larger and is usually red in colour. It carries the positive (hot) electrons to both the battery and the load. The negative wire is the same size as the positive wire and is usually black in colour. All of these wires go through the voltage regulator before being connected to the battery and the load, (see plate no. 74, fig. 1 and 2).

If a dynamo does not have a field (F) terminal, it means that it has permanent magnets and does not require a field wire to energize them.

The purpose of the automotive regulator is to control the output of the dynamo. It does this by rapidly switching the field current on and off. When the field is turned, on the dynamo puts out as much current as it can. When the field is turned off by the voltage regulator, its output drops toward zero. The average output is determined by the amount of time that the field is allowed to be turned on, in other words, by the amount of time the magnets are energized by their own stator.

The regulator thus prevents overproduction of voltage and current (amperes) which can damage the electrical system, the battery, and even the dynamo itself.

When the battery is low, the regulator steps up the charging rate and then reduces it, or rather, causes it to taper off as the battery charge becomes full.

The regulator also adjusts the dynamo voltage output to the proper lever in compensation for a voltage drop in the connecting wires to the battery.

The regulator is the connecting link between the dynamo and the battery or the load. It should be placed at the bottom of the tower where you can keep an eye on it.

There should also be a breaker switch next to it so the current can shut off when the machine is shut down, as long as the wind is blowing at seven to eight miles an hour.

But, how do you get the wires down there if the dynamo is on the rotating table and constantly moving around?

One solution is just to run them anyway, and untwist them when you have to. This may not be too often as the rotating table only makes a complete revolution once in a while.

The best solution is to select one of the "slip ring" arrangements, illustrated in plate no 67, fig. 2, 3 and 4, as well as in plate no. 63, fig. 3, and plate no. 69, fig. 1, 2, 3 and 4.

The slip ring system connects the dynamo wires to individual carbon brushes on the rotating table, which constantly rub against brass, copper or aluminum rings on the core or the support pipe. The rings are connected to the voltage regulator field, positive or negative terminals.

There will be two slip rings if there is only a (hot) positive and a negative wire. If there is also a field wire, there will have to be three slip rings, one for each wire.

The rings, of course, must be insulated, that is to say they must be separated from the core or support pipe by some kind of insulating material, (see plate no. 69, fig. 3 and 4).

The brushes must also be insulated from their mountings on the rotating table. At the same time, they must be spring motivated so they can keep constant but gentle contact with the rings on the support pipe as the table rotates.

The best brushes to use are those from automobile starter motors, because they come in their own spring loaded holding boxes.

If starter motor brushes are not available, you can use the simple spring steel mechanism illustrated in plate no. 69, fig. 5 and 6.

CHAPTER TWELVE
ELECTRICAL GENERATION - SIX

WIRES AND WIRING FOR THE 12-VOLT D-C SYSTEM

WIRING OUTSIDE THE WIND SYSTEM (SEE PLATE NO. 74)

As we have seen, alternating current, A-C), transmits over distances of wire more readily than does direct current, (D-C), which is why the power companies use A-C.

The wind system, however, has to use D-C, because A-C cannot be stored in a battery, and a battery is essential to protect the output against fluctuations in wind velocity.

There are, however, a number of factors governing the transmission of D-C current flow in a wire. The first is that the distance you run any wire will determine the resistance to D-C current flow in that wire. As the distance increases, do does the potential voltage drop. You can, in other words, end up with 10 volts instead of 12 if you run the wire too far.

Copper wire is the best conductor, and stranded wire is the easiest to work with. Stranded copper wire, therefore is recommended.

Losses diminish as the wire size increases. Wire size is measured in numbers; the larger the wire, the smaller the number. Number ten is, therefore, smaller than number one. Over a hundred foot distance, number "0" wire will lose 0.1 volts, whereas number "10" wire will lose 1.0 volts.

If the distance from the wind machine to the house is 100 feet or less, number "4" wire is recommended. It should be of stranded copper and of the direct burial type. This is because most people would rather bury their wires 18" in the ground than have them visible, unsightly nuisances above the ground. One hundred feet, therefore, is a good safe distance for a 12 volt D-C wire to travel.

Remember that the electrons in the current must travel all around the circuit, out through the positive wires and back through the negative wires. That means that the current in a 100 foot wire actually travels 200 feet, 100 feet out in the positive wire and 100 feet back in the negative wire.

If the one way distance gets close to 200 feet, you should still use number "4" wire, but a

D-C to A-C convertor and switching regulator will be necessary to boost the amperage from the batteries.

Wire size no. "8" is recommended for your 12 volt D-C appliances inside the house. Number "10" will be cheaper, but may cause power fluctuations.

You can, therefore, have number "4" burial type wires running from the battery back to the fuse box in the house, and number "8" wires running from the fuse box to the various appliances.

The wires within the wind machine itself should be of the automotive number "8" type because they are heavily coated for protection against heat, weather and stress. This coating makes them two or three times more expensive than "in door" wires.

If there are both 12 volt D-C and 120 Volt A-C systems in the house, they must be colour coded to tell them apart. The same wires can not be used for both systems, or damage, even fire, will result. The A-C wires can have a stripe along the side and the D-C wires can be of plain colour.

All wires should also be colour coded to tell the positive, (red), from the negative, (black). This is very important in a D-C system because the current only flows one way. Crossed wires are dangerous.

Terminals may be obtained from auto supply houses. They should always be kept very clean from dust, dirt, grease and rust.

Plugs are usually of the cigarette lighter type and may be obtained from marine supply outlets.

Fuses are necessary for all of the circuits within the load. They will protect the appliances from overloading as a result of regulator or some other malfunction.

WIRING INSIDE THE WIND MACHINE

A 12 volt system on a wind machine apparently differs from the 12 volt system on a motor car, only in that there is no "ground" system on a wind machine.

On a motor vehicle, the alternator, the regulator, the spark plugs and the negative pole of the battery are all "grounded" to the engine or to the chassis frame. Positive wires run from the alternator, through the regulator to the load and to the positive pole of the battery, but no negative wires run from the negative pole of the battery back to the regulator; they run, instead, to the engine. The automotive ground system, therefore, runs through the engine and the frame.

On a wind machine, the D-C system forms a continuous circuit of wire, from, and back to, the regulator. Positive wires run from the regulator to the load and to the positive pole of the battery, while negative wires run back from the negative pole of the battery, and from the load, to the regulator. The negative wire, therefore, replaces the engine and frame as a ground connection. The wind system is grounded to the negative wire.

The automotive and wind electrical systems are, therefore, the same, despite the apparent difference in their grounding systems.

In both systems, the load circuit wires branch off from the positive and negative wires at some point above the battery terminals.

The regulator must then be connected to the alternator in exactly the same way as it is in a motor car and, it must, of course, be the one designed for that particular alternator.

Of the two most common automotive alternators, the Ford and the General Motors, the G.M. "Delcotron", is the easiest to work with because it has its own solid state regulator built right into its own end frame.

In both cases, there will be a "ground" terminal, as previously stated, which will be connected to the negative terminal of the battery.

Also, in both cases, there will be a main relay and a "solenoid" switch for the starter. These must be ignored. The Solenoid is only a by-pass switch to direct surge power, often as much as 250 amps, to the starter. A wind machine does not have a starter.

On the G.M. "Delcotron", there will be three terminals besides the "ground". There will be a "battery" terminal from the stator, or stationary armature, and there will be two terminals, a "number one" and a "number two", from the revolving electromagnetic field.

Connect the "ground" terminal to the negative pole of the battery.

The "number one" is the "field" wire. It should be connected, through the wind switch, the regulator and the tower base breaker switch, to the positive pole of the battery.

The "number two" controls the voltage output. It should be joined to the "battery" wire and, thence, to the positive pole of the battery. This is the "hot" positive, (red), wire.

The "field" or "number one" wire can, of course, be connected to the "hot" wire to the battery after it has passed through the tower base breaker switch.

If there is ever a problem in identifying the field wire on any alternator, it is always the wire that goes through the ignition switch on the automotive application.

On the Ford charging system, the same principles apply. Even though the alternator and voltage regulator are separate entities, they have corresponding terminals which connect to each other, ("ground" goes to "ground", etc.).

From the regulator, "ground" goes to the negative battery pole, "field" goes through the wind switch, and the breaker switch to the "hot" line which runs from the "battery" stator terminal to the positive pole of the battery. The only difference is the "number one" (1) terminal which is meant to run to the "idiot" light on the dashboard. This can be ignored.

On a generator system, remember, you need no wind switch or tower base breaker switch, especially if there is no field terminal.

As generator magnets are permanent, as opposed to electromagnetic, the voltage output is increased by increasing the number of coils in the armature winding, increasing the R.P.M. of the armature, increasing the number of coil windings in the magnetic field shoes or, by all three of these. The result most often is an increase in size and weight which, combined with higher starting R.P.M. or "cut-in speed" are the generators detracting features.

The advantages, of course, are that the permanent magnets do not need a power injection, (initial energizing), from the battery to get them going as alternator magnets do. Voltage output is controlled by the "voltage limiter", usually on the regulator, so the battery won't overcharge. Battery draw down, (back flow), is controlled by the "cut-out relay" which is usually part of the generator itself.

Spring tension helps hold the relay points open so no power can get through when the wind machine is stopped or operating below cut-in speed. When the generator output reaches 12 volts, the coils of the relay become energized and close the points permitting current to pass through to the battery and the load.

When the generator output drops because of lessened mechanical, (wind), input, the relay coils de-energize and the spring opens, thereby halting the passage of current to the battery and from the battery to the generator. The voltage limiter works in exactly the same way.

The generator, therefore, can not drain the battery as an alternator can when the wind dies down or stops, irrespective of weather or not, the ignition switch is on or off.

In fact, the purpose of an ignition switch on an automotive D-C system is to prevent the ignition points from being burnt by electric current when the motor is not running. There are no ignition points on a wind system so there is no need for a generator wind switch.

You need, therefore, only two wires, a "ground" wire from the ground terminal on the regulator to the negative pole of the battery, and a "hot" wire from the "battery" terminal of the regulator to the positive pole of the battery. If there is a "field" wire, you should be able to connect it directly to the "hot" wire.

Remember though, D-C automotive generators have not been made since the 1950's, so they are now quite old and may be difficult to repair. Bear in mind also, that their cut-in speeds were high, so they require considerably more gear-up than does an alternator.

They will never "charge" at engine idle as an alternator will. You could easily run their batteries down if you were caught in a traffic jam on a cold day with the radio and heater turned on.

It might be best to search for another, recently made, generator type with a (much) lower R.P.M. cut-in speed.

No matter what type of dynamo you select, there should be an amp meter where the field wire meets the hot wire and above where the load wire branches off. The amp meter will tell you whether the dynamo is drawing in or putting out power. It will also tell you how much.

TABLE OF ILLUSTRATIONS
GROUPED BY SECTIONS

PLATE NO.

SECTION ONE
THE MAJOR TYPES

SECTION TWO
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SECTION FOUR
THE AIR FOIL ROTOR BLADE

SECTION FIVE
THE SAIL WINDMILL

SECTION SIX
DESIGN ALTERNATIVES

SECTION SEVEN
PUMP PLANS

SECTION EIGHT
ELECTRICAL CONNECTIONS

SECTION NINE
THE TOWER

PLATE NO. 1-A

Figure no. 1 shows the wooden multiblade in full 3/4" view, so the builder can form an idea as to how all of the parts fit together. These parts are all shown with greater detail in subsequent illustrations.

Figures no. 2 and 3 show the 36 and the 18 blade sails, in view, for purposes of comparison.

The 18 blade sails are the faster turning and will require gearing down if they are to run a water pump, (see plate no. 11, et. al.).

The 36 blade sails are slower turning so they can run a pump directly off of the wind axle by means of an eccentric, (see plate no. 8, et al.). See text chapter two, plates No. 1-30.

See also the metal multiblade, text chapter three, plates No. 31-36.

PLATE NO. 1-B

Shows the two blade rotor or wind generator for making electricity, (see chapter four, text, and plates No. 37-47). It is here shown on a tower similar to the one used for the Wooden Multiblade, (plate No. 1-A).

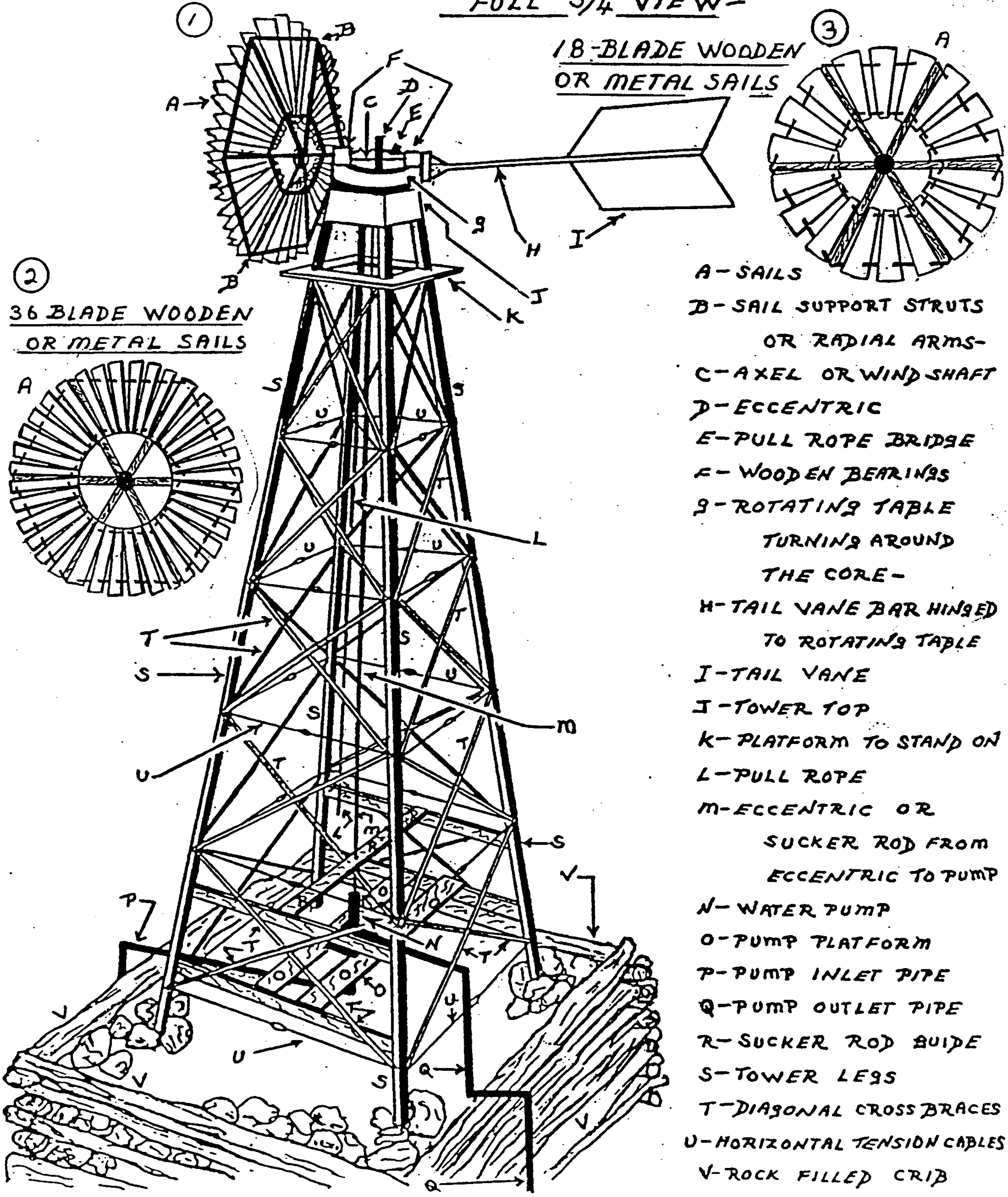
Note the mast rising from the tower top (plate No. 81) to allow clearance for the larger and longer blades. This is also necessary for the bigger metal multiblades (plates No. 35-36).

Note also, the pipe swivel (plate No. 70), as well as the generator or alternator, the connecting wire and the battery bank (plates No. 74 and 75).

The more efficient three blade rotor (see text reference and plate No. 41) is set up in the same way.

PLATE No. 1

THE WOODEN SAIL - WOODEN ROTATING TABLE WINDMILL FULL 3/4 VIEW -



- A - SAILS
- B - SAIL SUPPORT STRUTS OR RADIAL ARMS -
- C - AXEL OR WIND SHAFT
- D - ECCENTRIC
- E - PULL ROPE BRIDGE
- F - WOODEN BEARINGS
- G - ROTATING TABLE TURNING AROUND THE CORE -
- H - TAIL VANE BAR HINGED TO ROTATING TABLE
- I - TAIL VANE
- J - TOWER TOP
- K - PLATFORM TO STAND ON
- L - PULL ROPE
- M - ECCENTRIC OR SUCKER ROD FROM ECCENTRIC TO PUMP
- N - WATER PUMP
- O - PUMP PLATFORM
- P - PUMP INLET PIPE
- Q - PUMP OUTLET PIPE
- R - SUCKER ROD GUIDE
- S - TOWER LEGS
- T - DIAGONAL CROSS BRACES
- U - HORIZONTAL TENSION CABLES
- V - ROCK FILLED CRIB

PLATE NO. 1-B

Shows the two blade rotor or wind generator for making electricity, (see chapter four, text, and plates No. 37-47). It is here shown on a tower similar to the one used for the Wooden Multiblade, (plate No. 1-A).

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The more efficient three blade rotor (see text reference and plate No. 41) is set up in the same way.

PLATE No. 1B

THE TWO BLADE ROTOR - OR WIND GENERATOR FOR MAKING ELECTRICITY - ON A THIRTY FOOT TOWER

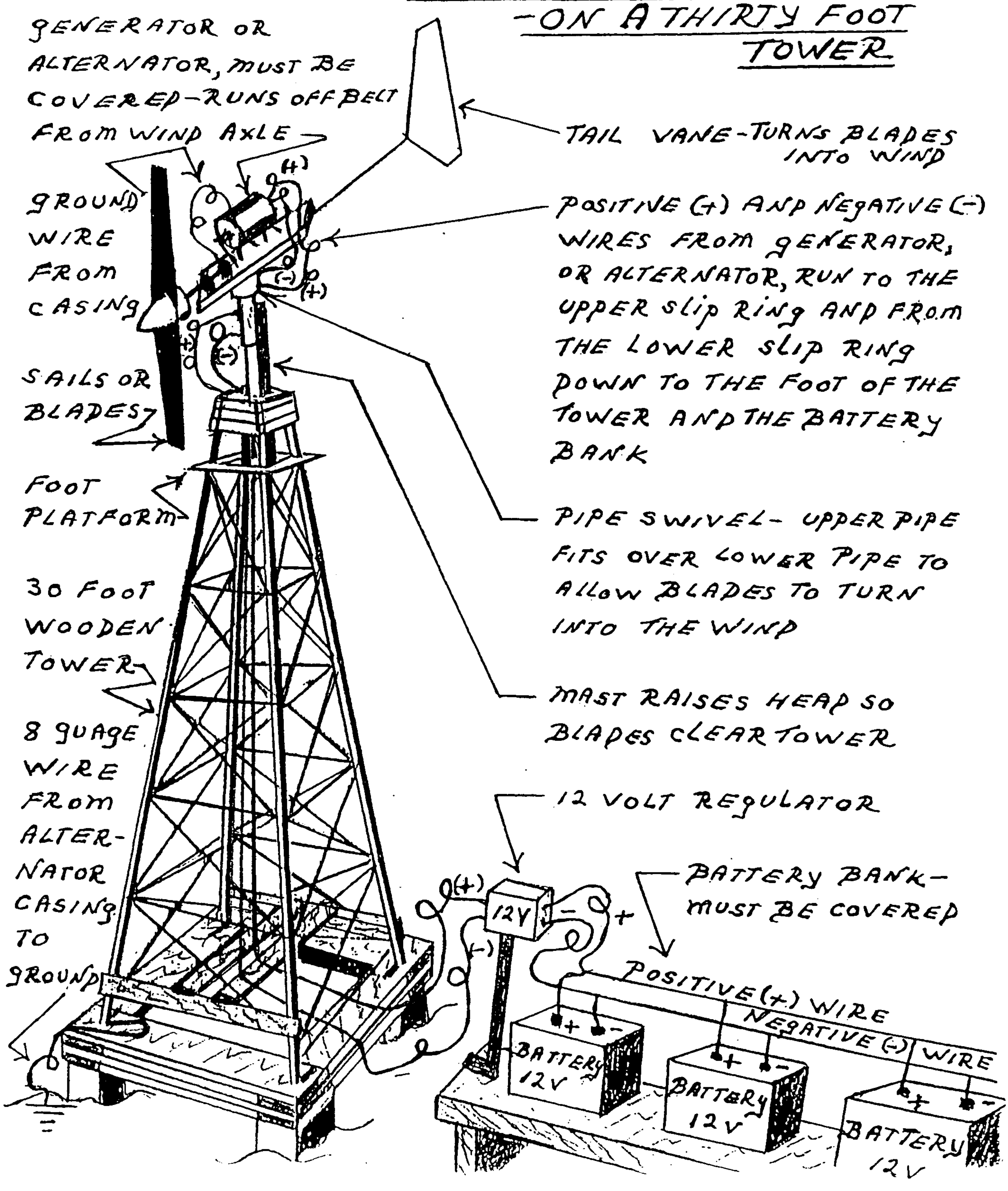
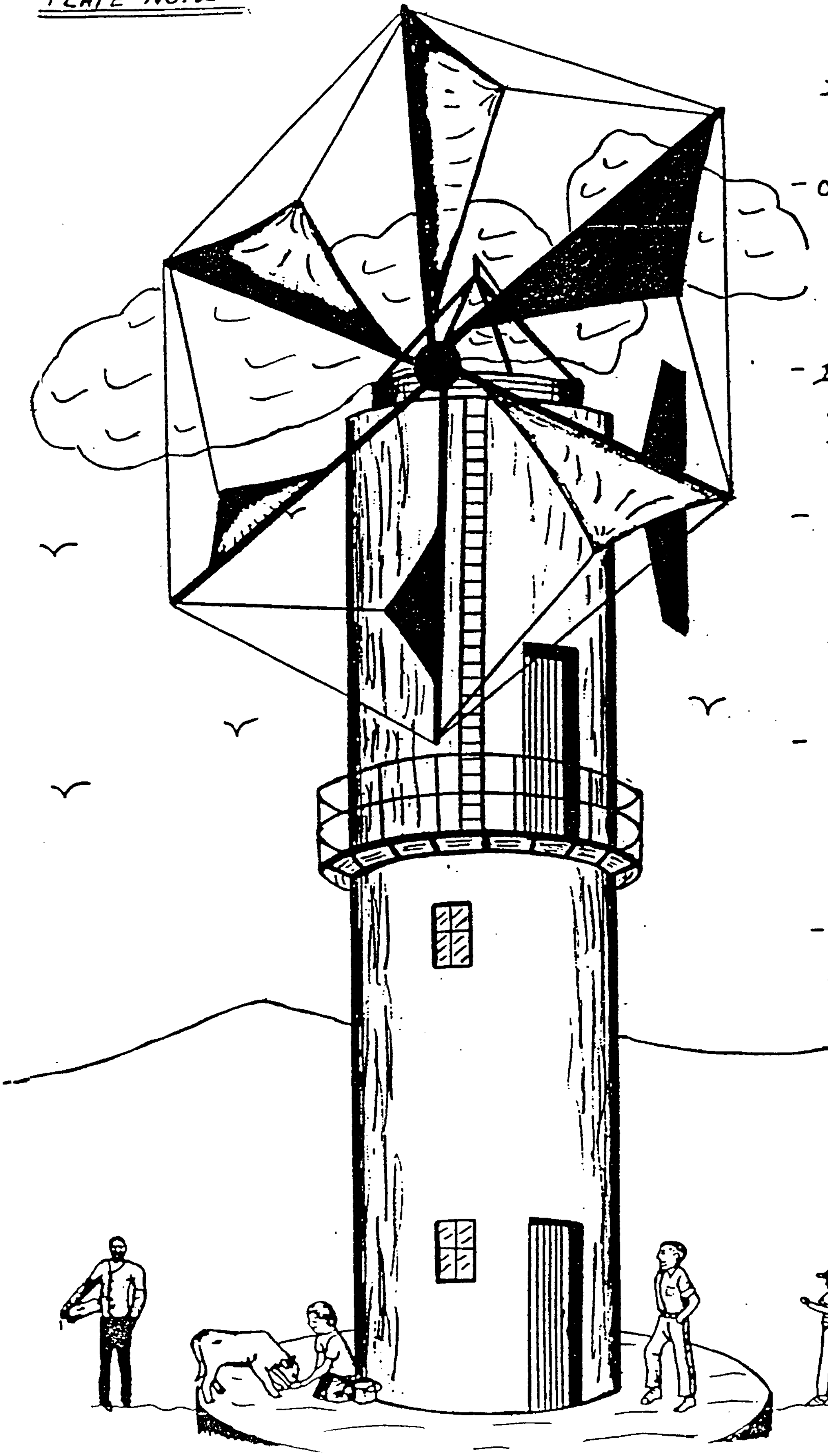


PLATE NO. 2

The sail windmill on a concrete tower with a large wooden rotating table.

The roundness of the tower reduces drag. This is a permanent, though expensive installation, (see sail windmill, plate no. 49, et. al). See text chapter five, plates No. 48-53.

PLATE No. 2



SAIL WINDMILL -

- ON A 40 FOOT CONCRETE BLOCK TOWER - 10 FEET IN DIAMETER -

- BLOCKS ARE STUCCOED OVER AS THEY ARE BUILT UP -

- STEEL RODS ARE RUN DOWN THE HOLES IN THE BLOCKS AND CEMENTED IN -

- THE ROTATING TABLE HAS A DIAMETER OF 8 FEET -

- SAILS HAVE A DIAMETER OF 30 FEET -

PLATE No 3

– THE WOODEN MULTIBLADE – I
– ROTATING TABLE AND CORE –

NOTE

– THE ROTATING TABLE AND CORE ARE THE HEART OF THE WOODEN WIND MACHINE – THE ROTATING TABLE IS MOUNTED ON CASTORS – IT RIDES FREELY ON THE BOTTOM PLATE – AROUND THE CORE –

– THE TAIL VANE – AXEL – AND SAILS – ARE MOUNTED ON THE ROTATING TABLE –

– THE TAIL VANE THEN ACTS AS A WEATHER VANE OR DIRECTION FINDER – CAUSING THE ROTATING TABLE TO BRING THE AXEL BEARINGS AND SAILS ALWAYS INTO A POSITION FACING THE WIND –

– THE "SHUT OFF" PULL ROPE – SUCKER ROD OR ECCENTRIC ROD PASS DOWN TO THE GROUND THROUGH THE HOLE (P) IN THE CENTRE OF THE CORE –

– THE BOTTOM PLATE IS NAILED – OR BOLTED – TO THE TOWER TOP –

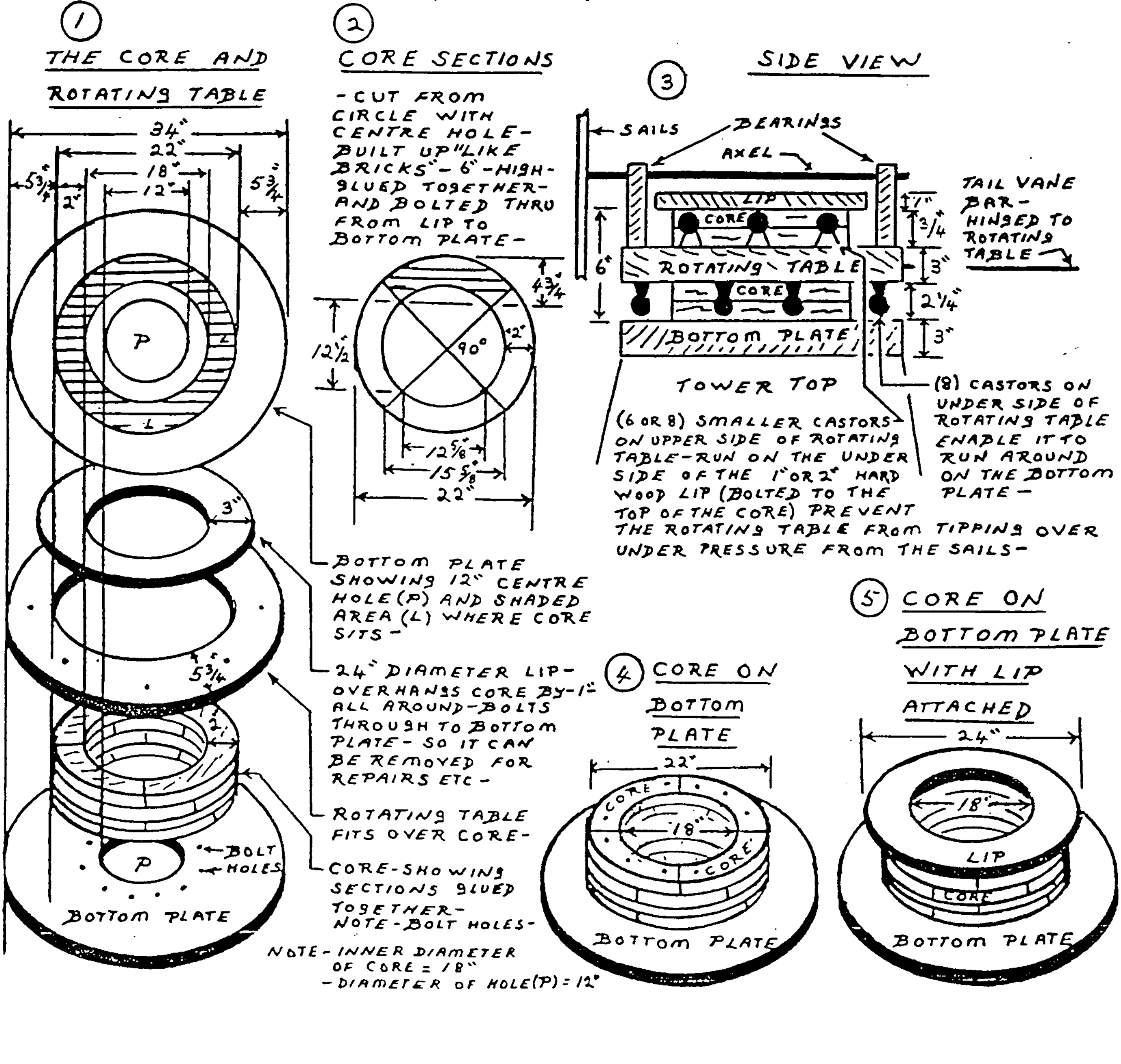


PLATE NO. 3

The wooden rotating table carries the sail axle bearings and the tail vane shut off system. It rotates around the hardwood core on 100 pound test castors. The advantages of this design are that it can be made of hardwood and that it can carry apparatus of almost any size and weight. See also plates no. 1, 2, 4, 5, 13, 14, 15, 21, 22, 23, 30, 36, 52, 53, 66 and 67.

PLATE NO. 4

Wooden rotating table construction: Remember, it is important that the inner surface of the rotating table be of hardwood where it rubs against the hardwood core. Only then, do you get a bearing surface. If the rotating table is made of plywood, there must be a hardwood ring fixed to the upper side of the same size as the centre hole, if not, the plywood will wear.

Be sure to leave enough space around the core to allow for swelling should the wood become wet.

The angled axle, (fig. 3), allows the sails to angle out so the bottom ends don't bang against the tower legs. The hub can then be closer to the bearing which reduces strain on the axle. This was a common practise among the old Dutch windmill makers.

The tower top, (fig. 5 and 6), is designed to give maximum strength while allowing space for the eccentric to operate through hole "P". See also plates no. 77, 78, 79 and 80.

First build the core, then build the rotating table and then build the bearings tail vane etc. onto the rotating table.

PLATE No. 4

– THE WOODEN MULTIBLADE – II

– ROTATING TABLE AND CORE – CONT'D

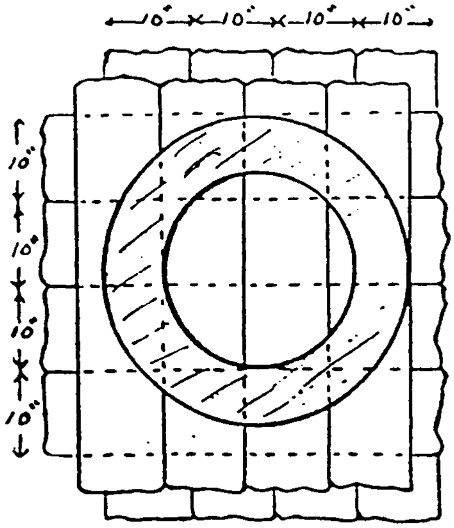
– THE BOTTOM PLATE

– THE ANGULAR AXEL

– THE TOWER TOP

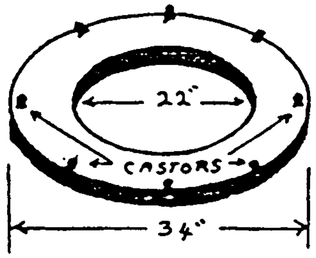
(1) ROTATING TABLE – CONSTRUCTION

– CUT FROM FOUR LAYERS OF 10" x 1" DRESSED HARDWOOD – LAID CROSSWISE TO EACH OTHER AND GLUED –
- – OUTSIDE DIAMETER = 34"
- – INSIDE DIAMETER = 22"
- – THICKNESS = (ABOUT) 3"



(2) 3/4 VIEW – TOP – ROT. TABLE

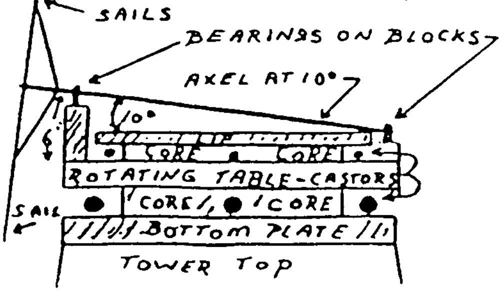
NOTE – (8) UPPER CASTORS CLOSE TO THE EDGE – RUN AGAINST LIP –



– LOWER SIDE CASTORS – WHICH RUN ON THE BOTTOM PLATE – ARE PLACED 1½" FROM THE EDGE –

(3) THE ANGULAR AXEL

– ANGLING THE AXEL AT 10° – ALLOWS THE SAILS TO CLEAR THE TOWER LEGS WITHOUT HAVING TO EXTEND THE AXEL LENGTH – A COMMON PRACTICE OF THE OLD DUTCH WINDMILL BUILDERS –



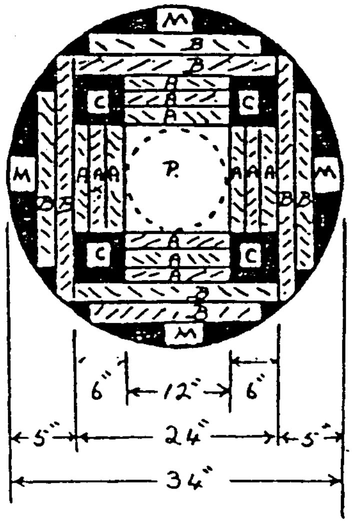
(4)

NOTE – THE BOTTOM PLATE IS MADE IN EXACTLY THE SAME WAY AS THE ROTATING TABLE (LEFT) – BUT WITH THE DIFFERENT DIMENSIONS ILLUSTRATED IN PLATE No. 3 – FIGURE No – 1

(5) THE TOWER TOP – TOP VIEW

NOTE – THE BOTTOM PLATE – NAILS – SCREWS OR BOLTS DOWN TO THE TOWER TOP – SO THE TOWER TOP SHOULD CONFORM TO THE (ROUND) SHAPE OF THE BOTTOM PLATE

– THE TOWER TOP NOT ONLY SUPPORTS THE BOTTOM PLATE ETC – IT ALSO HOLDS THE (6"x6") TOWER LEGS (ON THE 30 FOOT TOWER) SO THEY DO NOT COME TOGETHER OR SPREAD APART –



M = BOTTOM PLATE

C = THE (4) 6"x6" TOWER LEGS

A = THE (4x) 3 PIECES OF 2"x6" THAT HOLD THE TOWER LEGS APART –

B = THE 2 OR MORE LAYERS OF 2"x6" NAILED TO THE OUTSIDE OF THE TOWER LEGS – HOLD THE TOWER LEGS TOGETHER –

P = THE 12" DIAMETER HOLE – THRU WHICH PASSES THE PULL ROPE – SUCKER ROD – ETC.

(6) TOWER TOP – SIDE VIEW

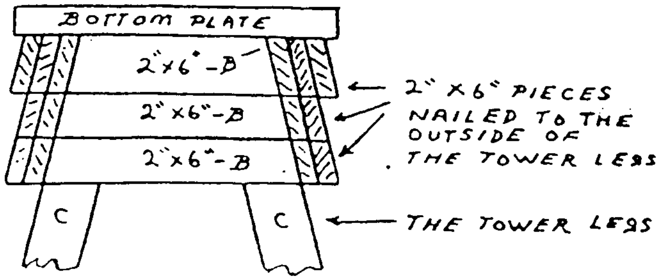


PLATE NO. 5

The tail vane operates as a gate swinging from the back end of the rotating table. Any strong heavy door or gate hinge arrangement will do, (see plates no. 13, 14, 23, 30, 31, 32, 36, 52, 53, 66, 68 and 70.

This system works in exactly the same way on both the wooden and metal rotating tables.

PLATE No. 5

– THE WOODEN MULTIBLADE III
– THE TAIL VANE– PRINCIPLES

NOTE

– A WIND MACHINE WORKS BEST WHEN IT IS FIRMLY HELD FACING THE MEAN DIRECTION OF THE WIND – THE SAILS MUST FACE INTO THE WIND –
– THOUGH – ATTEMPTS TO FOLLOW MINOR WIND CHANGES – I.E. GUSTS – ARE CONSIDERED TO BE COUNTER PRODUCTIVE IN TERMS OF POWER PRODUCTION – THEY ARE ALSO CONSIDERED TO BE UNDESIRABLE IN MECHANICAL TERMS – DIRECTION STABILITY IS THEREFORE OF MORE SIGNIFICANCE THAN SUPER SENSITIVITY IN WIND DIRECTION FINDING –

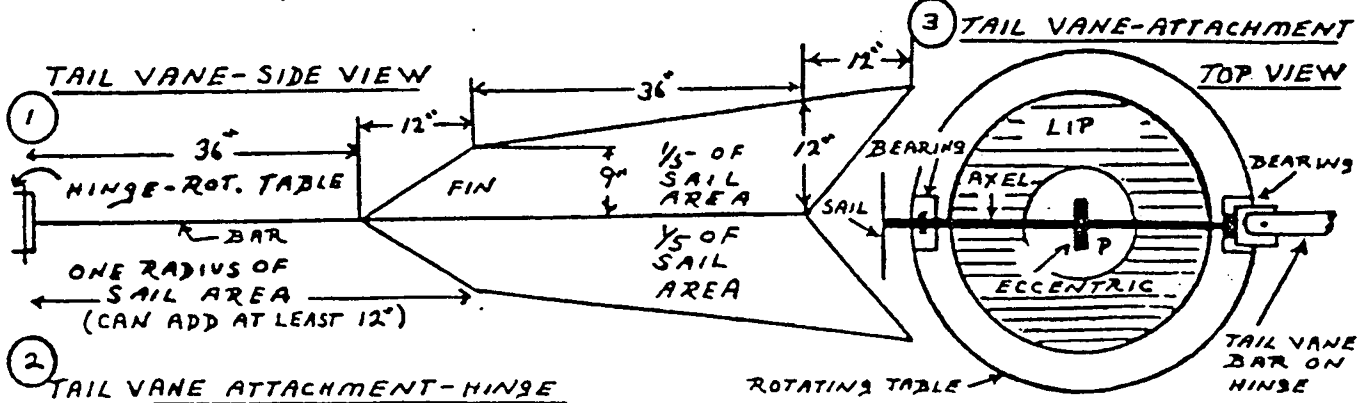
– THE TAIL VANE ACTS AS DIRECTION FINDER – LIKE THE VANE ON A WEATHER VANE WHICH CONTINUALLY POINTS THE ARROW IN THE DIRECTION FROM WHICH THE WIND IS COMING –

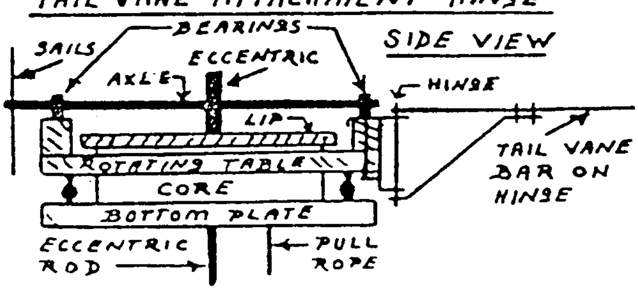
– THE TAIL VANE IS ATTACHED TO THE ROTATING TABLE – ON THE SIDE OPPOSITE TO THE SAILS – BY MEANS OF A HINGE – THE TAIL VANE THEREFORE SWINGS ON THE ROTATING TABLE AS A GARDEN GATE SWINGS ON A GATE POST –

– WHEN HELD IN DIRECT LINE WITH THE AXEL – BY MEANS OF A SPRING – IT ACTS AS A DIRECTION FINDER – WHEN THE WIND DIRECTION CHANGES – THE ROTATING TABLE TURNS ON ITS CASTORS – AROUND THE CORE – TO FACE THE SAILS INTO THE WIND – SO THEY WILL TURN – IF BOTH THE CORE AND THE ROTATING TABLE ARE MADE OF HARD WOOD (OAK OR MAPLE) – THEY WILL ACT AS BEARING SURFACES UPON EACH OTHER TO FACILITATE TURNING –
– A LITTLE GREASE ON THESE TOUCHING OR BEARING SURFACES WILL ALWAYS HELP –

– TO "SHUT OFF" OR "TURN OFF" THE WINDMILL – PULL THE TAIL VANE – ON ITS HINGE – BY MEANS OF THE PULL ROPE – SO THAT IT IS AT 90° TO THE SAIL AXEL –
– THE TAIL VANE WILL STILL ACT AS A DIRECTION FINDER – SO IT WILL TURN THE AXEL AND SAILS – ON THE ROTATING TABLE – SO THEY ARE AT 90° TO THE WIND – AND WILL NOT TURN – THE PULL ROPE PASSES DOWN TO THE GROUND – THROUGH THE CENTRE HOLE (P) IN THE CORE –

– MAINTAIN – (A) – THE SHORTEST POSSIBLE OVERHANG OF THE SAILS IN FRONT OF THE ROTATING TABLE –
– (B) THE LONGEST POSSIBLE OVERHANG OF THE TAIL VANE BEHIND THE ROTATING TABLE – AT LEAST ONE DIAMETER OF THE SAILS FROM THE CENTRE OF THE ROTATING TABLE TO THE FIN SECTION OF THE VANE – OR ONE RADIUS OF THE SAILS FROM THE ROTATING TABLE TO THE FIN –
(C) AS MUCH OF THE FIN AS POSSIBLE IN THE UNDISTURBED WINDFLOW ABOVE THE ROTATING TABLE –
(D) FIN AREA SHOULD BE AT LEAST 1/5 OF SAIL AREA –





4 OTHER CLASSIC TAIL VANE SHAPES

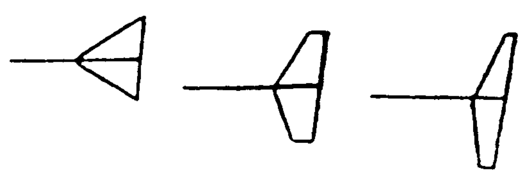


PLATE 6

The flange adaptation for a wooden hub, flat belt or "V" belt pulley, depends on the axle pipe fitting into the nipple pipe, which it should, but does not quite do. You can file the inside of the nipple pipe, which is tedious, or you can drill it out with a one inch drill, which is much easier.

Pipes are always measured by their inside diameters and both water and gas pipes have 1/8" walls, meaning that their outer diameters are always 1/4" greater than their inner diameters. Therefore, a pipe should always be able to fit into another pipe with an inner diameter 1/4" greater than its own. In real life, however, it takes a small amount of urging

Gas pipes are stronger than water pipes. See also plates no. 7, 8, 11, 19, 20, 21 and 24.

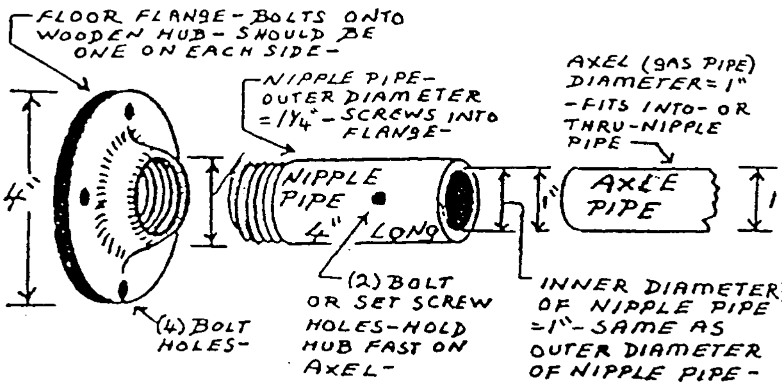
PLATE No. 6

- THE WOODEN MULTIBLADE IV
- THE MAIN HUB - 10" DIAMETER - DETAIL

FLOOR FLANGE - ADAPTATION

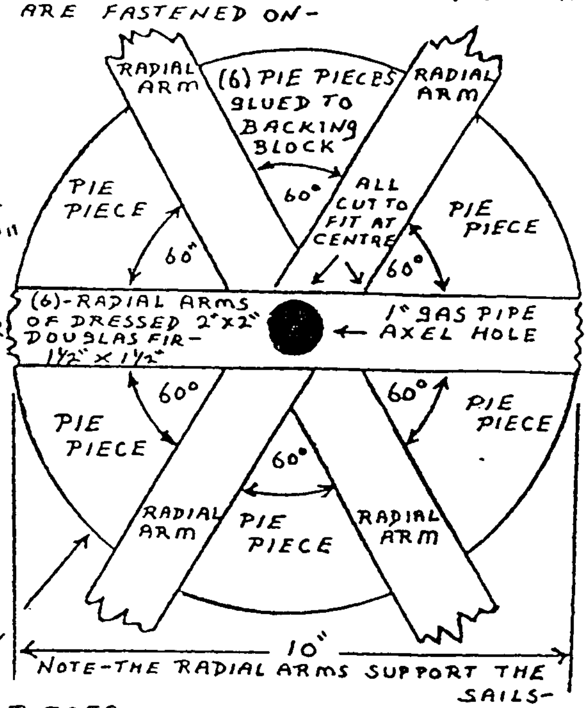
- FLOOR FLANGE HOLDS WOODEN HUB ONTO GAS PIPE AXLE -

(1)



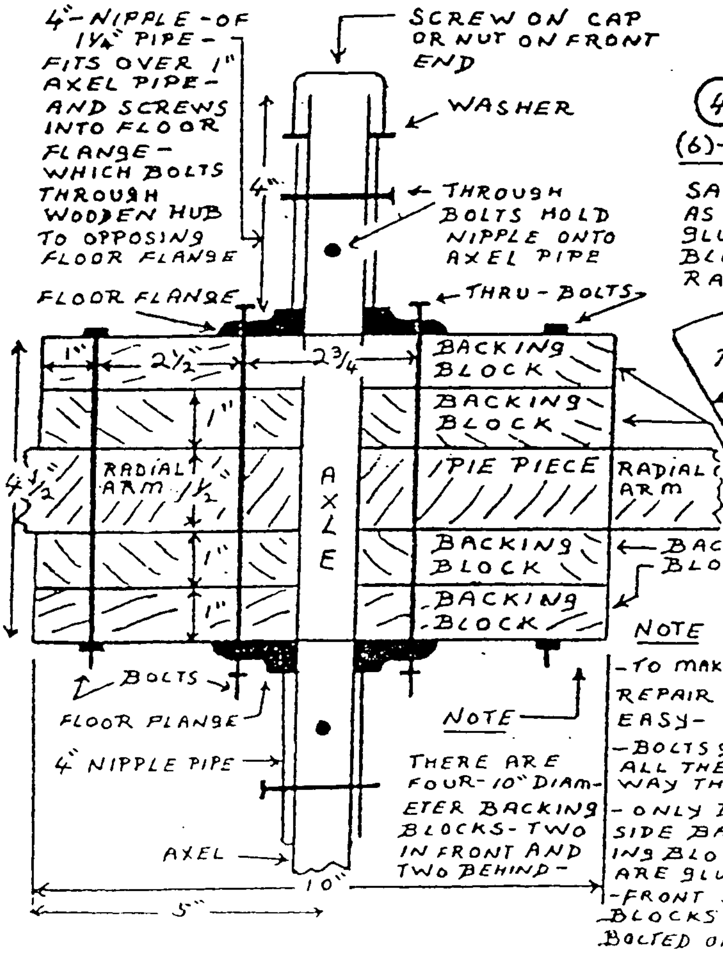
(3) FRONT VIEW - 10" HUB

- SHOWING THE PIE PIECES AND RADIAL ARMS BEFORE THE TWO FRONT BACKING BLOCKS ARE FASTENED ON -



(2)

CROSS SECTION - SIDE VIEW - 10" HUB



(4) (6) - PIE PIECES

SAME THICKNESS AS RADIAL ARMS - GLUE TO BACKING BLOCKS BETWEEN RADIAL ARMS -

(5) FRONT (OR BACK) VIEW - 10" - HUB

WITH BACKING BLOCKS GLUED AND FASTENED OVER PIE PIECES AND ARMS

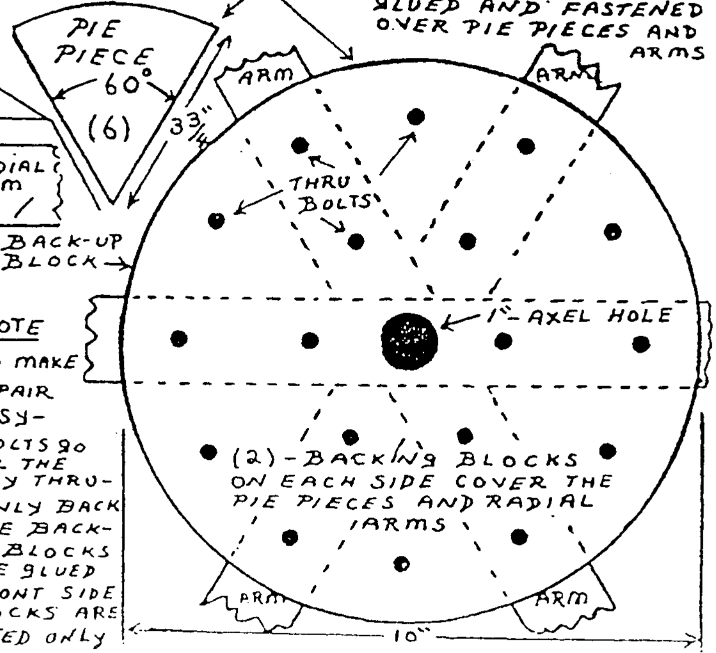


PLATE NO. 7

The floor flange and nipple pipe system work the same as in the main hub shown in plate no. 6.

Note especially, that the back up arms are held into their notches at both their top and bottom ends by wire cords so they have a degree of resiliency against the wind and will not break, (see fig. 1 and 5, also plate no. 8, fig. 3).

PLATE No. 7

– THE WOODEN MULTIBLADE V

– THE BACK UP HUB –

–THE BACK-UP HUB BRACES THE BACK UP ARMS – WHICH SUPPORT THE RADIAL ARMS AGAINST WIND PRESSURE

THE BACK-UP HUB IS FITTED ONTO THE AXEL – 12" BEHIND THE MAIN HUB – SEE PLATE No. 7

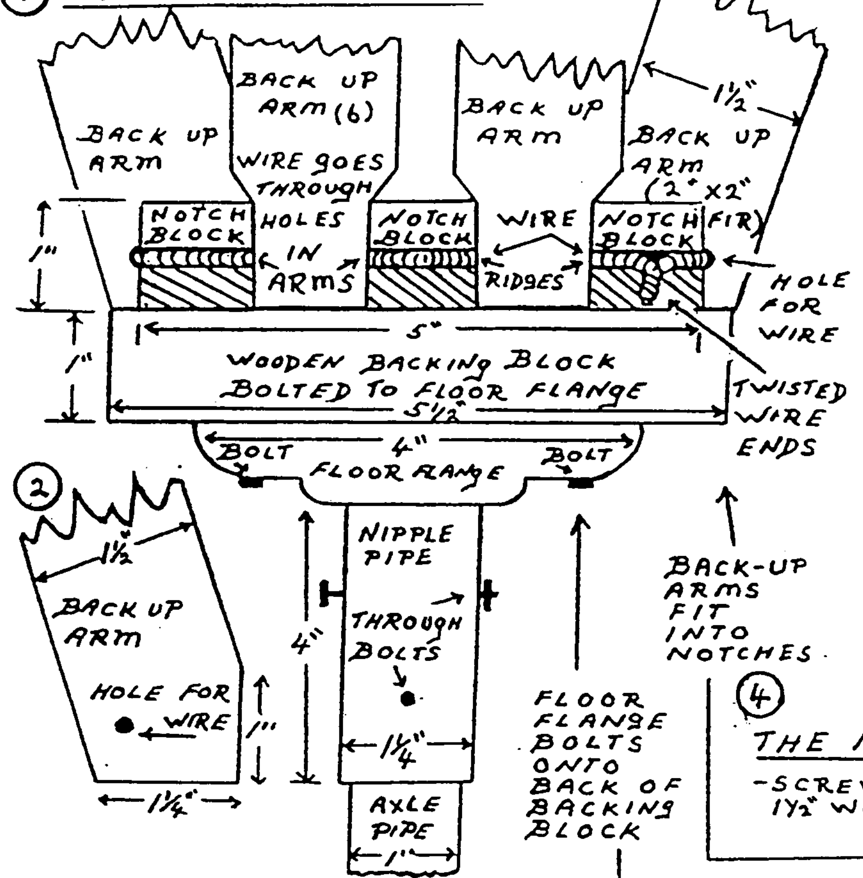
–THE BACK UP BLOCK FITS ONTO AXEL WITH 4" NIPPLE AND FLOOR FLANGE – JUST LIKE THE MAIN HUB –

–BACK UP ARMS ARE HELD INTO THE NOTCHES OF THE NOTCH BLOCK (AGAINST THE BACKING BLOCK) BY TIGHT WIRES PASSING THROUGH HOLES IN THE BACK-UP ARMS AND THE 1/4" RIDGES AROUND THE OUTSIDE OF THE NOTCH BLOCK –

–THE NOTCH BLOCK IS GLUED AND SCREWED TO THE BACKING BLOCK –

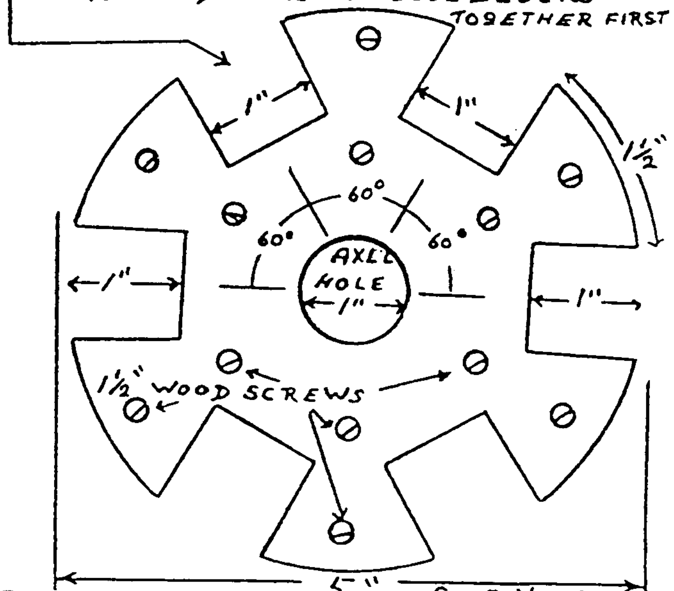
–THE BACKING BLOCK IS BOLTED TO THE FLOOR FLANGE –

① SIDE-VIEW-DETAIL

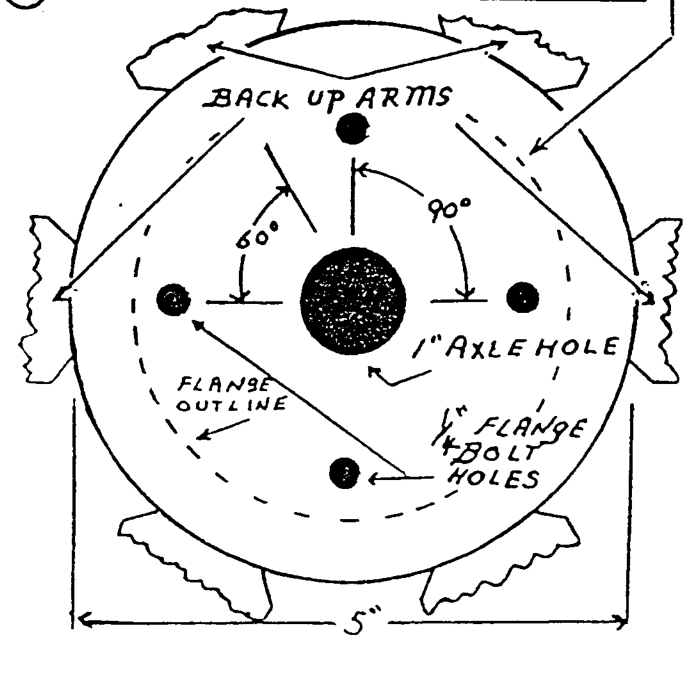


④ THE NOTCH BLOCK – FRONT VIEW

–SCREWS ONTO BACKING BLOCK WITH 1 1/2" WOOD SCREWS – GLUE BLOCKS TOGETHER FIRST



③ THE BACKING BLOCK – BACK VIEW



⑤ SIDE VIEW

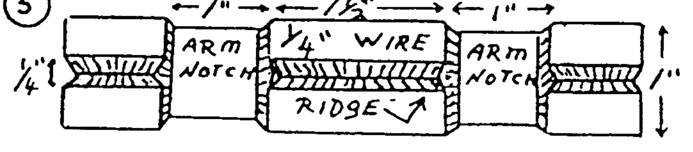


PLATE NO. 8

The 36" blade sails will turn slowly, because, theoretically, the larger the number of sails, the slower will be the R.P.M. Also, a 30° pitch, especially if the blade is flat rather than curved, will reduce the airfoil effect.

This is all discussed with greater detail in the theoretical and rotor blade, (airfoil) sections.

The 36" blade design is especially suited to the eccentric rod application illustrated in plate no. 19, et. al., which works right off the wind shaft axle without any gear down system to slow it's up and down pump rod action.

It may, however, have trouble lifting the eccentric rod to the pump in the case of tower heights of more than fifteen or twenty feet. If this turns out to be so, you can aid the up stroke by the use of springs connected from a point on the eccentric rod to cross pieces on the tower. Four spring connections, to four cross pieces, from the same point on the eccentric rod will be better than one strong spring, because four will hold the rod in its central position.

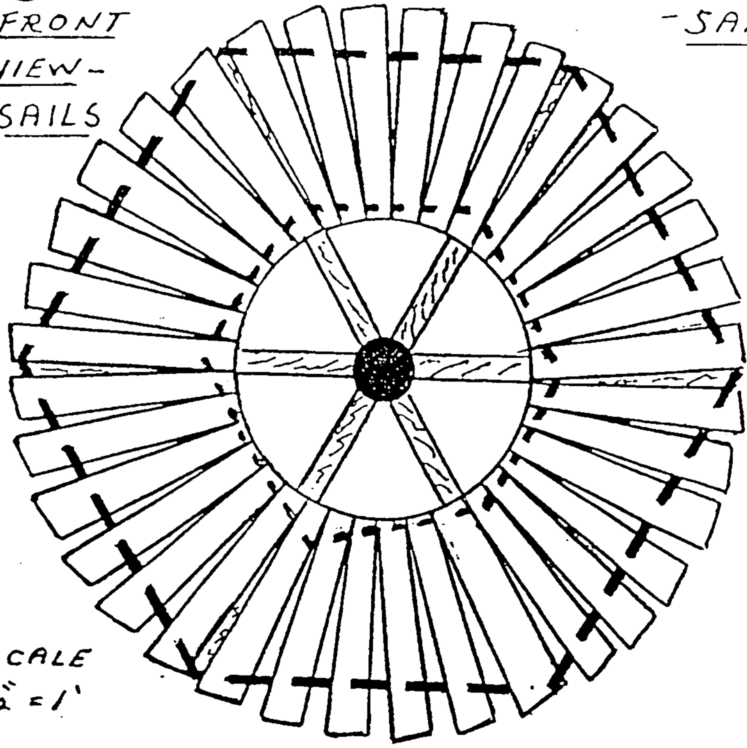
See pump plans, plate no. 61, et. al.

PLATE No. 8

-THE WOODEN MULTIBLADE-VI
-SAILS-I- SAIL FRAMES-I
-36 SAIL BLADES-
-SLOW TURNING-
-8-FOOT DIAMETER

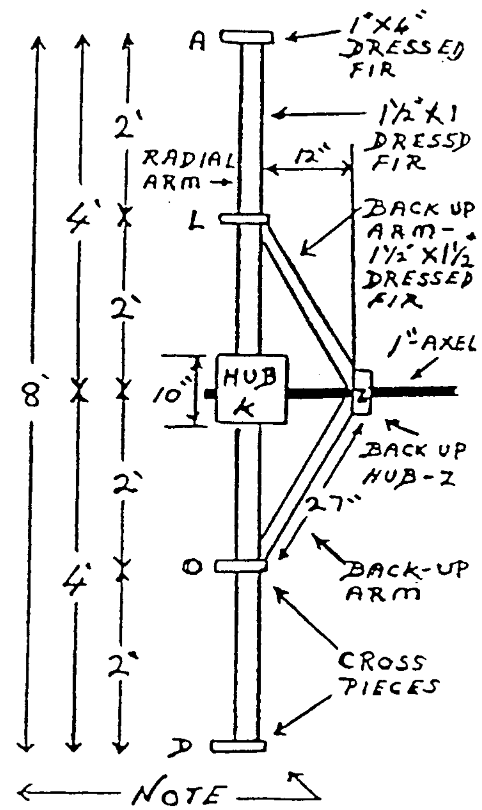
-AXEL CONNECTS DIRECTLY TO ECCENTRIC OR CRANK-

(1) FRONT VIEW-SAILS

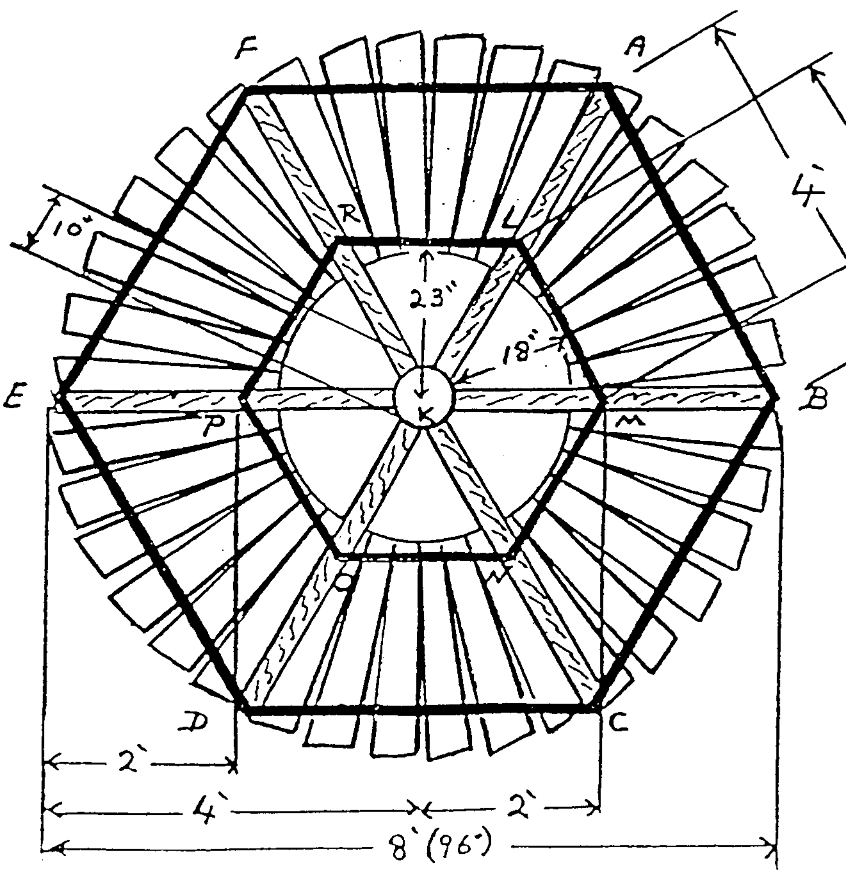


SCALE ½" = 1'

(3) FRAME-SIDE VIEW



(2) BACK VIEW - FRAME DETAIL



NOTE

RADIAL ARMS - A-K; B-K; C-K; D-K; E-K AND F-K ARE ALL OF 2"X2" FIR 48"-LONG-DRESSED = 1½"X1½"-

CROSS PIECES - A-B; B-C; C-D; D-E AND E-F ARE ALL MADE FROM 1"X4" DRESSED FIR 48" LONG-

CROSS PIECES - L-M; M-N; N-O O-P; AND P-R ARE ALL MADE FROM 1"X4" DRESSED FIR - 24" LONG-

HUB-K-DIAMETER = 10"

BACK UP HUB-Z-(ABOVE) DIAMETER = 5"

SAIL BLADE-LENGTH = 30"

OVER ALL DIAMETER = 96"

PLATE NO. 9

The sails can be made from plywood, wood, plastic or tin, (galvanized iron). They can also be made from steel drum sections, (see plate no. 54, fig. 3 and plate no. 35, fig. 6), which will give the proper aeronautical curve. If steel drum sections are used, the 30_ pitch angle should be measured from point to point of the inside curve.

The batteries can be made 1/2" instead of one inch thick. In this case, there can be two battens at each station, one above and one below the cross piece. There can then be another one inch batten between the two from the cross piece out. The three pieces can then be glued and bolted to each other and to the cross piece.

PLATE No. 9

- THE WOODEN MULTIBLADE - VII
- THE SAILS II
- SAIL ATTACHMENTS - SHAPES

- SAILS ARE;

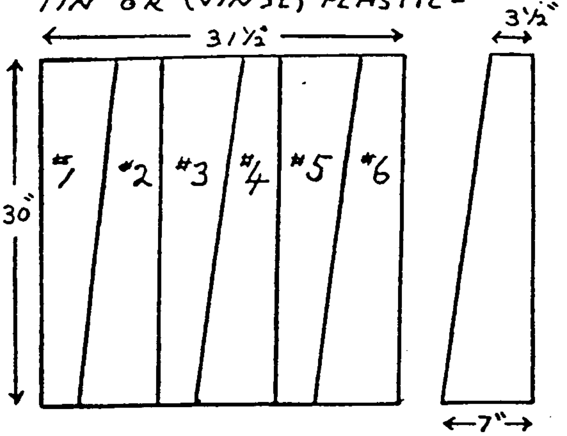
(A) - CUT TO SIZE

(B) - FITTED INTO SLOTS IN CROSS PIECES

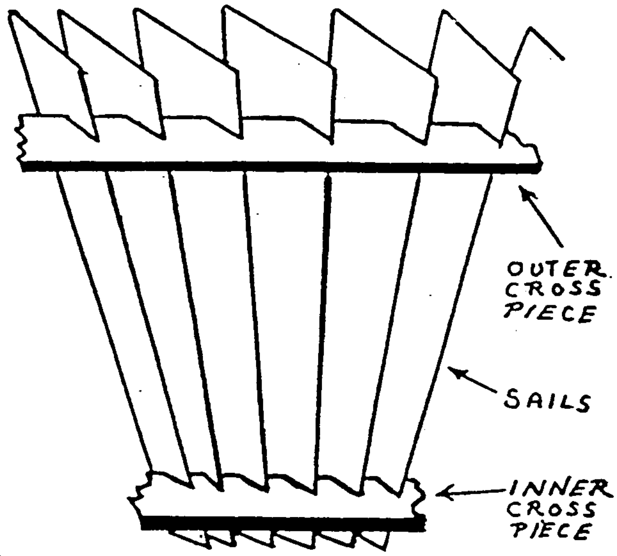
(C) - NAILED TO BATTENS

(1) THE SAILS - SHAPE

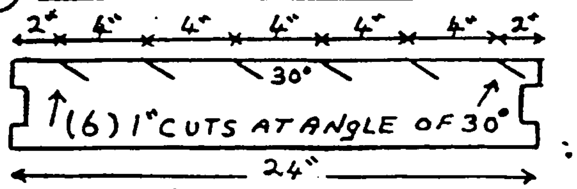
CUT FROM A SINGLE SHEET OF 20 GUAGE GALVANIZED IRON-TIN OR (VINYL) PLASTIC -



(2) SAILS FITTED TO CROSS PIECES

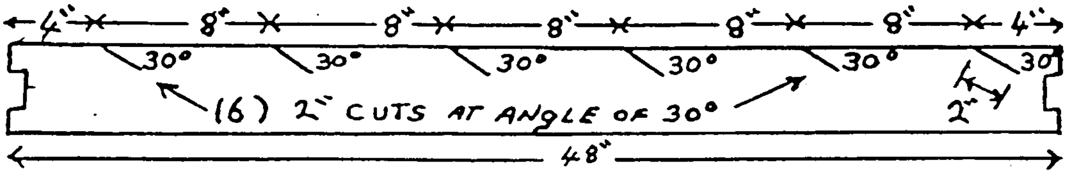


(3) INNER CROSS PIECE



- 1"x4"x24" - WITH SIX 2" CUTS AT 30°

(4) OUTER CROSS PIECE - 1"x4"x48" - WITH SIX 2" CUTS AT 30°



(5) OUTER CROSS PIECE SAIL FITTINGS

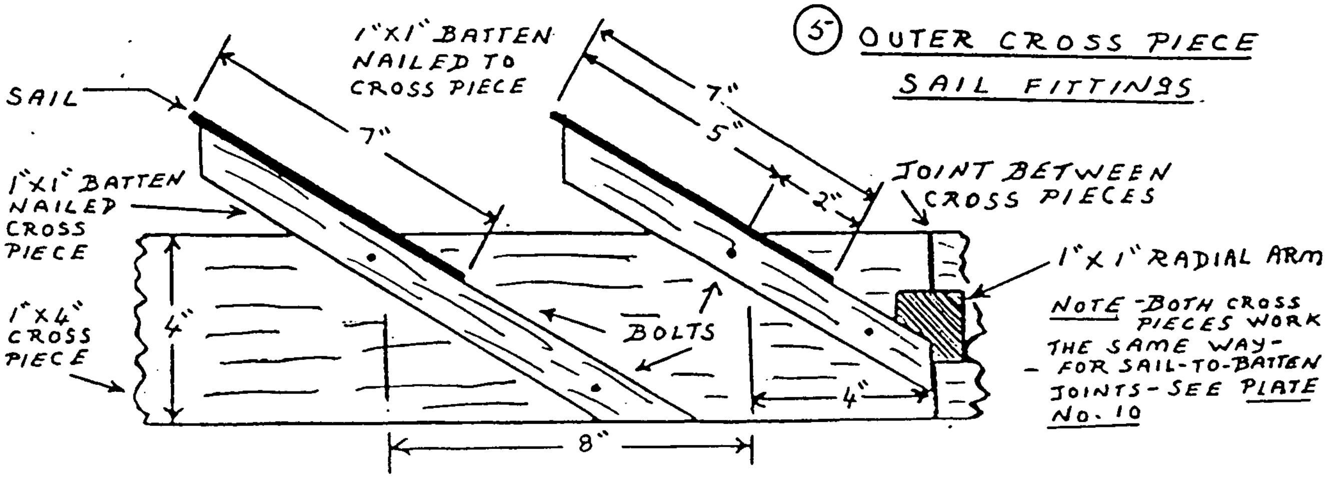


PLATE NO. 10

The tightened metal strapping around the outer side of the outer cross piece, (fig. 10), and the crossed wires around the outside of the inner cross piece, (fig. 9), add tremendous strength against centrifugal force. The circle is the great secret of ship rigging. It is the strongest of all binding systems and should make this wooden frame system almost as strong as its metal counterpart.

The strapping and "strapping tightener" can be obtained from a local lumber yard. The tightener, of course, will be on a loan basis.

The strapping should be sanded and painted to prevent rust.

If there is no strapping available, you can use several wrappings of tightened iron stove wire.

PLATE No. 10

– THE WOODEN MULTIBLADE – VIII
– THE SAILS – III

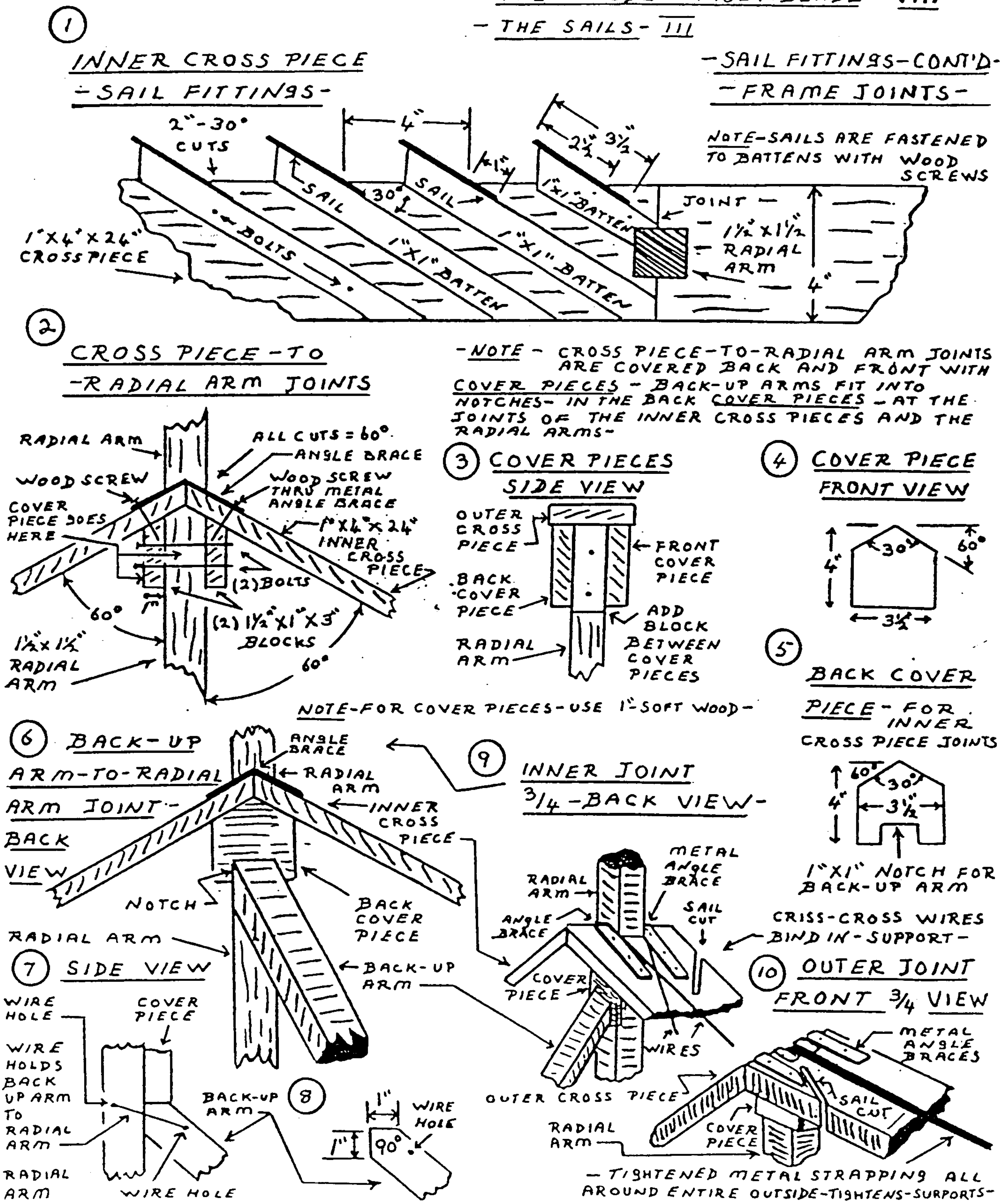


PLATE NO. 11

The 18 blades will turn faster and should perform in the same way as the 15 sails of the metal multiblade, (plate no. 33).

Because of the higher R.P.M., this design should be geared down in a one to four ratio. as illustrated in plate no. 22.

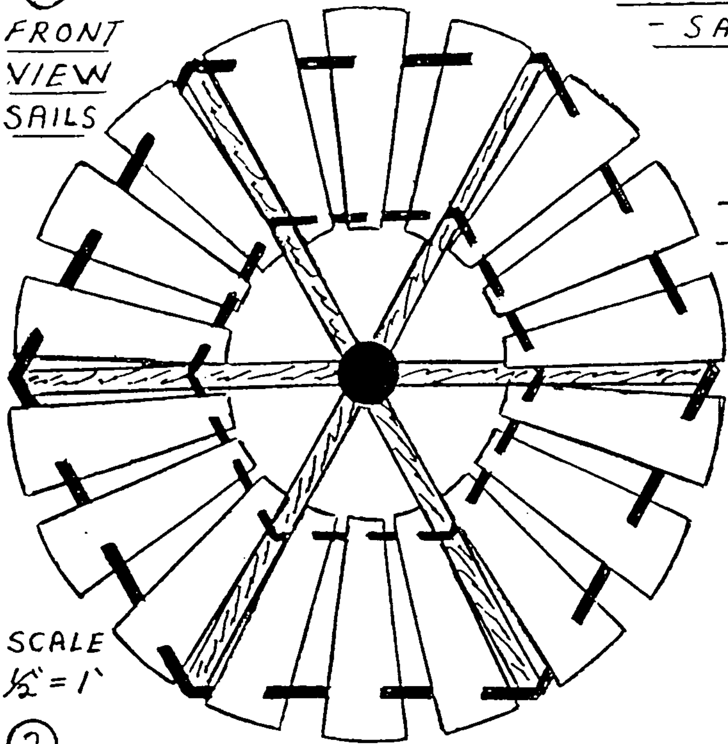
It should perform well on a 30 foot tower as illustrated in plate no. 78, et. al.

See pump plans, plate no. 61 through to 65.

PLATE No. 11

-THE WOODEN MULTIBLADE- IX
- SAILS-IV - SAIL FRAMES- II
-18 BLADES-
-FASTER TURNING-
- 8 FOOT DIAMETER-

(1) FRONT VIEW SAILS



SCALE ½" = 1'

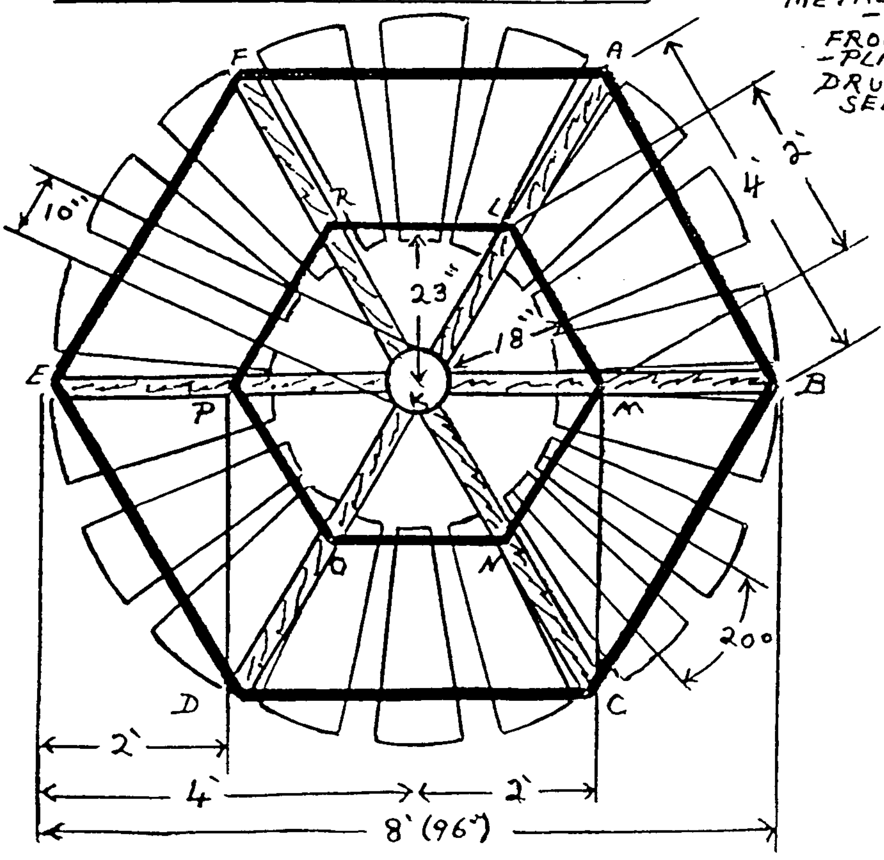
-REQUIRES GEAR DOWN-RATIO OF FOUR OR FIVE TO ONE-
- WINDSHAFT AXEL CONNECTS TO JACK SHAFT (SECONDARY) AXEL- WHICH CONNECTS TO THE ECCENTRIC OR CRANK - SEE PLATE No.

-SAIL FRAMES SAME AS ON 36 SAIL WINDMILL - SEE PLATE No-8 - EXCEPT FOR SAW CUTS IN CROSS PIECES - SEE PLATE No.

- SAIL AREA IS NEARLY THE SAME AS ON 8 FOOT DIAMETER. -15-BLADE - MULTIBLADE - SEE PLATE No.
-SO SHOULD DO ABOUT THE SAME AMOUNT OF WORK-

-SAILS ARE LARGER THAN THOSE ON 36 BLADE WOODEN MULTIBLADE - BUT SLIGHTLY SMALLER THAN THOSE ON 15 BLADE - 8 FOOT DIAMETER METAL MULTIBLADE.
-SAILS CAN BE MADE FROM WOOD - SHEET METAL - PLASTIC OR FROM STEEL DRUMS TO GET THE CURVES- SEE PLATE No. -FIG. 3-
- CURVES WILL INCREASE POWER OF BLADES-

(2) BACK VIEW - FRAME DETAIL



(3) -SAIL BLADE- -MEASUREMENT-

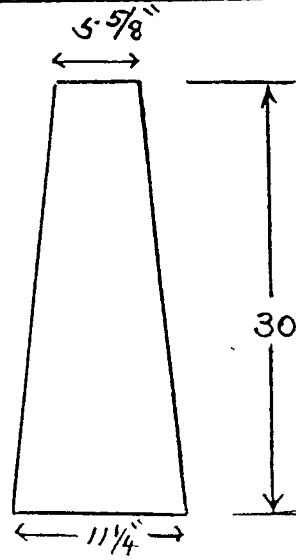


PLATE NO. 12

The sails and sail frames work in exactly the same way as on the 36 blade, illustrated in plates no. 9 and 10.

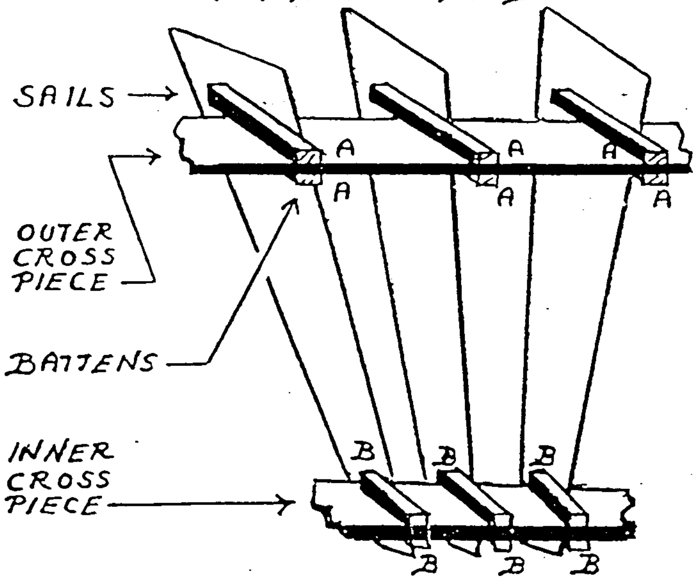
PLATE No. 12

- THE WOODEN MULTIBLADE - X
- THE SAILS - V
- 18-BLADE MULTIBLADE -
- 8-FOOT DIAMETER -

- SAIL FITTINGS -
- CROSS PIECES -

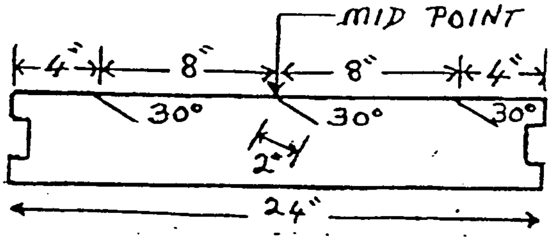
(1) SAILS FITTED TO CROSS PIECES -

NOTE - ½" X 1" TOP AND BOTTOM BATTENS AT A-A, A-A AND A-A -
- ALSO AT B-B, B-B AND B-B -



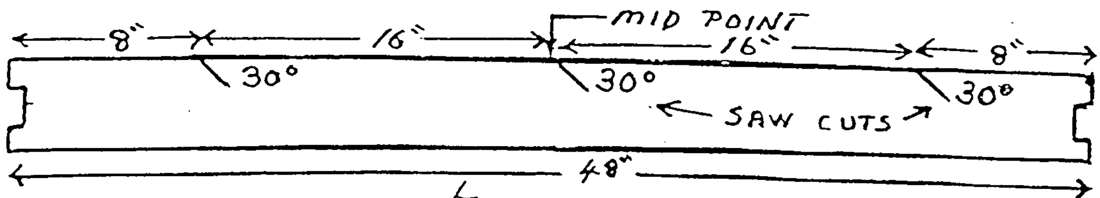
(2) INNER CROSS PIECE

- 3 BLADES PER CROSS PIECE -
- 1" X 4" X 24" PIECE OF FIR WITH THREE 2" CUTS AT 30° -



(3) OUTER CROSS PIECE

- 3 BLADES PER CROSS PIECE -
- 1" X 4" X 48" PIECE OF FIR - WITH THREE 2" CUTS AT 30°



(4)

- OUTER CROSS PIECE -
- SAIL FITTINGS -

TOP VIEW

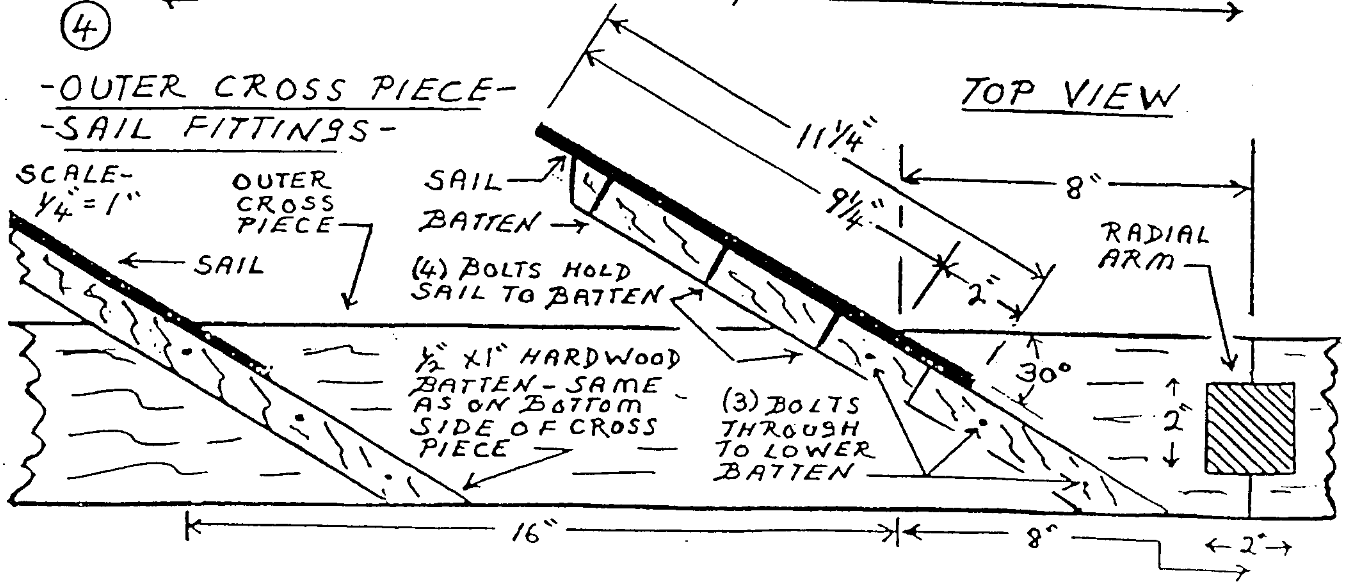


PLATE NO. 13

The tail vane swings like a gate on the hinge post at the back end of the rotating table as described in the notes on plate no. 5.

Note the brace and spring "shut off" mechanism, illustrated in fig. 3, 4 and 5.

The tail vane should always be pulled "closed" by the spring and pulled "open" by the pull rope, so that if there is trouble with storms etc., it will close by itself and not depend on the pull rope which could break.

The pull rope is operated by a person standing on the ground at the base of the tower. It should have a clothes line type swivel on it to prevent twisting and should be tied off to a cleat on one of the tower legs. Better type swivels can be obtained from marine supply stores.

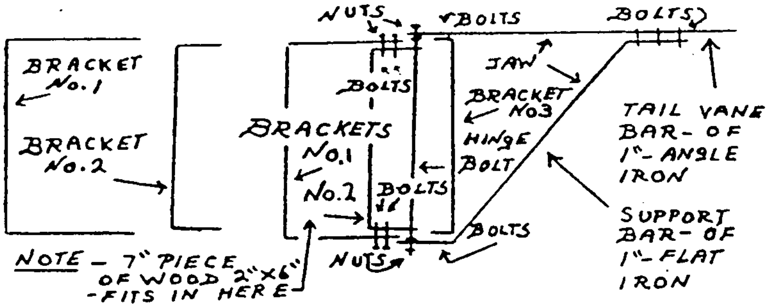
Note also, the "bridge", illustrated in fig. 3, 4, 5, 6 and 7, which carries the pull rope over the core lip, (which does not move as the rotating table rotates), and down through the centre hole so that it can pass to the ground.

The bridge is simply a big gate hinge bolted to a 10 1/2" triangular shaped board. There is a pulley on the pointed end of the board to accommodate the pull rope which passes down through the hole. There should be one or two castors on the under side of the board so that it can run around on the lip without straining the hinge.

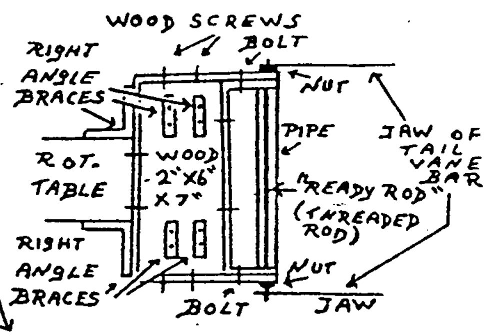
PLATE No. 13

- THE WOODEN MULTIBLADE XI
- THE TAIL VANE I
- SWING CONNECTIONS - SHUT-OFF - BRIDGE

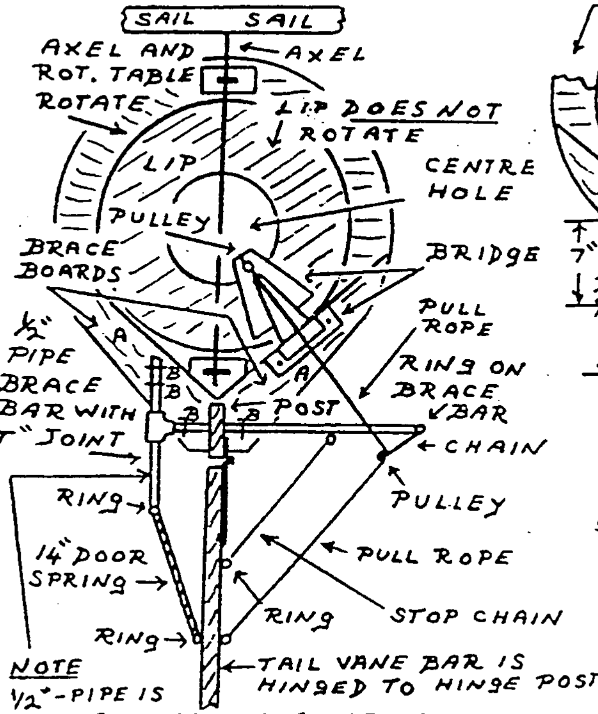
(1) METAL TAIL VANE HINGE - AND BRACKET - (A)



(2) SAME HINGE AND BRACKET - (B) ATTACHED TO ROTATING TABLE

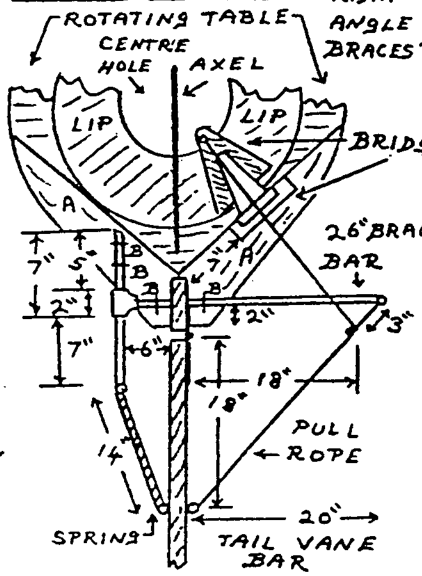


(3) THE SHUT-OFF - OPEN POSITION - SAILS TURNING

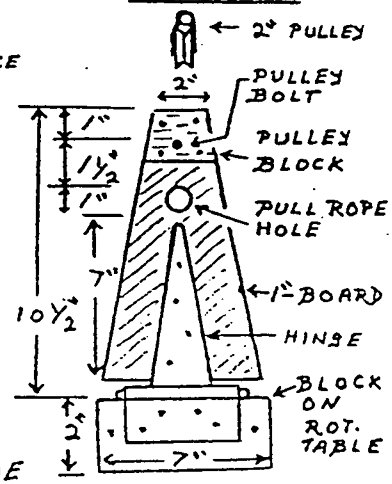


NOTE
½"-PIPE IS HELD TO ROTATING TABLE - BRACE BOARDS (A) BY "U" BOLTS - B-B-B AND B -
- FOR BRACE BOARDS (A) - SEE PLATE No. 12 -

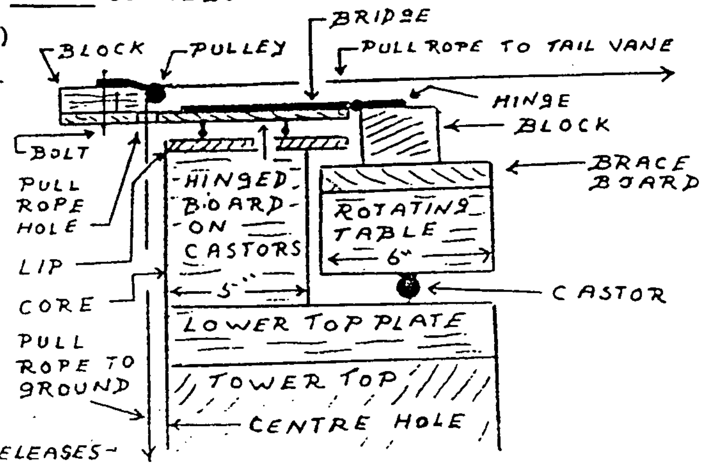
(4) SHUT-OFF AND BRACE BAR DETAIL



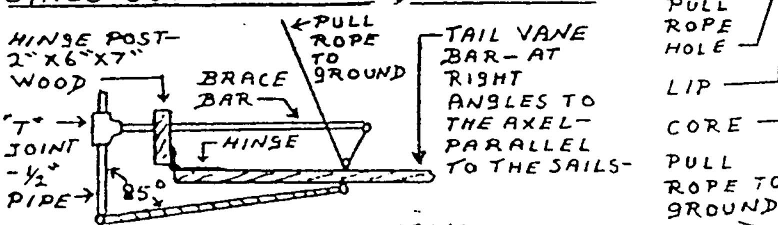
(6) THE BRIDGE TOP VIEW



(7) THE BRIDGE - SIDE VIEW - CONVEYS PULL ROPE OVER CORE AND LIP -



(5) SHUT-OFF CLOSED POSITION - SAILS OUT OF THE WIND - NOT TURNING -



STEEL DOOR SPRING WILL PULL TAIL VANE BACK TO OPEN POSITION - WHEN PULL ROPE RELEASES -

PLATE NO. 14

Note the "brace boards" illustrated in fig. 5, which are nailed onto the rotating table to create extra length for the hinge post notch. The hinge post fits into the notch and is held firm by the metal right angle brackets c.c, c, c, and c, above and below the brace boards. See also the side view in figure 6. See also plates 22 and 23.

PLATE No. 14

- THE WOODEN MULTIBLADE - XII
- THE TAIL VANE - II
- SWING CONNECTIONS - CONTINUED

(1) ALTERNATE TAIL VANE DESIGN - SEE PLATE No. 5

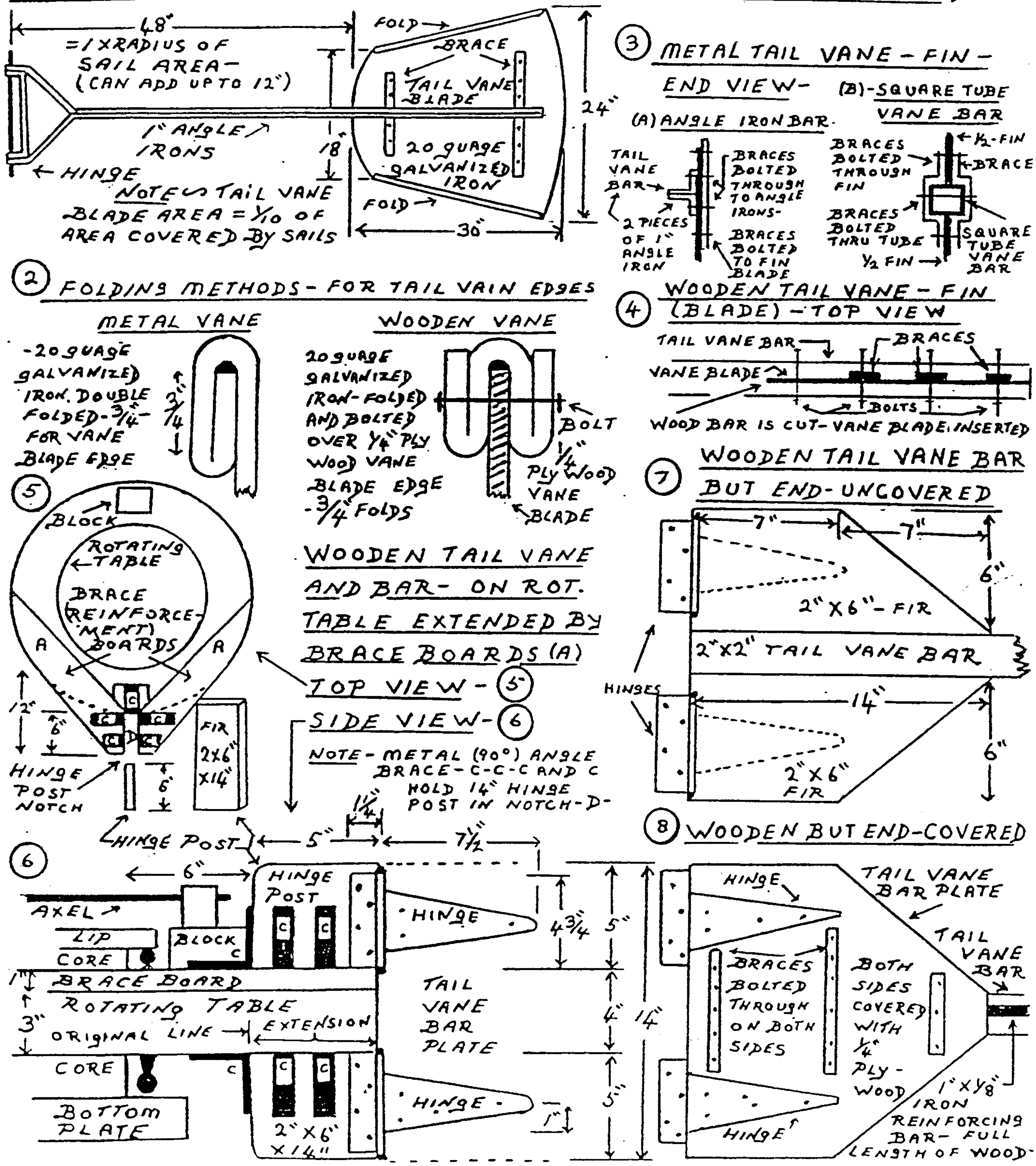


PLATE NO. 15

Hard wood bearings are used in many developing countries as axle bearings in wagons. They are also used on modern grain harvesting combines of the larger variety. The point is, that they work and they work well.

Note the "thrust bearing", or back bearing, in fig. 5, 6 and 7 which is essential to absorb the "push" of the wind on the sails that is translated to the axle.

The "screw on" cap must be smoothed and polished to reduce friction, and fitted into the widened portion of the axle hole. The "back piece" that it rotates against should be simmered in crank case oil like the rest of the bearing.

Use the hardest wood you can find, like oak, maple or birch. Oak is the best.

— THE WOODEN MULTIBLADE — XIII
— THE WOODEN BEARINGS

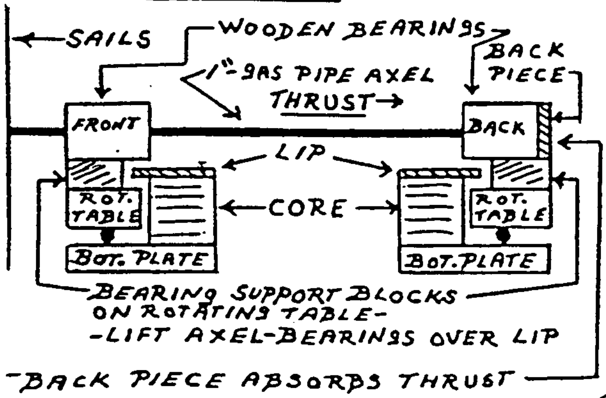
(1) PRINCIPLES — THRUST —

— DIRECTION OF WIND ⟶
= DIRECTION OF THRUST ⟶
= DIRECTION OF FORCE EXERTED BY THE WIND ON THE SAILS ⟶

— THIS THRUST MUST BE ABSORBED BY A THRUST BEARING OF SOME KIND — OR THE EXCESSIVE SIDE PRESSURE ON ORDINARY BEARINGS WILL CAUSE PREMATURE WEAR — AND MAY EVEN STOP THEM TURNING —

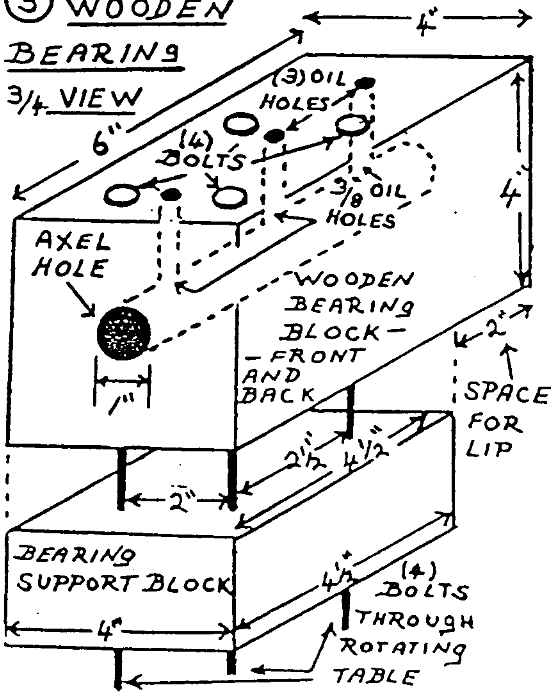
(2) WOODEN BEARINGS —

SIDE VIEW



(3) WOODEN BEARING

3/4 VIEW

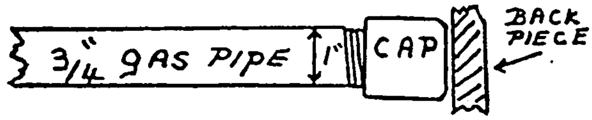


(4) WOODEN BEARING — PRINCIPLES

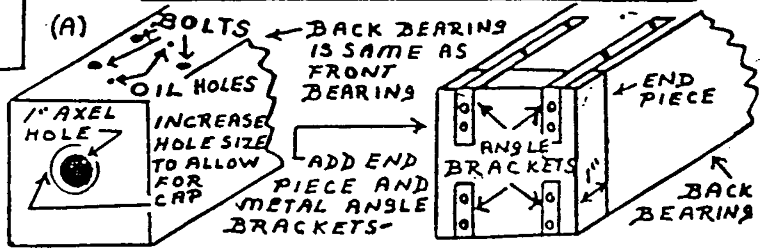
— WOOD BEARINGS ARE SIMPLY HARD WOOD BLOCKS — WITH HORIZONTAL HOLES DRILLED LARGE ENOUGH TO ALLOW AXEL TO PASS THROUGH AND TURN FREELY —
— 3 OIL HOLES MAY BE DRILLED DOWN FROM THE TOP SIDE —

— FINISHED BEARING SHOULD BE SIMMERED FOR SEVERAL HOURS IN USED CRANK CASE OIL — THE GRAPHITE IN THE USED OIL WILL PROVIDE LONG TIME LUBRICATION — COMING OUT WHEN BEARING GETS WARM —

(5) AXEL WITH (POLISHED) SCREW ON CAP — TAKES THRUST AGAINST BACK PIECE —



(6) BACK PIECE — HELD ONTO BEARING WITH METAL ANGLE BRACKETS —



(7) SIDE VIEW — WOOD BEARING ASSEMBLY — SHOWING SPACE FOR CAP —

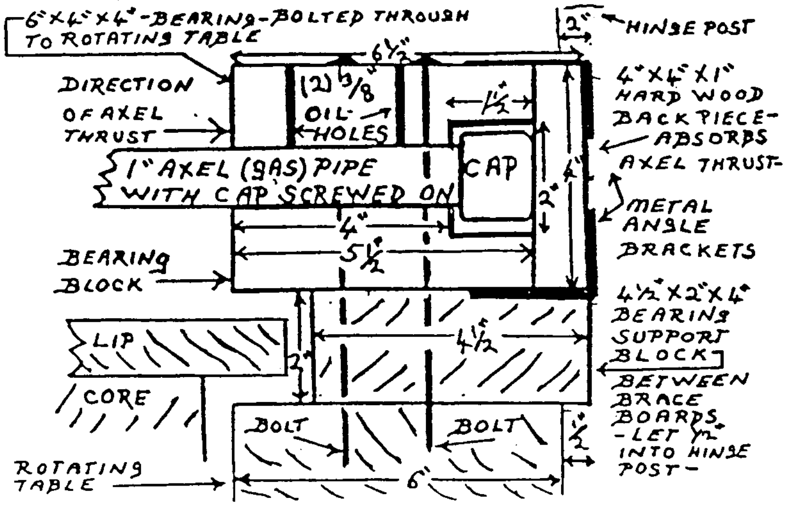


PLATE NO. 16

Metal bearings are usually thought of in connection with solid steel axles, but there is no reason why they sound not go onto a gas pipe axle as well because the bearing grips the axle by means of the eccentric locking collar, (fig. 5, 6 and 7). In other words, the axle does not rotate in the collar, it rotates on the roller bearings or the ball bearings.

The double row roller bearing absorbs the wind "thrust" on the sails as translated to the axle. It, therefore, should be the bearing closest to the sail hub. In fact, it should be as close to the hub as it can get without causing the sail tips to knock against the tower legs.

If possible, go to a special bearing shop and buy the best bearings you can afford.

PLATE No. 16

- THE WOODEN MULTIBLADE - XIV
- METAL BEARINGS

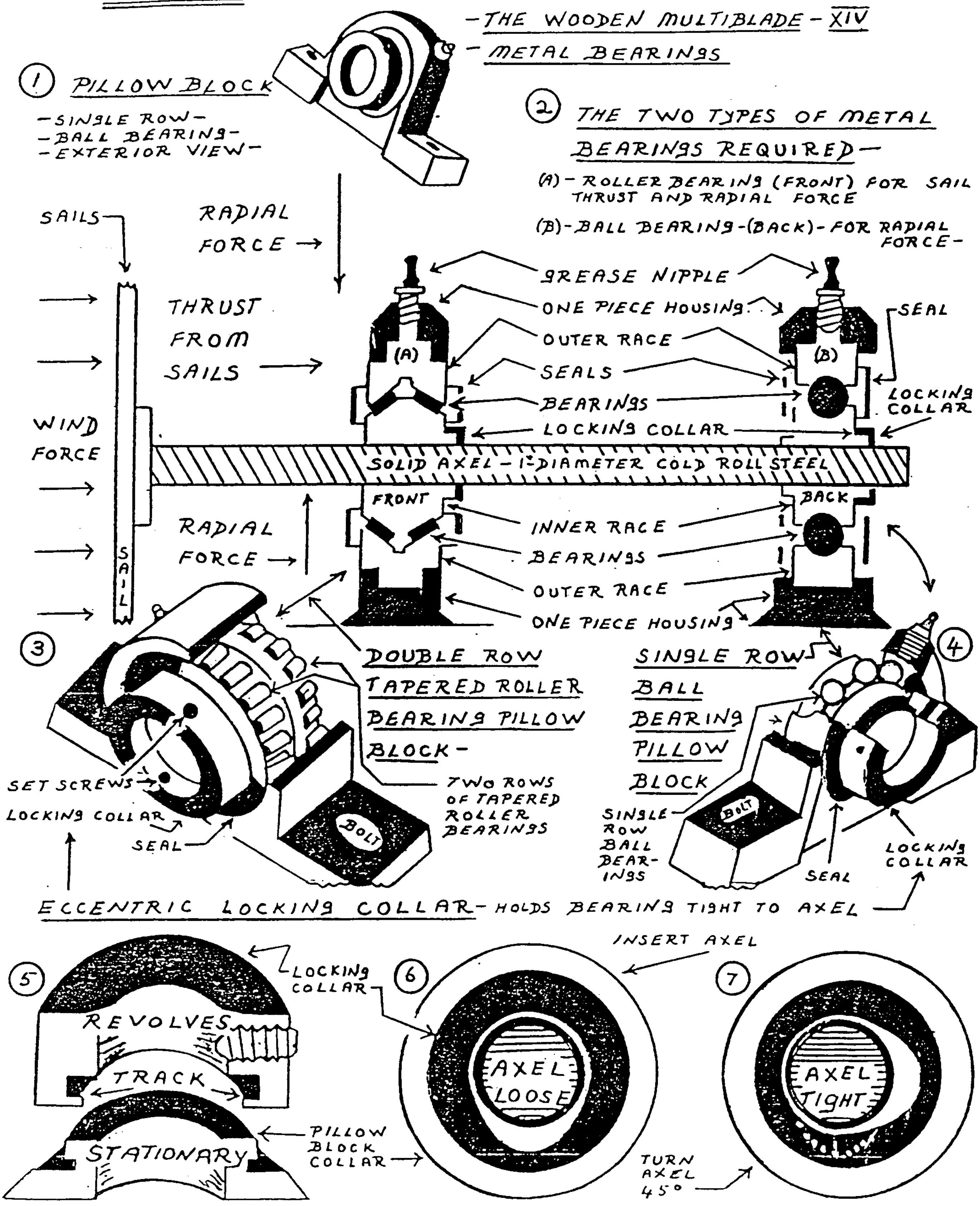


PLATE NO. 17

This is the best type of professional hub used by professional machine builders on a wide variety of mechanical devices.

They can be bought from bearing dealers and from some automotive type catalogues. Remember, though, you will have to go to a machine shop and have key-ways cut in the axle at the proper places, which will cost about $15 each.

The idea is that you weld a circular steel plate, (say 10" diameter), to the hub piece and bolt the radial arms to the plate, (fig. 2 and 4).

If you are using wooden hub parts, as you would with a rotor, (plate no. 39, et. al.), you place the wooden parts onto the circular plate and bolt a second circular plate, of the same size, over the wood parts and bolt through to the first plate, (fig. 3).

Insert the key in the key-way; fit the bushing over the key and then hammer the hub down over the bushing. You can remove the hub by hammering it off the bushing.

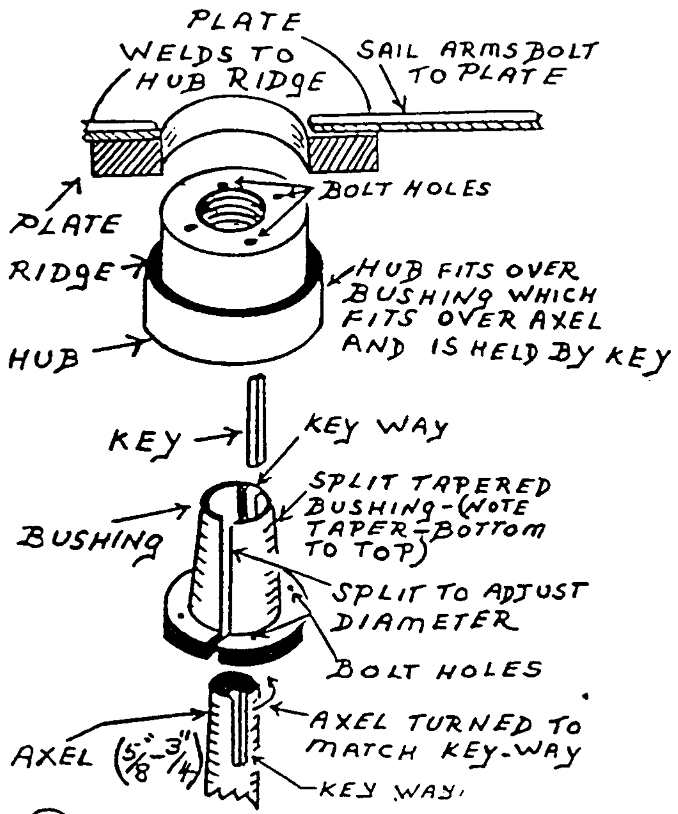
This works with pulleys and sprockets as well as wheel or sail hubs.

Note also the alternative metal hub in fig. 6.

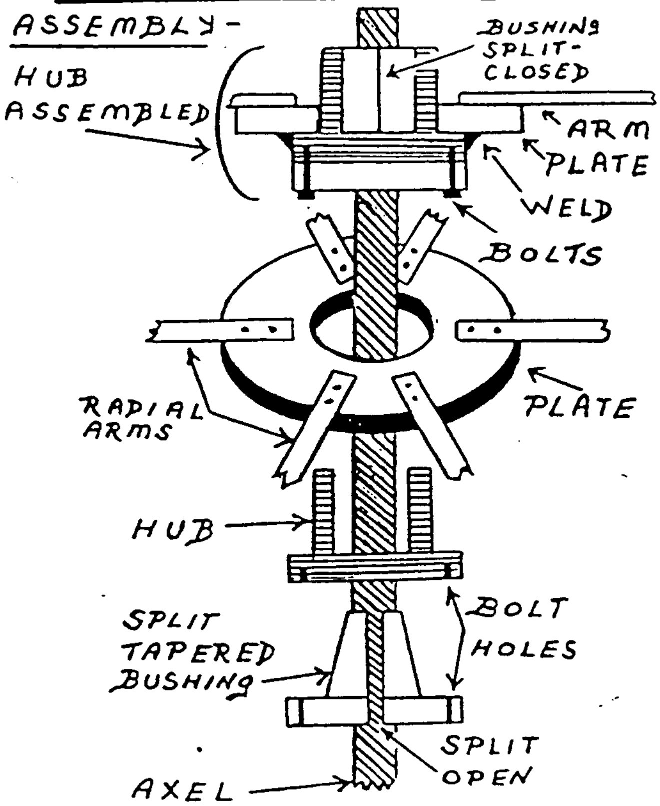
PLATE No 17

– THE WOODEN MULTIBLADE XV
– THE METAL HUB

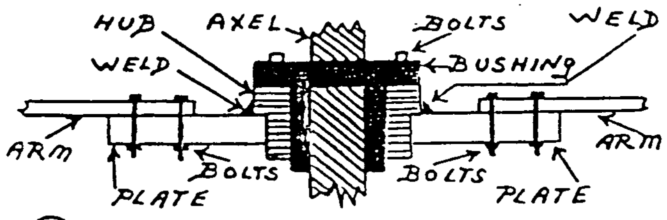
(1) METAL HUB - PARTS DETAIL



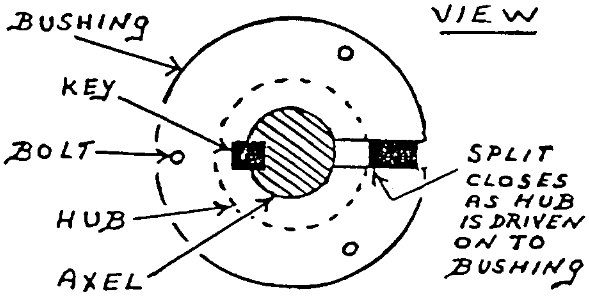
(4) METAL HUB - ON WIND MACHINE ASSEMBLY -



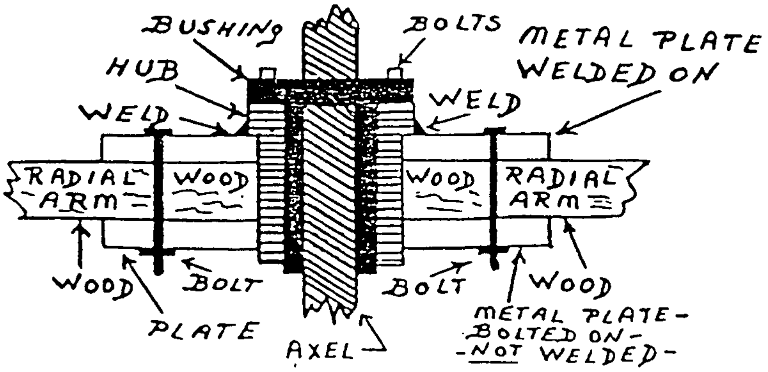
(2) METAL HUB - METAL ARMS



(5) BASE OF BUSHING - BOTTOM VIEW



(3) METAL HUB - WOODEN ARMS



ALTERNATE HUB (6)

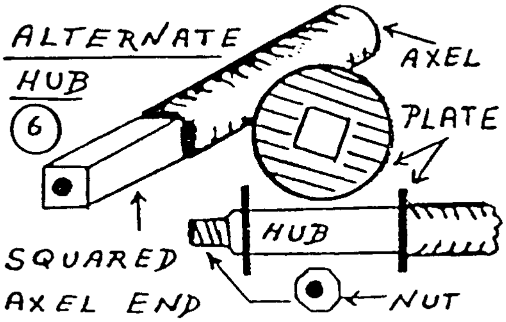


PLATE NO. 18

A swivel is necessary on an eccentric (pump), rod because the rotating table and eccentric will constantly turn to keep the sails facing into the wind.

The swivel should be placed on the rod about three or four feet above the pump. There should be two guides about 12" to 18" apart between the pump and the swivel, so the rod keeps a straight vertical angle going into the pump, and so the pump will not wear in the wrong places. The guides are simply two inch boards stretched across with holes in them the same size as the sucker rod, (see fig. 1, and also see plate no. 1, “M” and “R”).

A “railroad union” is an ordinary pipe fitting used to join two pipes together. A steam pipe fitting is best because it can be welded.

PLATE No. 18

— THE WOODEN MULTIBLADE - XVI
— THE ECCENTRIC (SUCKER) ROD SWIVEL —

(A) - FROM RAILROAD UNION -
(B) - FROM BOLTS AND BRACKETS -
(C) - FROM ROLLER BEARING AND HINGE -
(D) - FROM UNIVERSAL JOINT -

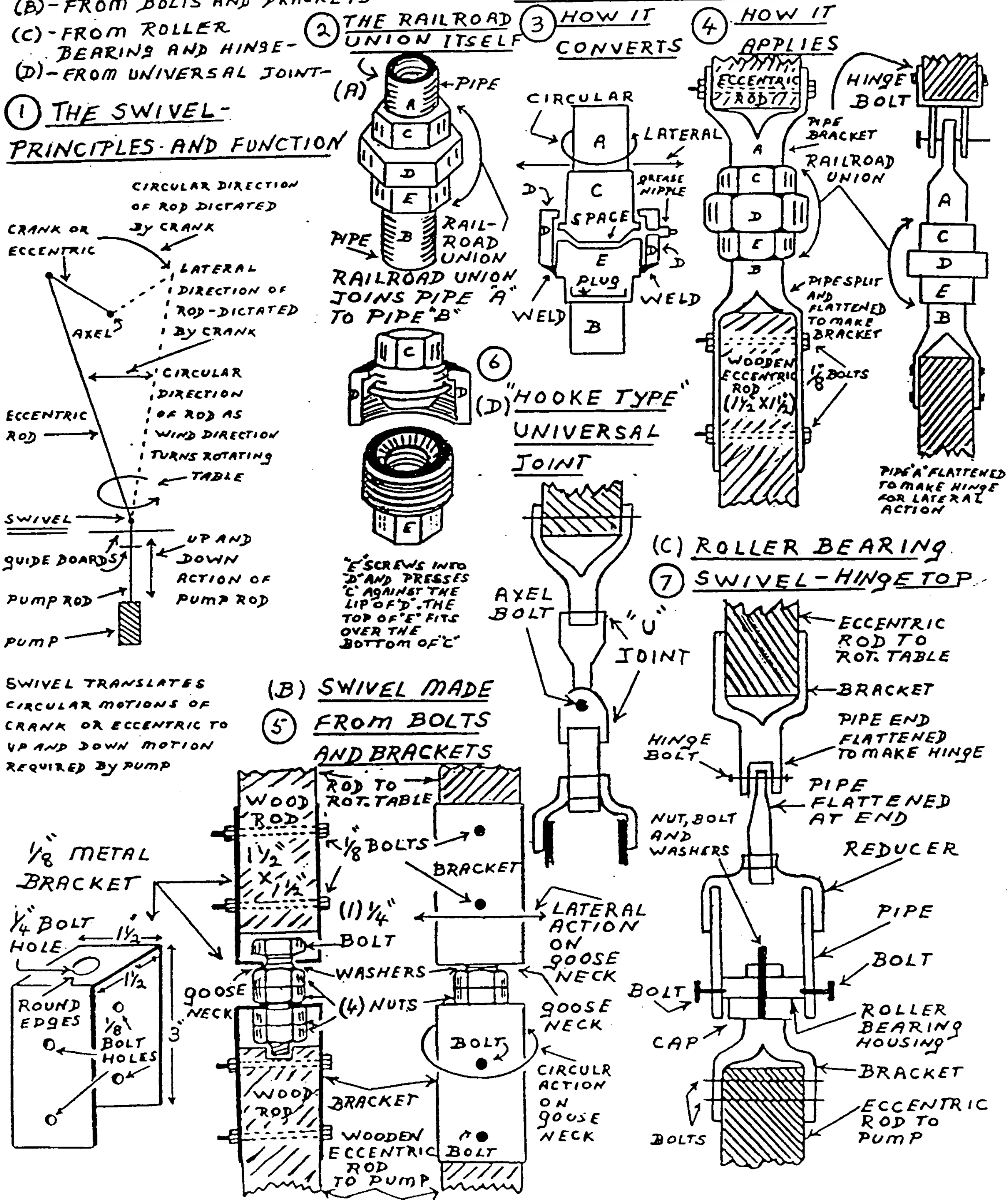


PLATE NO. 19

The eccentric does the same job as a crank shaft or a cam, in that it causes the eccentric pump rod to move up and down so that it can work the pump, (see plate no. 1).

In other words, it translates the circular action of the axle to the up and down action of the rod and hence, the pump.

An eccentric is easier to make than a crank shaft and it is usually stronger because it does not require the axle to be broken in two pieces, (see plate no. 25, fig. 4).

PLATE No. 19

- WOODEN MULTIBLADE - XVII
- THE ECCENTRIC I - PRINCIPLES
- DISC PLATE -

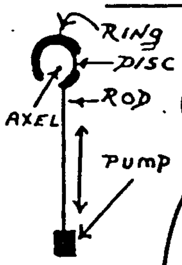
(1) PRINCIPLES - FUNCTION

THE ECCENTRIC FUNCTIONS AS A CRANK SHAFT BUT IS EASIER TO CONSTRUCT AS IT IS MADE OF WOOD AND IS SET ON A GAS PIPE AXEL.

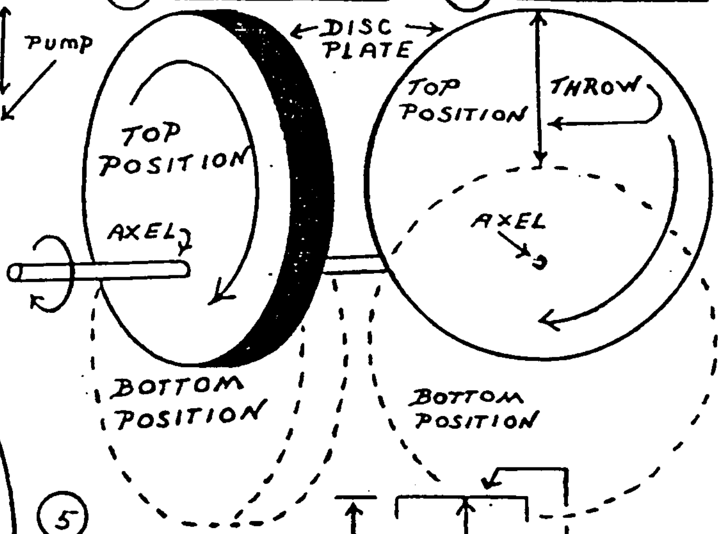
A WOODEN DISC IS SET ON AN ECCENTRIC (OFF SET) AXEL.

A RING SURROUNDING THE DISC IS DIRECTLY CONNECTED TO TO THE PUMP ECCENTRIC ROD.

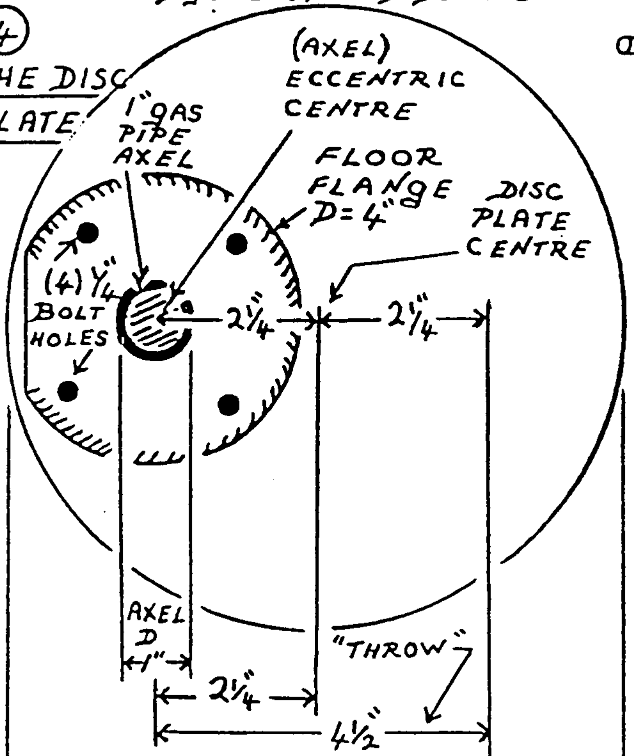
AS THE AXEL REVOLVES, THE PUMP ROD GOES UP AND DOWN.



(2) FRONT VIEW (3) SIDE VIEW



(4) THE DISC PLATE



- CENTRE OF AXEL TO CENTRE OF DISC = 2¼"
- 2¼" X 2 = 4½ = "THROW" OF ECCENTRIC
- THROW OF ECCENTRIC = (UP AND DOWN) STROKE OF THE PUMP = 4½"

RADIUS OF DISC = 4¼"

DIAMETER OF DISC = 8½"

NOTE - DISC PLATE DIAMETER DOES NOT RELATE TO PUMP STROKE.
- PUMP STROKE IS ALWAYS EQUAL TO TWICE THE DISTANCE BETWEEN THE AXEL CENTRE AND THE DISC PLATE CENTRE

(5)

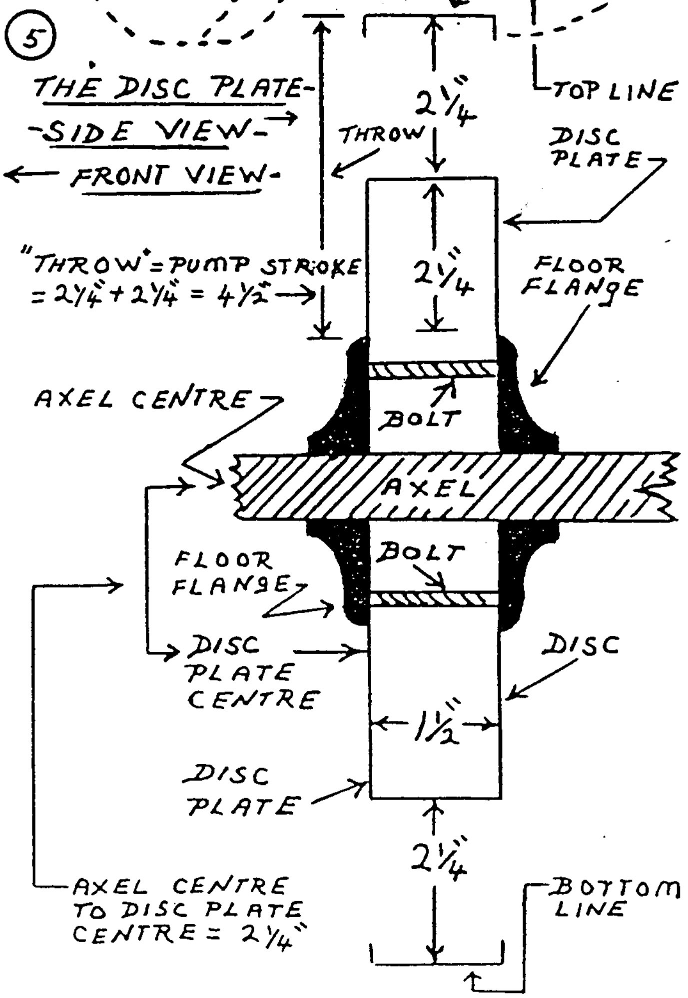


PLATE NO. 20

The outer ring takes all of the knocking and stress, so it should be made of two or three thicknesses of hard wood laminated together so it will not split off. Be sure all of the grains are going in different directions. Note the oil hole for lubrication.

It can be made from teflon which provides an excellent bearing surface.

The upper portion can also be made from several layers of greased leather strapping nailed to the outer sides of the lower portion.

Note how the side covers hold the outer ring over the eccentric so it can move freely, (see fig. 3, 4 and 5).

Note also, the use of the floor flange application to hold the eccentric on the axle, (see fig. 2, 3, 4 and 5).

PLATE No. 20

- THE WOODEN MULTIBLADE - XVIII
- THE ECCENTRIC - II
- THE OUTER RING -

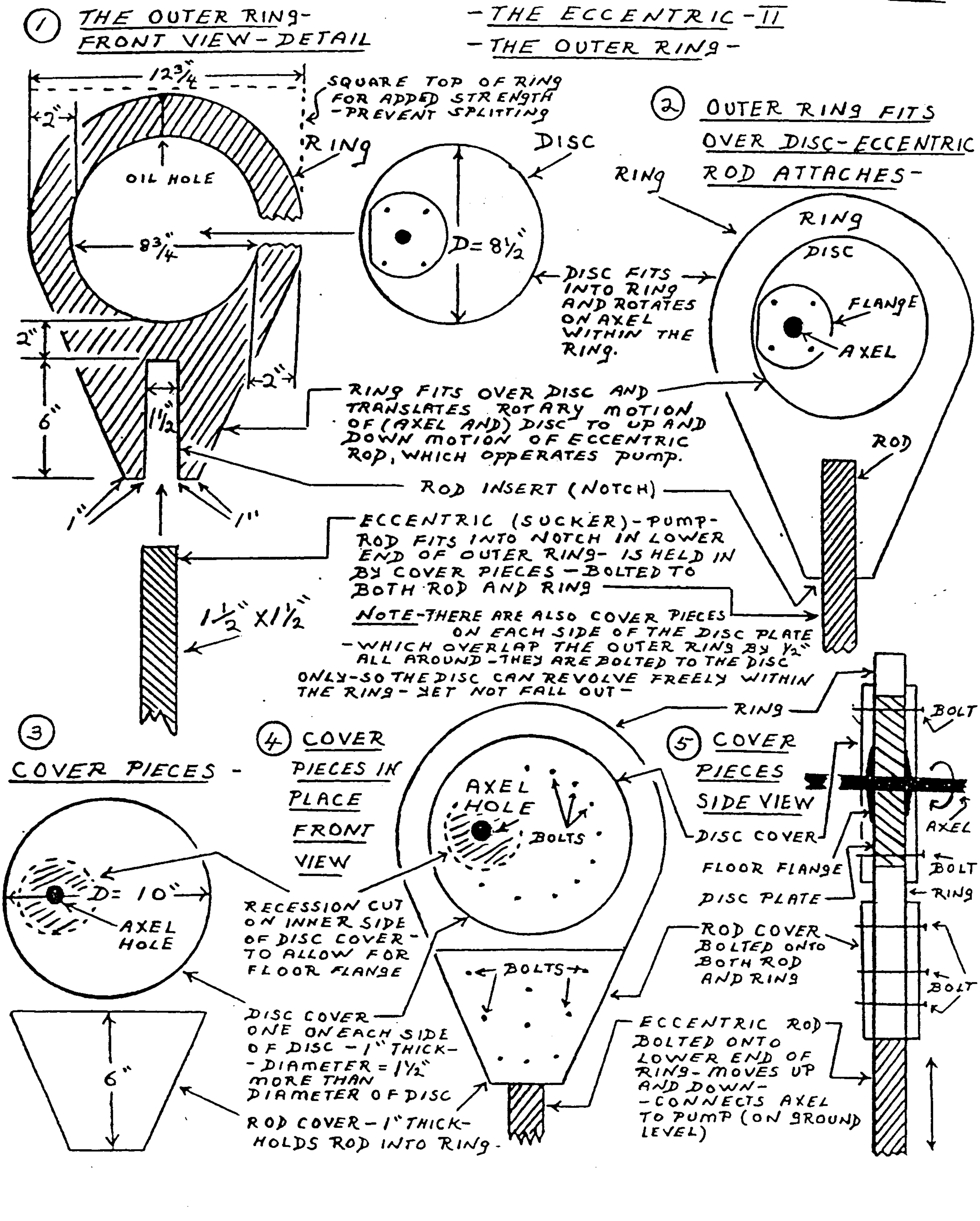


PLATE NO. 21

Note how the eccentric must have space for both vertical and horizontal movement within the centre hole of the core. If there is not enough space, the axle and axle bearings will have to be raised up.

PLATE No. 21

— THE WOODEN MULTIBLADE — XIX
— THE ECCENTRIC — III
— APPLICATION

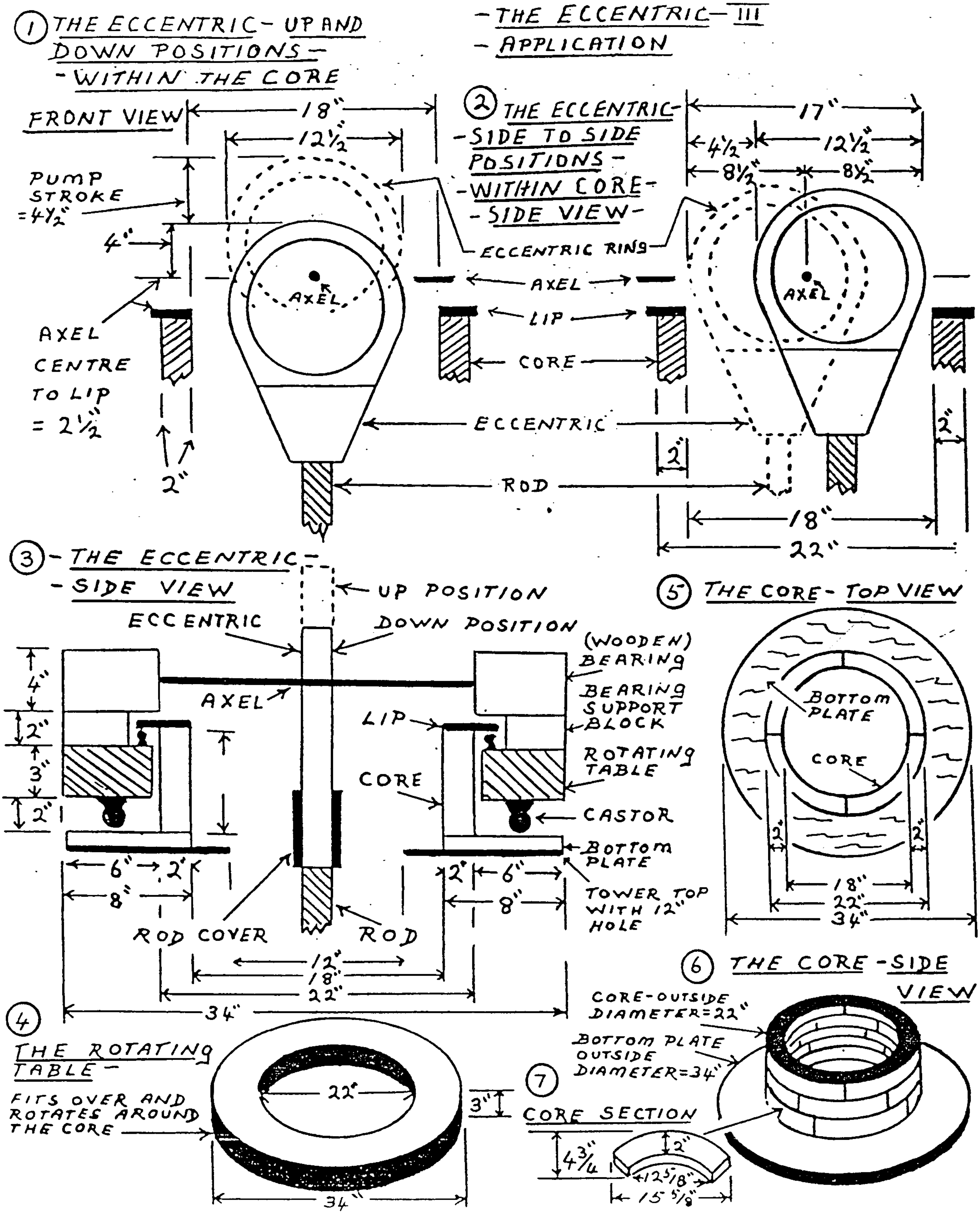


PLATE NO. 22

Gear down, (four to one, or even five to one), should be accomplished with only two "V" belt pulleys, the small one, (say 2" diameter), on the wind shaft axle above, and the large one, (say 8" or 10" diameter), below on the eccentric axle. Be sure there is at least one inch clearance between top dead centre of the eccentric and the bottom side of the wind shaft axle.

Both of these axles can be either of gas pipe or of solid steel.

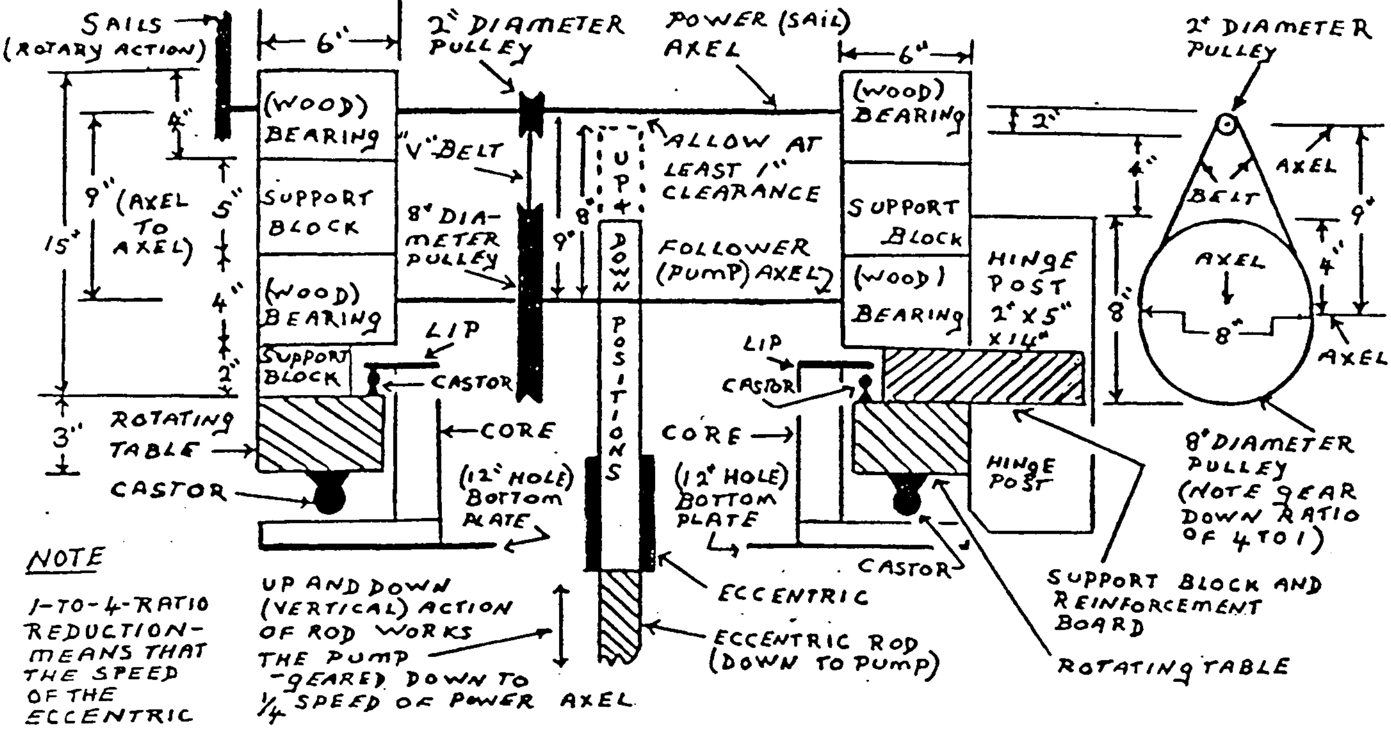
The bearings can be wood or metal.

The gear down should be for the 18" blade wooden multiblade, (plate no. 11, et. al.). It should also be for the 15" blade metal multiblade, (plate 33, et. al.), and the 13 foot diameter metal multiblade, (plate no. 35, et. al.), if they are mounted on the wooden rotating table.

PLATE No. 22

— THE WOODEN MULTIBLADE - XX
— THE ECCENTRIC - IV
- GEAR DOWN - FOR PUMP - I

① GEAR DOWN - UPPER-LOWER-AXEL LEVELS-SIDE VIEW - ONE TO FOUR RATIO -



NOTE

1-TO-4-RATIO REDUCTION-MEANS THAT THE SPEED OF THE ECCENTRIC ROD AND PUMP IS REDUCED TO 1/4 THE SPEED OF THE SAILS-AND AXEL-

② GEAR DOWN - LOWER (AXEL) LEVEL - TOP VIEW - ONE TO FOUR RATIO -

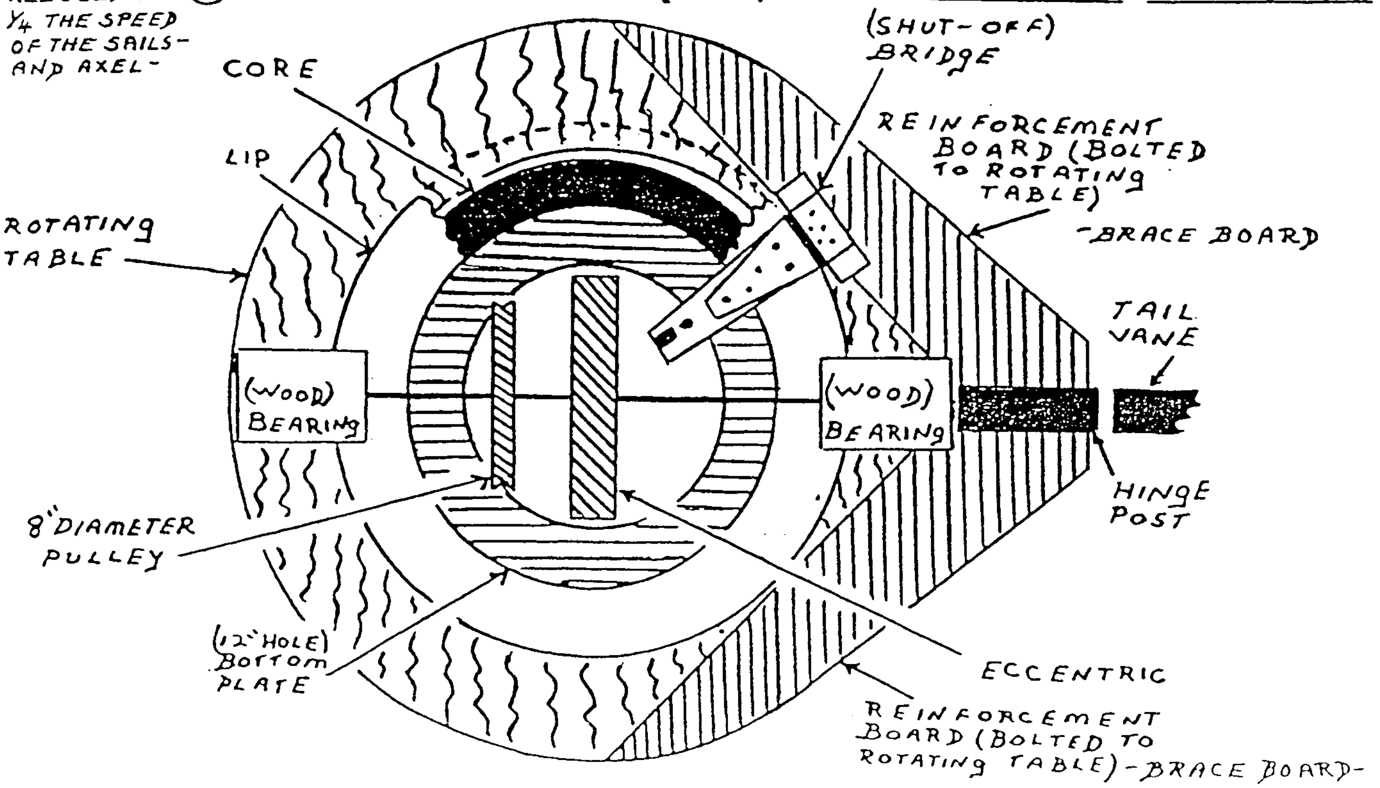


PLATE NO. 23

Note that the wind shaft axle must be on top so it won't interfere with the eccentric even though it does cause extra wind leverage against the raised wall on the rotating table.

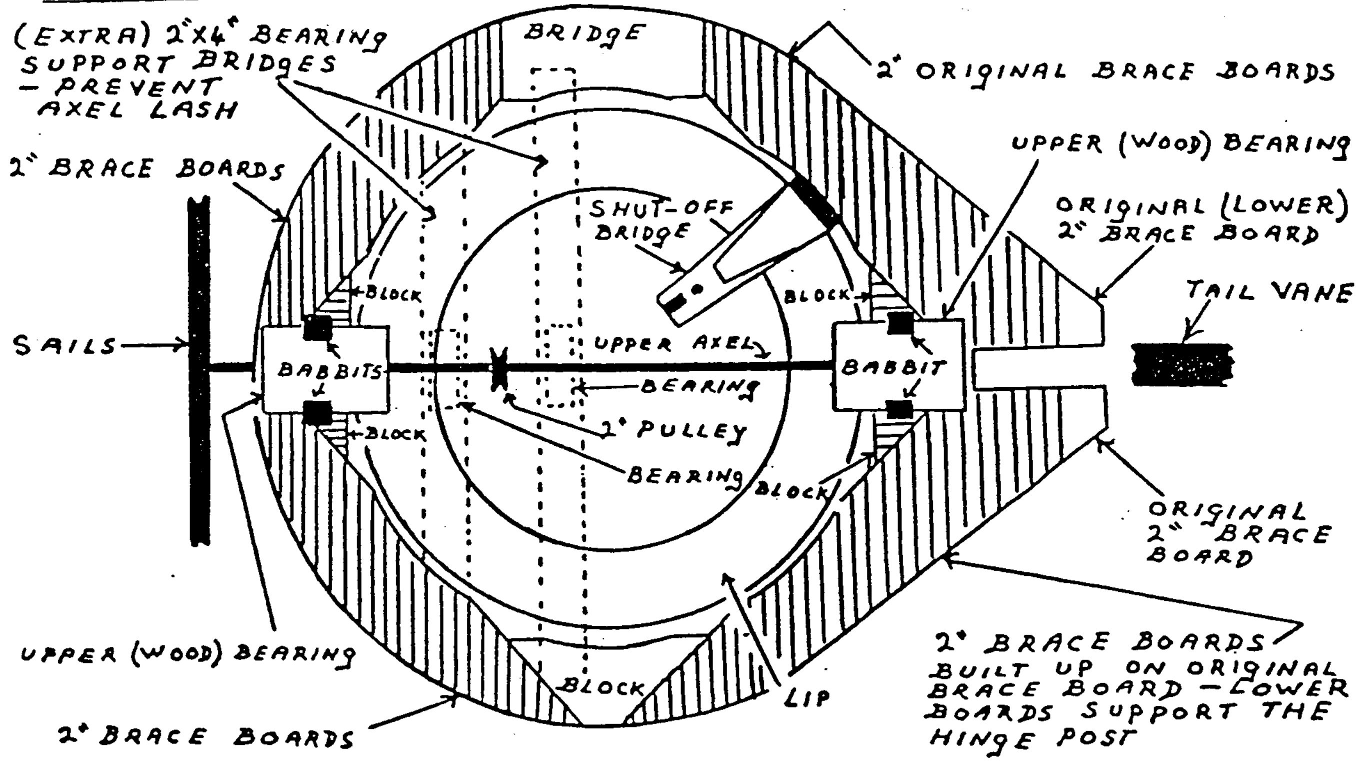
Walls should be built up with overlapping quarter pieces, so the front, the back, and both sides look like the side shown in fig. 2.

Entry should only be gained by means of the removable, water tight, cover lid.

PLATE No. 23

- THE WOODEN MULTIBLADE XXI
- THE ECCENTRIC V
- GEAR DOWN II - SUPPORT-
- RAISED POWER AXEL

(1) RAISED POWER AXEL-
BRACE BOARDS-



(2) BRACE BOARD - GEAR DOWN SUPPORT
- SIDE VIEW

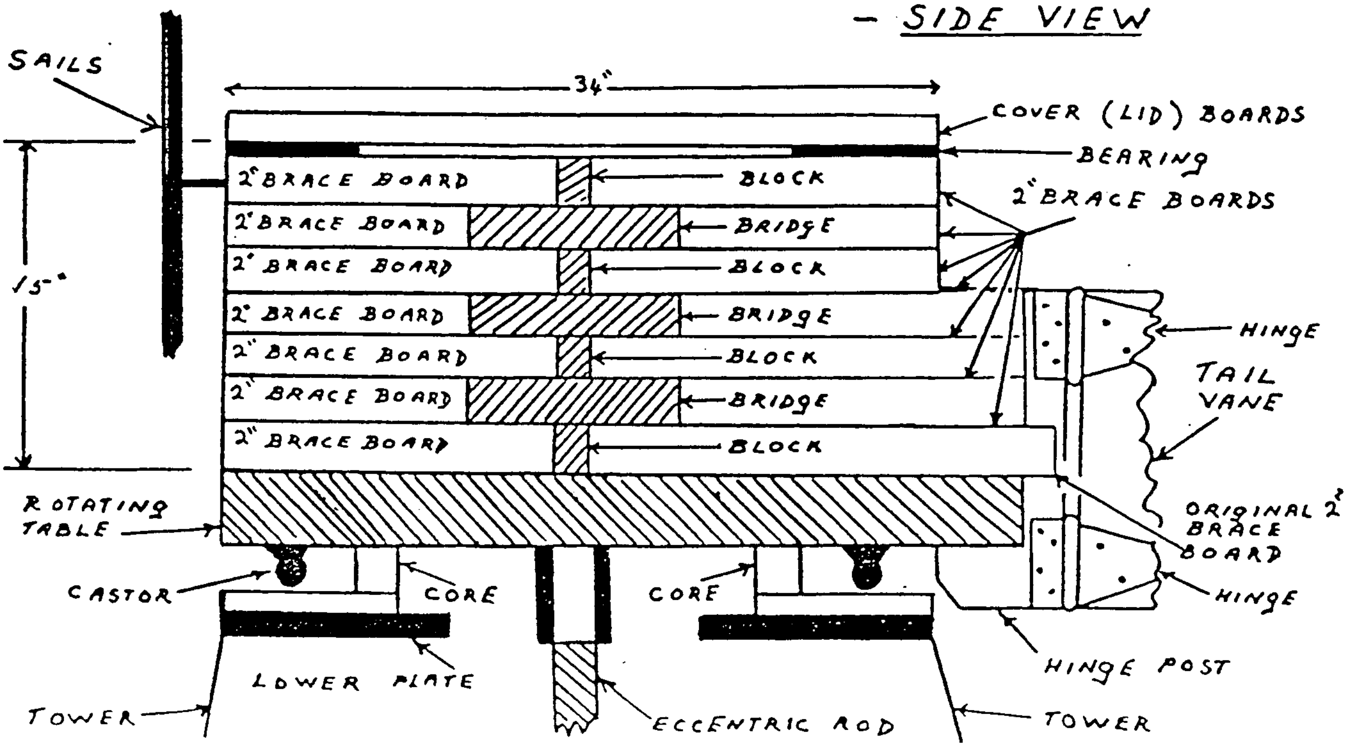


PLATE NO. 24

Sprockets and gears are made from bicycle sprockets between pieces of hardwood, and floor flanges, constructed in the same way as the wooden hub illustrated in plate no. 6.

Note the wooden "V" belt pulley, (fig. 5), is made in the same way as the sprocket but without the bicycle sprocket itself, the insides of the hardwood circles are bevelled to form the "V".

PLATE No. 24

—THE WOODEN MULTIBLADE—XXII
—ECCENTRIC VI
—GEAR DOWN—III
—SPROCKET—FROM BICYCLE SPROCKET—

—BICYCLE PEDAL GEAR COMBINES WITH FLOOR FLANGES AND WOODEN DISCS TO MAKE SPROCKET-GEAR—
—SEE "V" BELT PULLEY—FIG. 5—

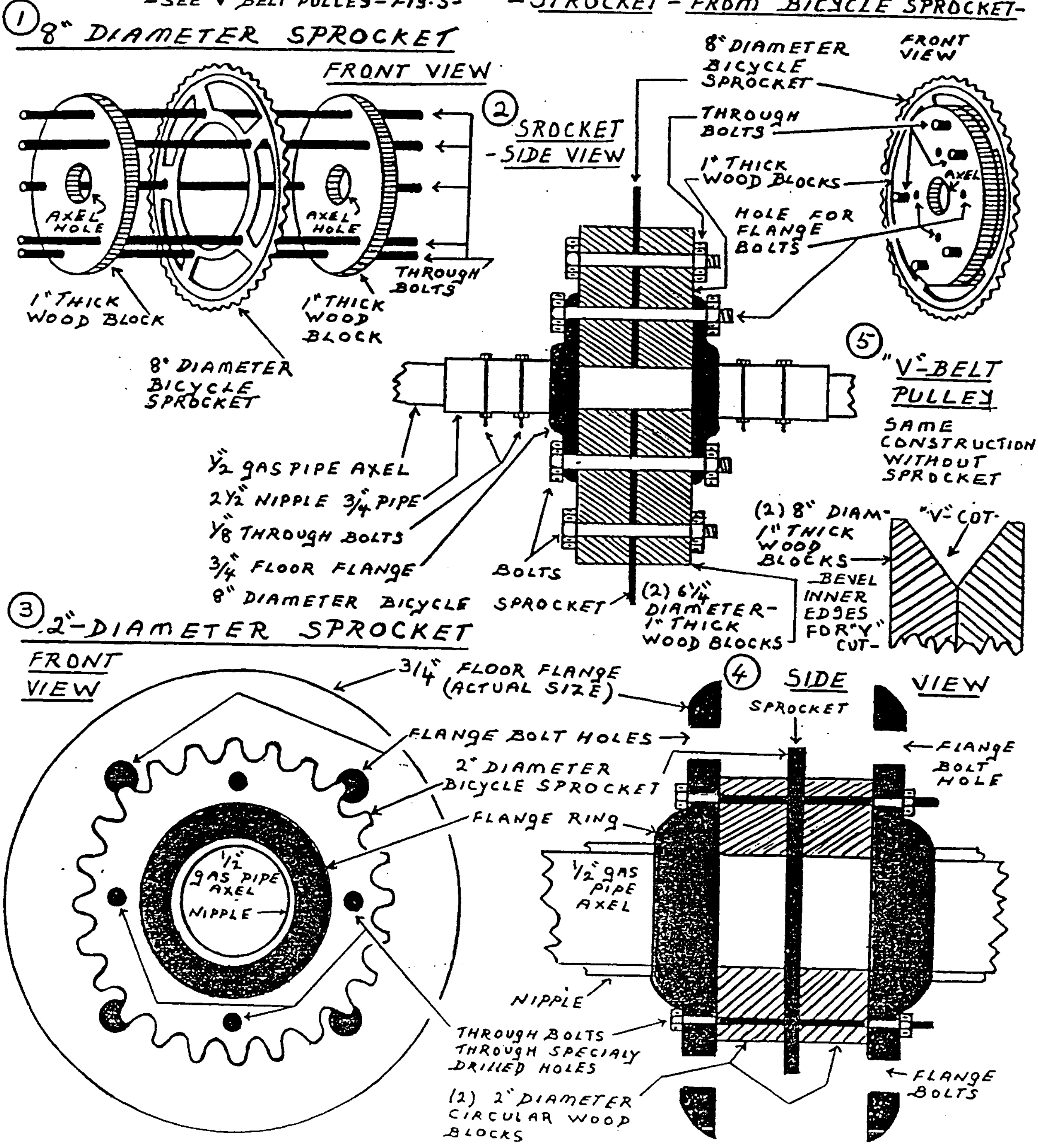


PLATE NO. 25

The bicycle frame crank shaft can replace the eccentric illustrated in plate no. 14, et. al.

It is better, however, with a solid steel axle which can be welded to the pedal arms, (fig. 4). The axle, therefore, must be in two pieces so each piece can weld to a pedal arm.

It should run on four ball bearing pillow blocks, (b, b, b, and b), to give it proper stability.

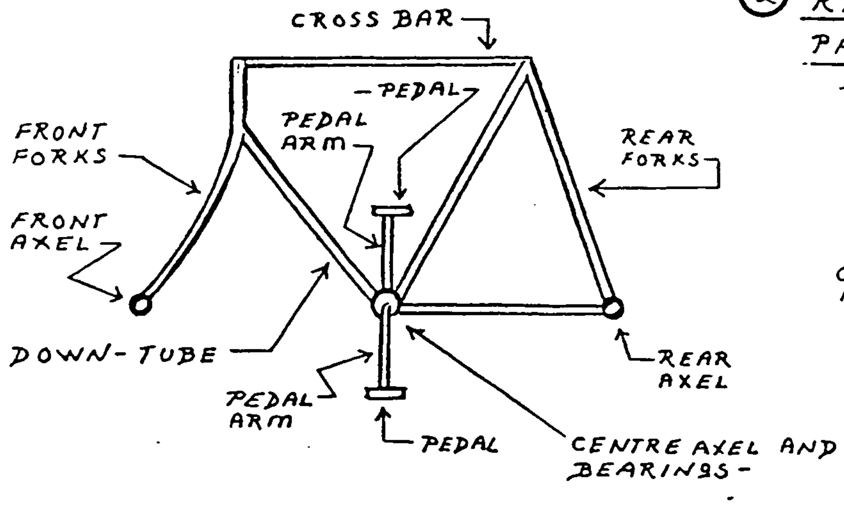
The bearings in the centre axle act as the crank bearings when the eccentric rod is bolted into the split end of the down tube. The centre axle bearings can be lubricated with light oil as often as they would be on a bicycle.

PLATE No. 25

- THE WOODEN MULTIBLADE - XXIII
- CRANK SHAFT - ALTERNATIVE
- FROM BICYCLE PEDALS -
- REPLACES ECCENTRIC -

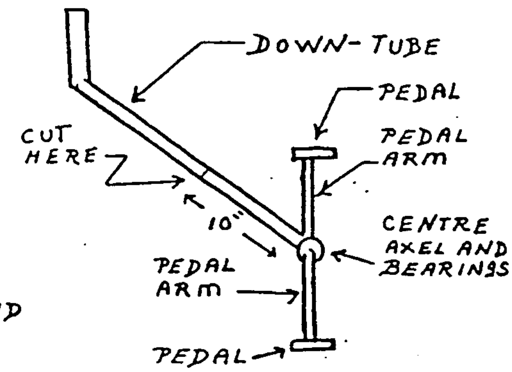
- STEPS REQUIRED TO MAKE CRANK SHAFT FROM BICYCLE FRAME AND PEDAL ARMS -

(1) BICYCLE FRAME



(2) REMOVE UNNECESSARY PARTS OF BICYCLE FRAME -

- SHOWING PARTS RETAINED -

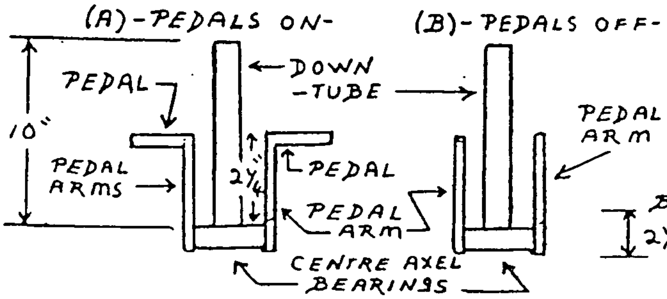


(3) UNNECESSARY PARTS REMOVED -

- CUT DOWN-TUBE TO A LENGTH OF 10" - THIS WILL BE ATTACHED TO THE ECCENTRIC ROD -

- REVERSE ONE PEDAL ARM SO THAT BOTH ARMS GO IN THE SAME DIRECTION -

- PEDAL ARMS WILL BE ATTACHED TO AXEL - AT POINTS WHERE PEDALS HAVE BEEN REMOVED -



(4) CRANK SHAFT - ASSEMBLED AND IN PLACE -

- PEDAL ARMS ARE CUT TO A LENGTH OF 3¼" - AND WELDED TO 1" STEEL AXEL - TO ALLOW A DISTANCE OF 2¼" FROM THE TOP OF THE AXEL TO THE TOP OF THE BICYCLE CENTRE AXEL -

- 2 × 2¼" = A STROKE OR "THROW" OF 4½" - FOR A 4½" - PUMP STROKE -

- THERE SHOULD BE TWO BEARINGS ON EACH SIDE OF THE CRANK SHAFT - TO REDUCE BREAKING FORCE ON AXEL AT CRANK SHAFT JOINTS -

- IF PEDAL ARMS CAN BE BOLTED TO AXEL - RATHER THAN WELDED - THEY WILL BE EASIER TO REMOVE FOR REPAIR -

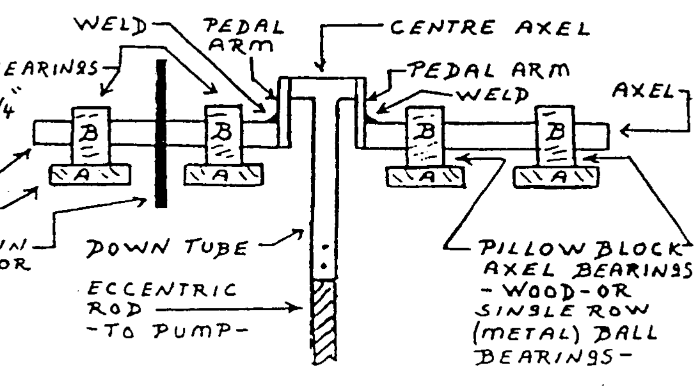


PLATE NO. 26

The upper right angle drive, (see plate no. 28, fig. 1), is the kind commonly sold by bearing shops, farm part catalogues and by some automotive catalogues. It bolts onto a 2" X 8" plank blocked up above the rotating table in such a way that it does not interfere with the pull rope bridge.

This is, perhaps, the most efficient system of transmitting power.

Note the number of power take-offs, including the generator with one large wheel to one small wheel gear up. When space is in abundance, fewer, but larger pulleys can be used which will cut down slippage and mechanical loss.

Note the take-offs for mechanical work at the bottom of the drawing.

Any kind of sail can be used, multiblade or rotor. It would however, be ideal for a four blade rotor high speed, (irrigation), pump assembly.

PLATE No. 26

- THE WOODEN MULTIBLADE - XXIV
- RIGHT ANGLE DRIVE ALTERNATIVE - I
- ON WOODEN ROTATING TABLE -

NOTE
- RIGHT ANGLE DRIVE REPLACES ECCENTRIC AND GEAR DOWN (OR GEAR UP) ON ROTATING TABLE -

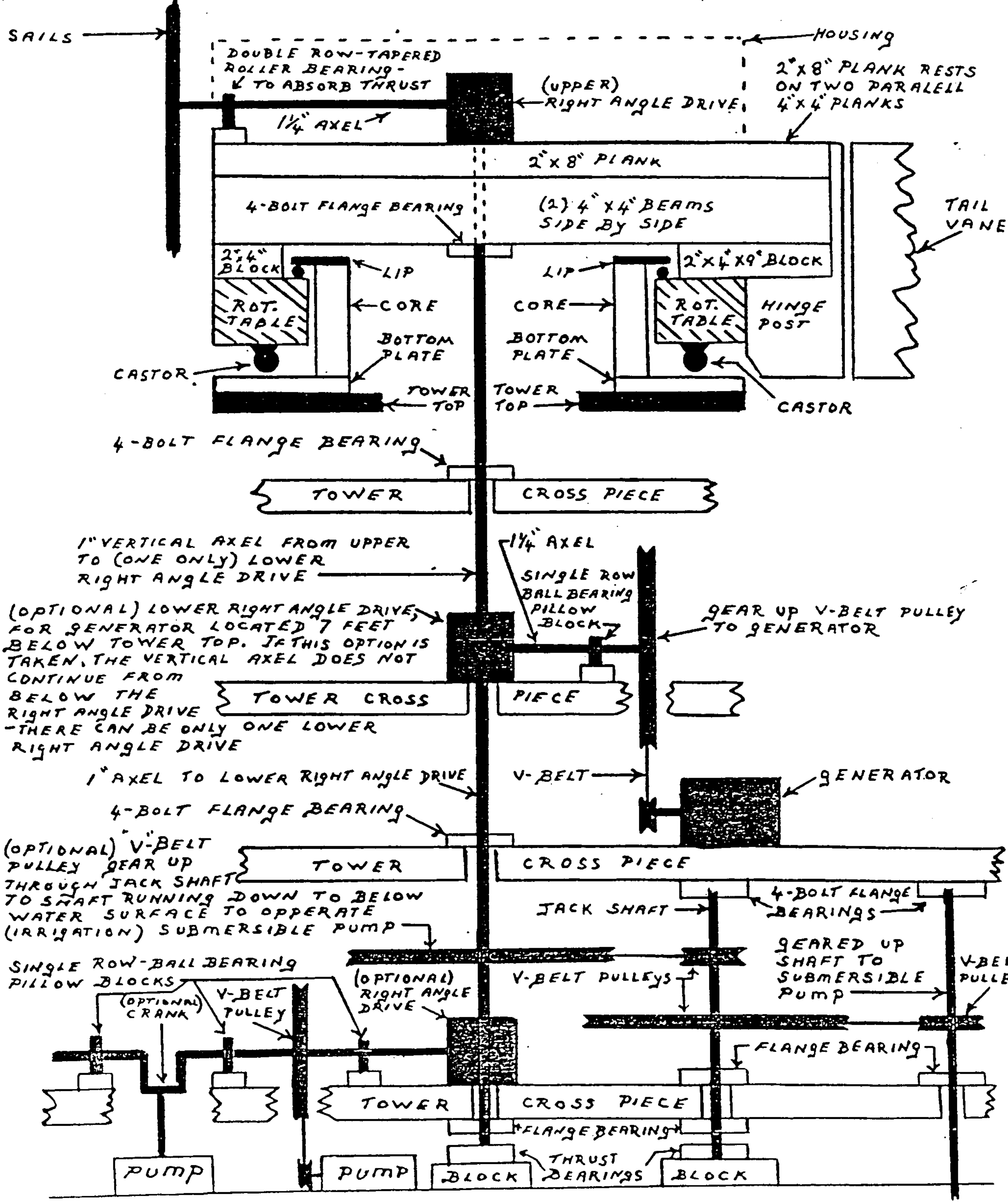


PLATE NO. 27

Flange bearings should be placed up the shaft every 6 to 10 feet or so to stop the shaft from over vibrating or "whipping".

The thrust bearing goes at the bottom of the shaft to reduce friction caused by the weight of the shaft.

PLATE No. 27

- THE WOODEN MULTIBLADE - XXV
- RIGHT ANGLE DRIVE ALTERNATIVE - II
- FLANGE BEARINGS - THRUST BEARINGS -

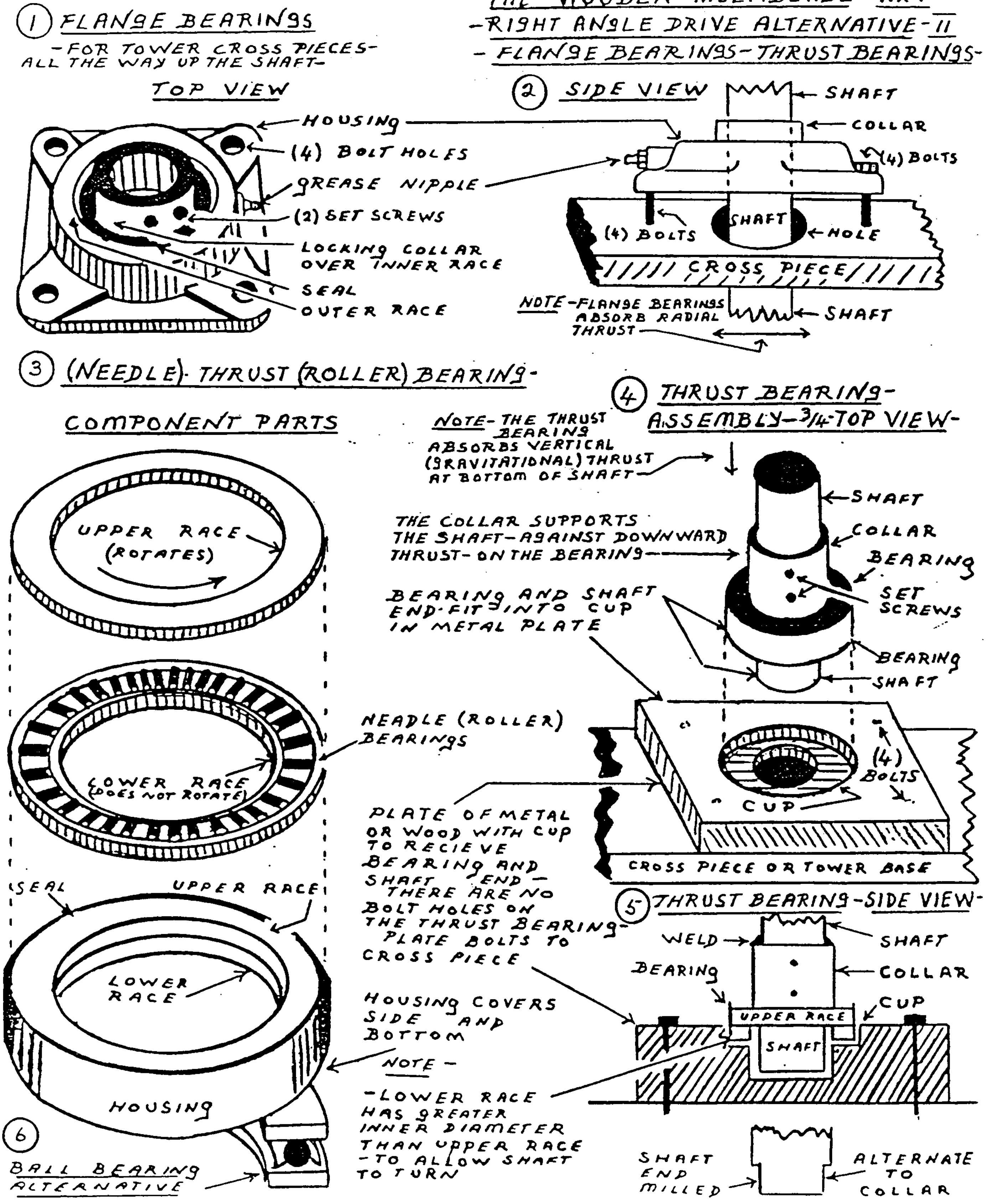


PLATE NO. 28

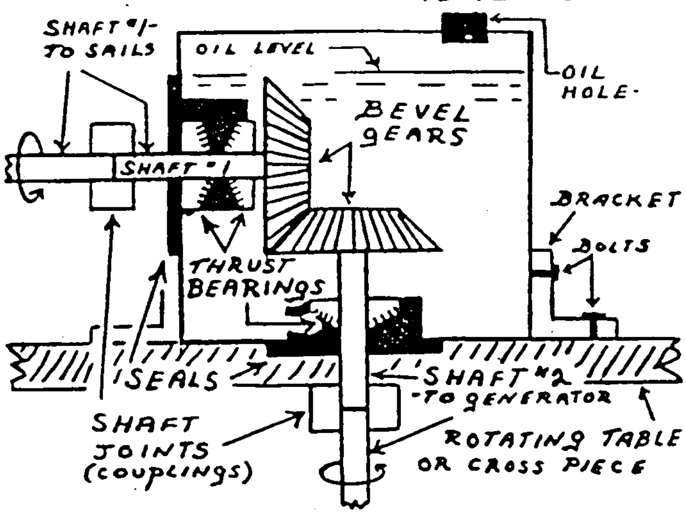
The chain coupling is the best way to join two pieces of shaft, either vertical or horizontal. There must, however, be a key-way cut in each piece. The two sprocket pieces then fit over bushings as the metal hub pieces do, (see plate no. 17), and the chain holds them together.

Note the crank shaft alternatives in fig. 5 and 6.

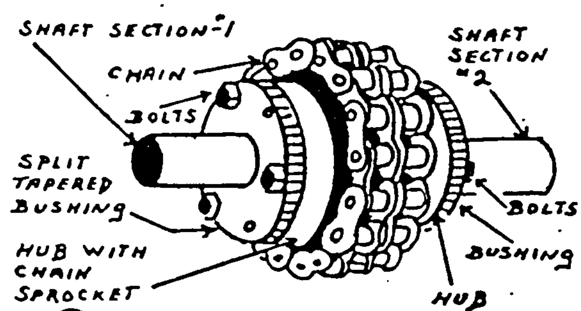
PLATE No. 28

— THE WOODEN MULTIBLADE — XXVI
— RIGHT ANGLE DRIVE ALTERNATIVE — III
- — CRANK SHAFT DESIGNS —
- — RIGHT ANGLE DRIVES —
- — SHAFT JOINTS (COUPLINGS)

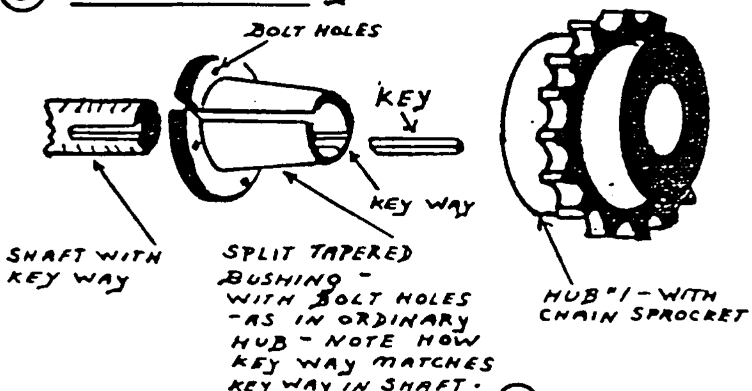
(1) RIGHT ANGLE DRIVE
— REDIRECTS MOTION — HORIZONTAL TO VERTICAL —



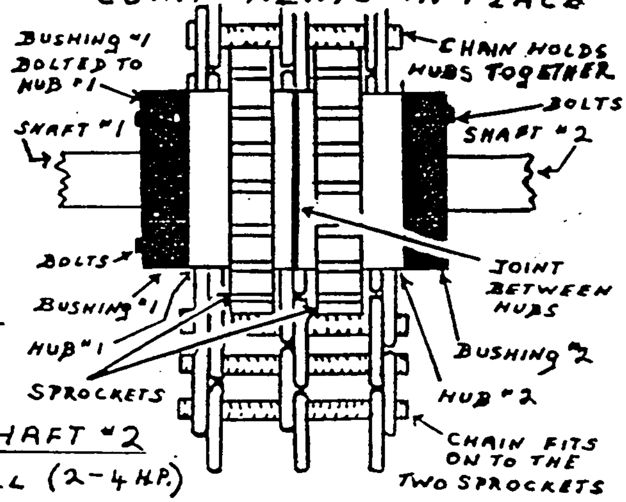
(2) CHAIN COUPLING — JOINS SHAFT SECTIONS



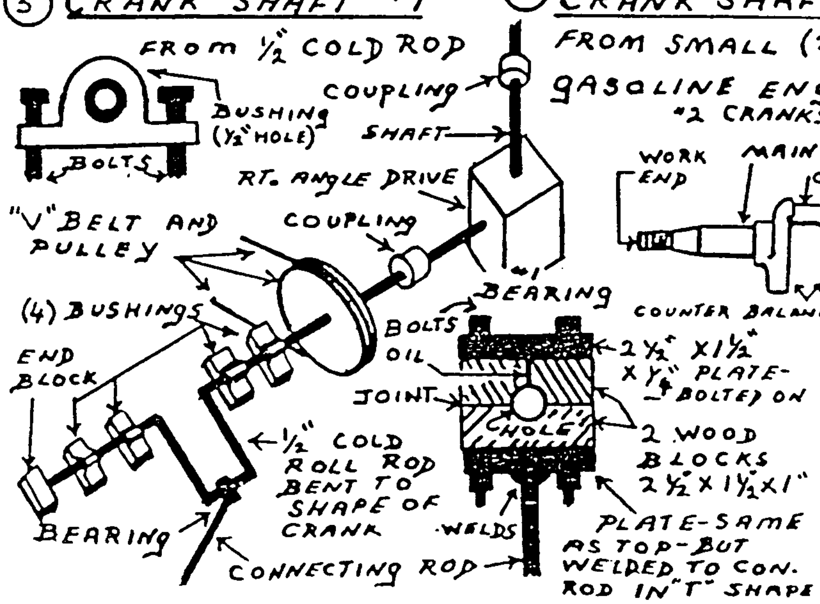
(3) CHAIN COUPLING — COMPONENTS



(4) CHAIN COUPLING COMPONENTS IN PLACE



(5) CRANK SHAFT #1
FROM 1/2" COLD ROD



(6) CRANK SHAFT #2
FROM SMALL (2-4 HP.) GASOLINE ENGINE CRANKSHAFT

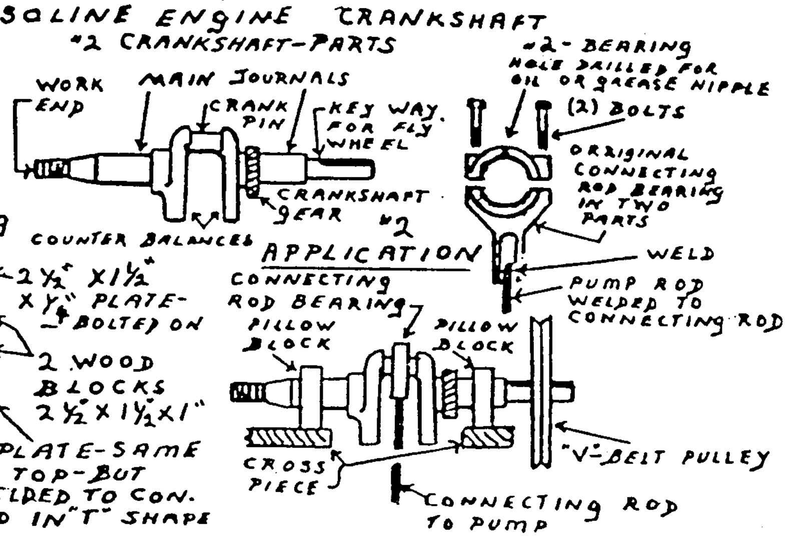


PLATE NO. 29

The auto rear end should make a right angle drive comparable to the one illustrated in plate no. 26 and plate no. 28, fig. 1.

A passenger automobile rear end will work just as well and be lighter than the more expensive truck rear end.

Figures 1 and 2 show the auto rear end in its original form with the gear housing in the centre and the axle housings projecting horizontally from it on each side.

The drive shaft, from the car engine, is connected to the gear housing by the universal joint which permits the drive shaft to move up and down and from side to side as dictated by road conditions under the car's wheels. This ability to move is not a consideration in wind machine construction.

The flanges on the ends of the axles seen protruding from the extreme ends of the axle housings are where the car wheels are bolted on.

The brake drum assemblies on the axle flanges serve no useful purpose on a wind machine, so they should be removed.

It is vital to remember the location of the oil seals at the extreme ends of the axle housings and at the entry point of the drive shaft to the central gear housing. If oil is not retained, the gears will burn out and this conversion idea will not work. The drive shaft oil seal is easy to remove and replace in case of damage or wear.

The plan is to select the axle you want for the wind machine hub and to lock the other axle off so it can't turn. Remember how the car makers say that their differentials, (rear ends), transfer the power "from the wheel that slips to the wheel that grips". So, the power would go to the wrong "grip" axle from the wanted "slip" axle, and the sails would not be able to turn the drive shaft.

The first thing to do then, is to remove the unwanted axle by simply pulling it out. Then cut off the housing at the point indicated by the dotted line illustrated in fig. 3.

Now put the axle back in, and cut it off so that it projects about an inch or so from the point where the housing has been cut off. Then weld a circular piece of 1/4" steel plate over the housing opening where the section has been cut off. The cut-off axle will project through a hole in the centre of the circular piece of steel. Weld the projecting axle to the circular piece as shown in fig. 5.

There should still be enough cut-off axle projecting to grip the support bracket, (fig. 6).

Cut an "oil hole" in what is now going to be the top of the gear housing. Be sure that no metal shavings fall inside. Fit the hole with a screw in plug. Always keep the gear housing filled with high quality oil.

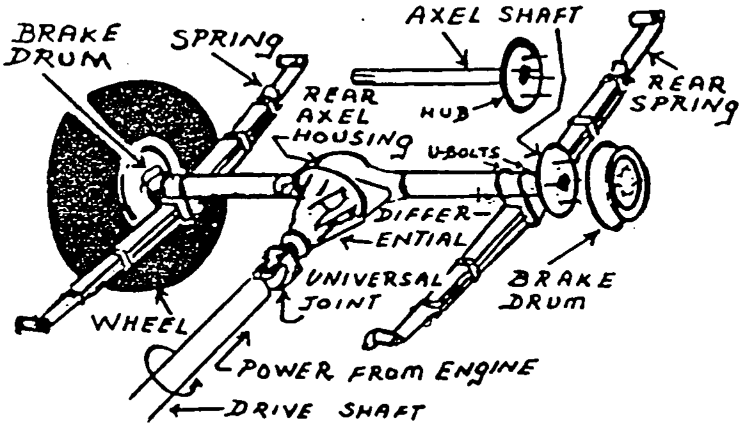
Note the "V" bolts and blocks holding the read end to the wooden support block, (fig. 4).

Note the bracket connection for the cut-off housing, (fig.6).

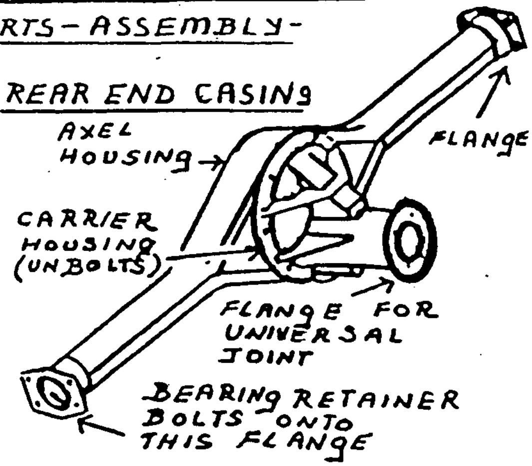
PLATE No. 29.

- THE WOODEN MULTIBLADE - XXVII
- RIGHT ANGLE DRIVE ALTERNATIVE - IV
- FROM AUTOMOBILE REAR END - I
- PARTS - ASSEMBLY -

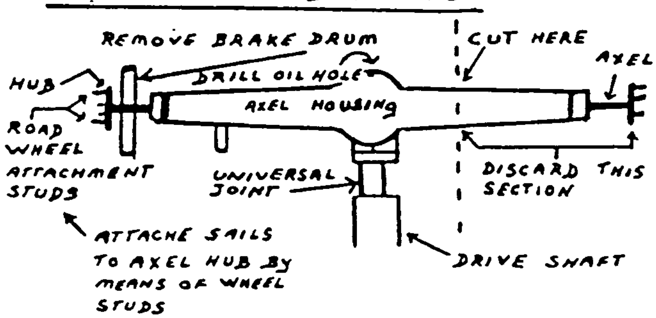
(1) AUTOMOBILE REAR END - IN ITS ORIGINAL STATE -



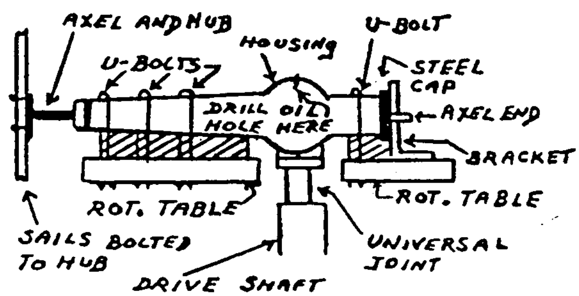
(2) REAR END CASING



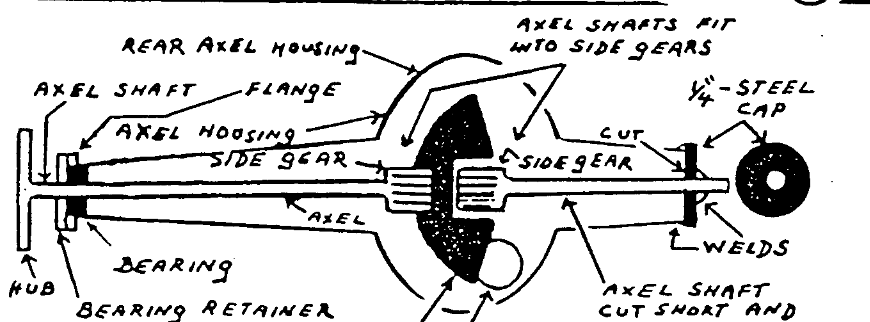
(3) METHOD OF ADAPTATION



(4) ADAPTATION - INSTALLATION



(5) ADAPTATION - PARTS EXPLAINED -



- RING GEAR TURNS THE TWO SIDE GEARS - ONE FITTED ONTO EACH OF THE TWO AXEL SHAFTS. RING GEAR THEREFORE TURNS THE AXELS.

- PINION GEAR IS EXTENSION OF THE DRIVE SHAFT.

- PINION GEAR TURNS THE RING GEAR WHICH TURNS THE AXELS.

(6) METHOD OF ADAPTING BRACKET -

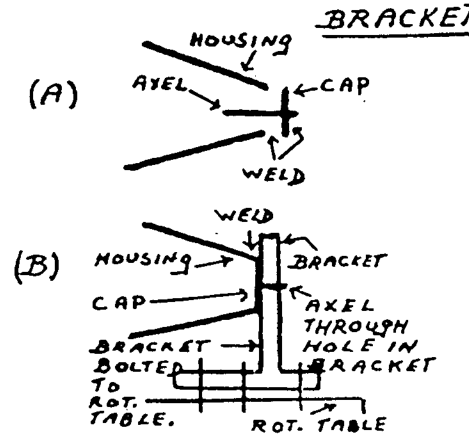


PLATE NO. 30

The upper auto rear end (a), is bolted onto the same kind of 2" X 8" plank, which is bolted to blocks to the rotating table, just as is the manufactured right angle drive illustrated in plate no. 26. The only difference is that "U" bolts, rather than straight bolts, hold the rear end down and wooden blocks are placed under it to keep it even. Just be sure that the "U" bolts are strong enough and there are enough of them.

The lower auto rear end (B), is fastened in exactly the same way, but to a vertical board between the tower cross pieces.

Note the oil hole at the top of the axle housing.

It will be evident that automobile tires rotate at a lower R.P.M. than does the engine driven drive shaft. In most modern cars, this amounts to a reduction, or gear down rate of three to one. The wheels turn three times each time the drive shaft turns once. Conversely, if the power is coming from the$wheel hub, motivated by the windmill sail, and is being transmitted (backwards), through the gear housing to the drive shaft, the gear up ration (increase), will be one to three. The drive shaft will turn three times every time the sail hub turns once.

If the lower rear end (B), is connected to the upper rear end (A), by means of it's wheel hub, then it too will have a gear up ration of 3 X 3 = nine to one.

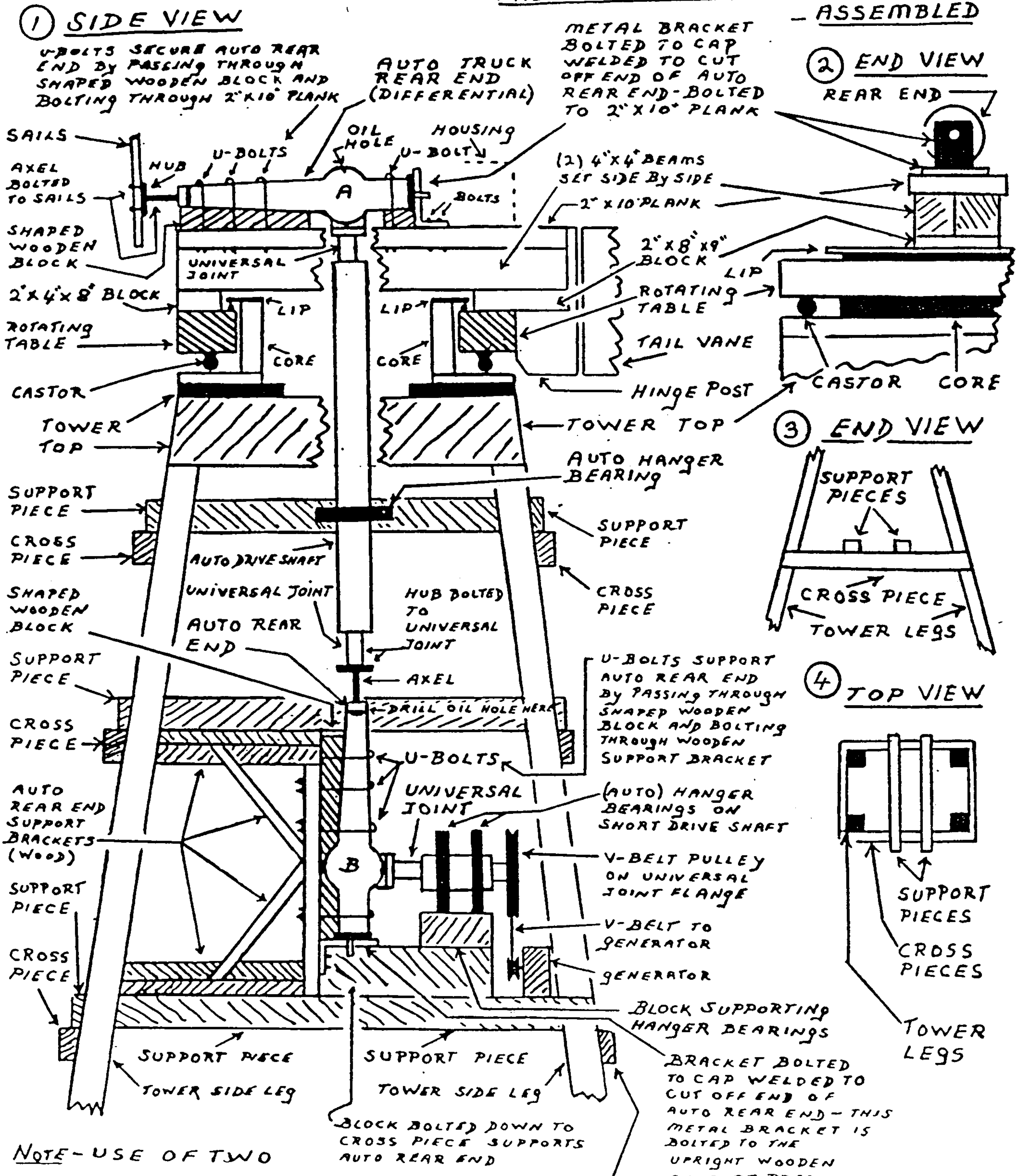
Remember, gear ups require more turning power from their sails. The principle of the gear up is that end product speed is increased at the expense of motor input power.

If the lower (B), rear end is connected to the upper (A), rear end by means of its drive shaft, it will reduce by three to one.

As one rear end gear up will then cancel the other, the result will be a one to one ratio. In other words, the lower end will turn at the same R.P.M. as the sails.

PLATE No. 30

– THE WOODEN MULTIBLADE – XXVIII
– THE RIGHT ANGLE DRIVE ALTERNATIVE – V
– FROM AUTOMOBILE REAR END II
– ASSEMBLED



NOTE – USE OF TWO AUTO REAR ENDS – A AND B

PLATE NO. 31

The pull rope shut off assemblies shown on this page differ in no way from any of the others in this book. They are all of the same design and have comparative measurements according to the size of the tail vanes they operate, (fig. 1).

Everything is mounted on a 40" X 14" piece of 1/4" steel plate which constitutes the "metal rotating table". The size of this plate can, and should be reduced if design warrants, (fig. 2).

As its size depends so much on the size of the right angle drive that you buy (for less than $100), the best idea is to set everything out in its proper place, on a piece of plywood, or even cardboard, and then cut the steel plate according to the lines on the cardboard.

The under side of the bed plate is welded to a 1 1/2" pipe ("A"), directly below the position of the right angle drive on the upper side of the plate, so that the vertical 3/4" shaft of the right angle drive passes down through a hole in the plate, (fig. 2), and down through the inside of pipe "A". The shaft must pass through the exact centre of the pipe.

The pipe ("A"), joint to the bed plate is reinforced, or strengthened, by three layers of 1/4" steel plate rings. (See plate no. 68, fig. 2 and 3); plate no. 69, fig. 1 and 2, as well as plate no. 70, fig. 1).

The 1 1/2" pipe, ("A"), fits over the 1 1/4" pipe, ("B"), which has been welded to the 1/4" steel "post plate". The post plate is bolted, (through), to the 10" X 10" tower post.

The 1 1/2" pipe "A", rotates on the 1 1/4" pipe "B", as in the principle of the gate hinge. Note the grease nipple at the top of pipe "A".

To avoid wear, the 3/4" right angle direct drive shaft can not be allowed to touch the sides of pipe "B", so a "guiding", (ball bearing type, pillow block, (plate no. 16), must be bolted to the steel post plate just below the mouth of pipe "B", (fig. 4).

Such pillow blocks should be placed at intervals of six feet or so, all the way down the tower post to prevent excessive vibration or "axle whip".
Shaft pieces can be joined together with chain couplings, (see plate no. 28, fig. 2, 3 and 4).

The PILLOW BLOCKS can be replaced by flange bearings on boards between the tower horizontal, (see plate no. 81, fig. 3).

Because the right angle drive shaft comes down through the swivel pipes "A" and "B", of the rotating table, the pull rope has to come down the outside. It can not come very far down or it will wrap around the tower when the table rotates.

The rope should be weighted at the end to stop it from flying around in the wind. It is held in the tail vane "open" position by catching a knot in the rope into a triangular bracket, as illustrated in figures 3 and 4. Someone will just have to climb up the tower to handle the pull rope. The weighted end will make it easier to "catch".

If it is desired to use a 1" shaft instead of a 3/4" shaft running down from the right angle drive, the diameters of the swivel pipes "A" and "B", will just have to be increased. This could be a good idea, but the shaft size should conform to the original shaft size on the right angle drive.

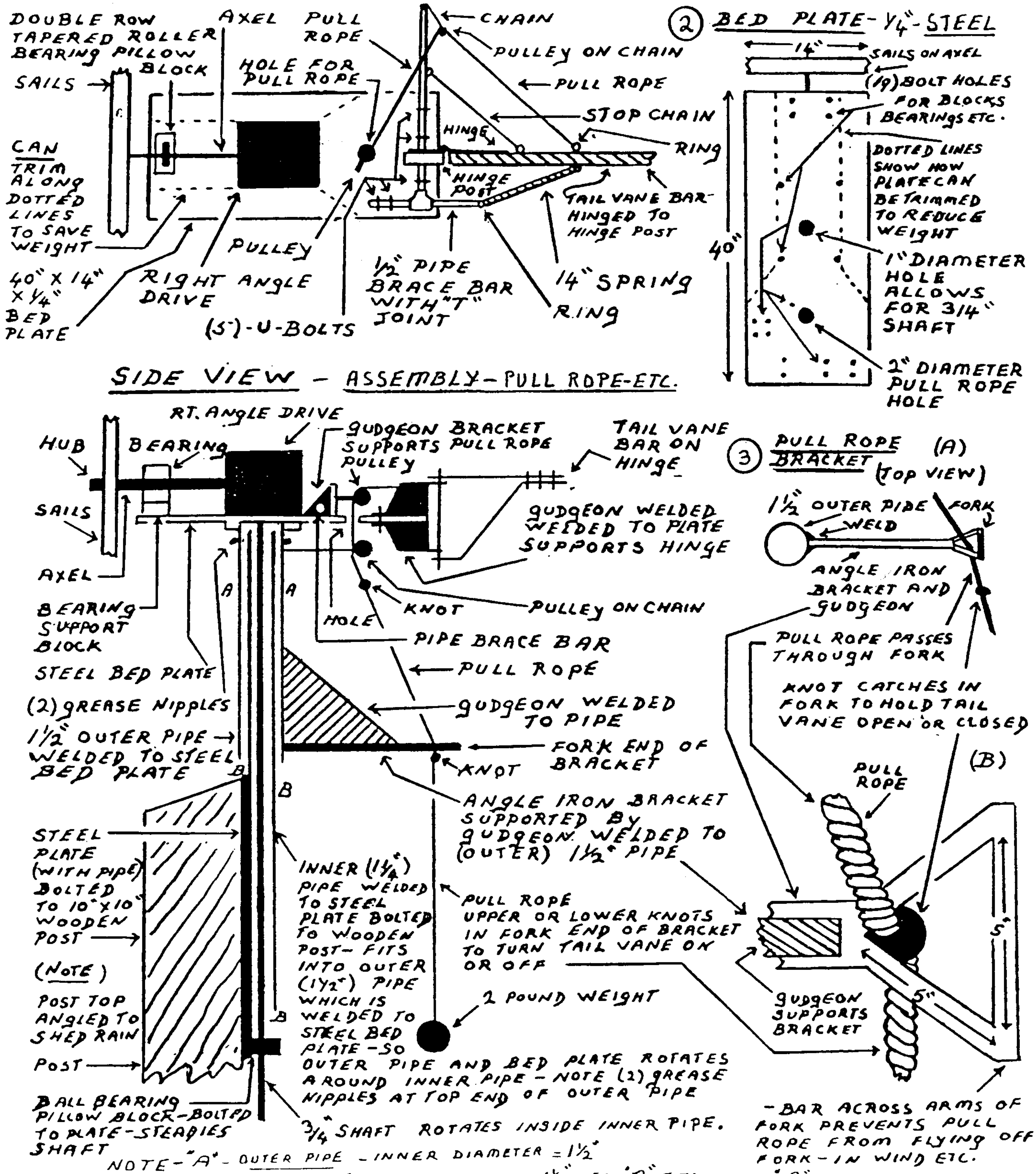
There will have to be a thrust bearing at the bottom of the shaft, (see plate no. 27, fig. 3, 4 and 5).

If the inner pipe "B", does not fit easily into the outer pipe "B", then pipe "B" should be taken down slightly on a lathe, as filing could take a long, long time. Do not forget to thoroughly grease the inner pipe so that it can turn easily inside the outer pipe.

This design will accept any type of sail arrangement, multiblade or rotor, for mechanical or electrical work. It is especially suitable to a four blade rotor connected to a high speed pump for overhead (spray), irrigation.

PLATE No. 31

— THE METAL MULTIBLADE — I
— RIGHT ANGLE DRIVE ON POST — I
— PARTS — DETAIL —



NOTE - "A" - OUTER PIPE - INNER DIAMETER = 1 1/2"
"B" - INNER PIPE - OUTER DIAMETER = 1 1/2" - SO - "B" FITS INTO "A"

PLATE NO. 32

Note how pipe "A" welds onto the bed plate and the joint is reinforced by steel ring "C", which is welded to the bed plate and the pipe.

Pipe "B" fits into Pipe "A".

The bed plate rotates on the top of pipe "B".

The direct drive shaft from the right angle drive, runs down the inside of pipe "B".

The tail vane causes the bed plate and pipe "A", to rotate on pipe "B".

Pipe "B", is welded to the steel post plate which is bolted to the 10" X 10" tower post, (see plate no. 81, fig. 3).

The bracket, (fork), holds the pull rope away from the tower post so it won't tangle.

PLATE No. 32

THE METAL MULTIBLADE II
RIGHT ANGLE DRIVE ON POST – II
ASSEMBLED

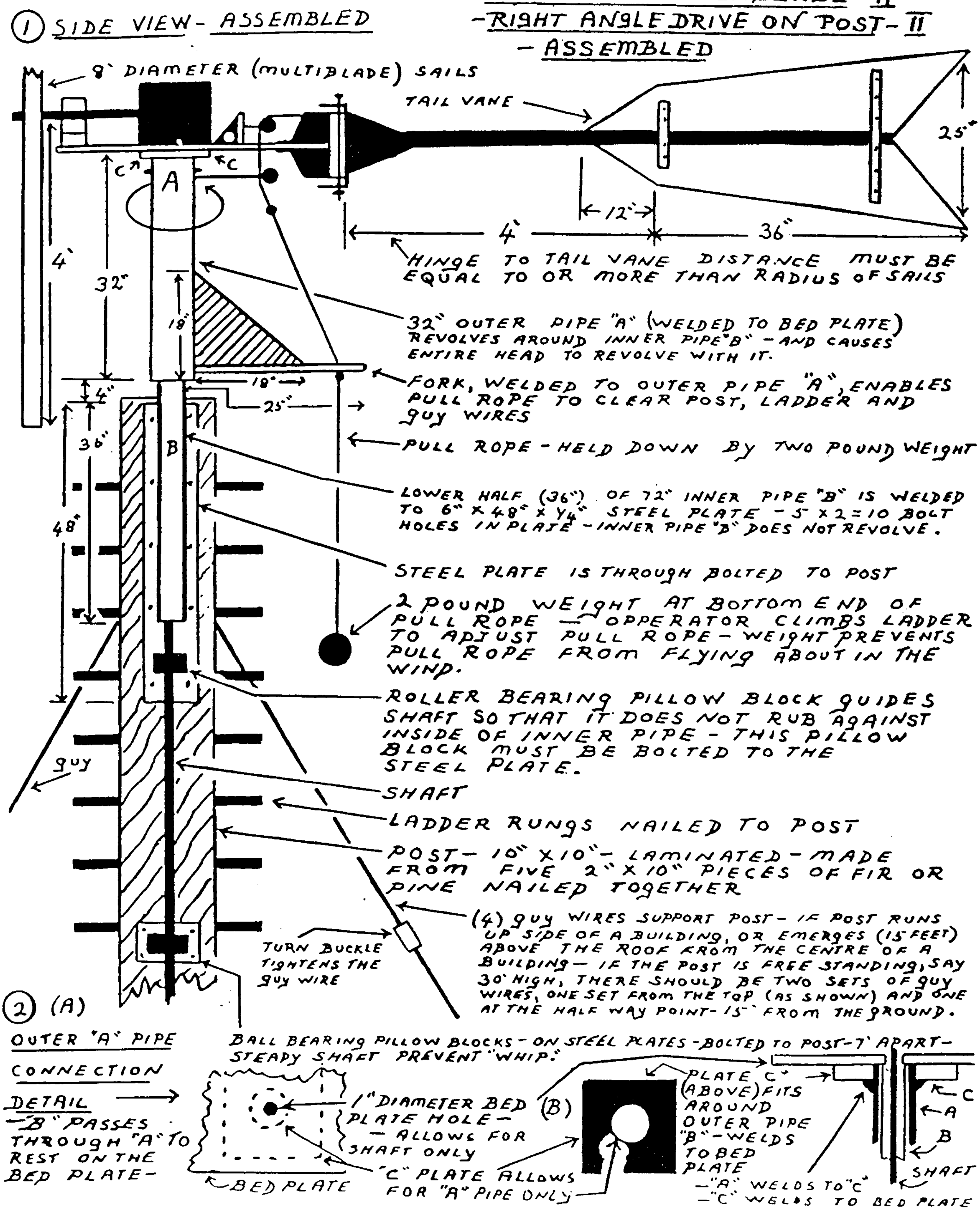


PLATE NO. 33

This is a replica of the most commonly used of all the American farm type multiblades. At one time there were millions of them in existence. Their primary purpose was the pumping of water, for homes, for livestock and for irrigation.

If you use the steel drum sections (fig. 3), you will get a perfect aeronautical curve on your blades that you would have a hard time getting on your own, especially when you have to make every blade the same.

The 1" X 1/8" flat bar is available at most hardware stores, (fig. 4). Just get it red hot on a gas stove or wood fire, bend it to shape and then stick it in cold water to give it temper.

Note that the cap on the radial arms is a separate piece that bolts on, and that the outer ring bolts on to the cap, (fig. 4).

The inner ring bolts to the bracket, and the bracket bolts to the radial arm.

The radial arms bolt to the hub, as illustrated in fig. 5. (See also plate no. 17, fig. 4).

PLATE No. 33

- THE METAL MULTIBLADE - III
- 8-FOOT DIAMETER MULTIBLADE - I
- SAILS - 15 BLADES - METAL -

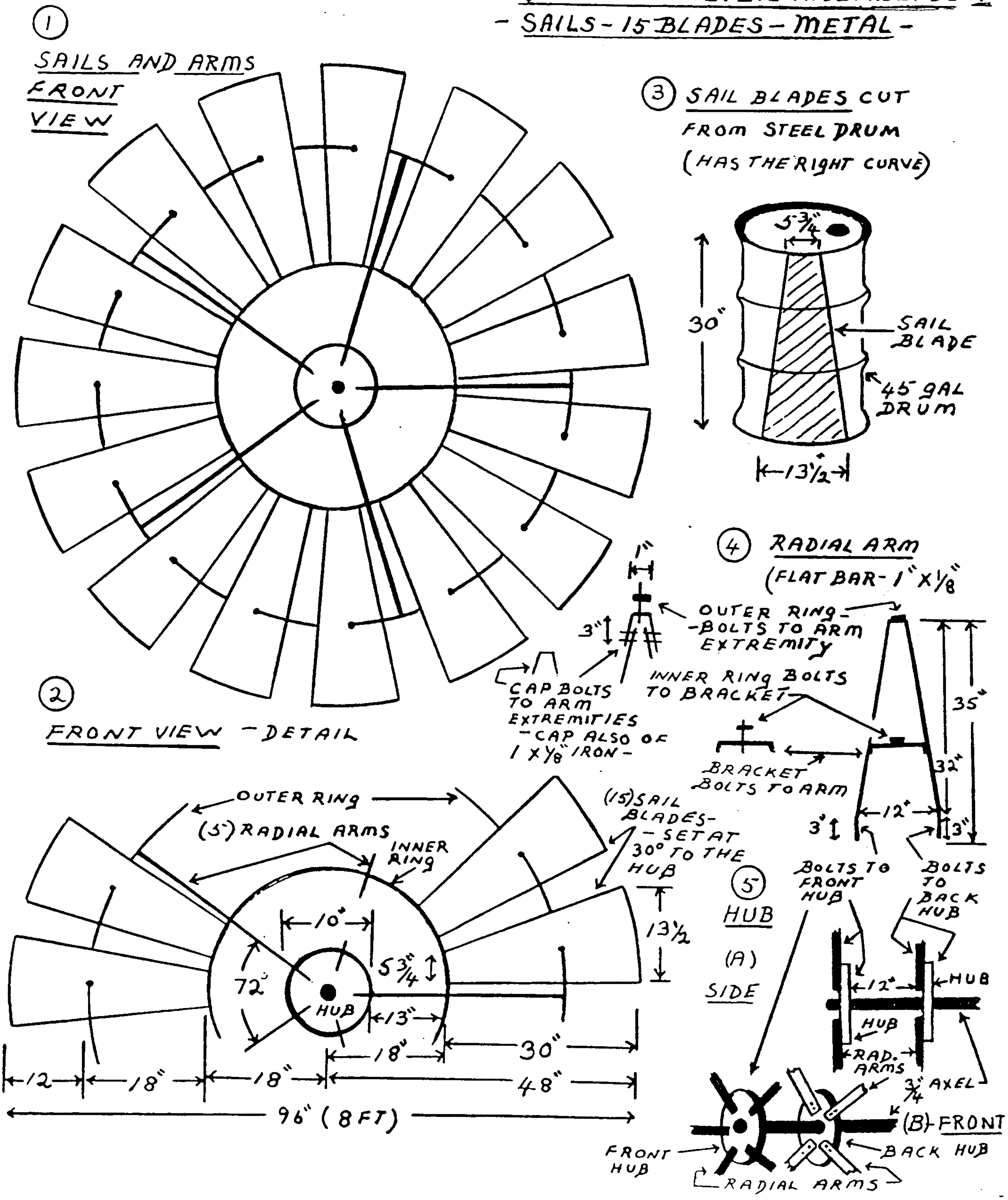


PLATE NO. 34

The sails are connected to the inner and outer rings by brackets made out of pieces of angle iron, (fig. 1, 2, 3, 4 and 5).

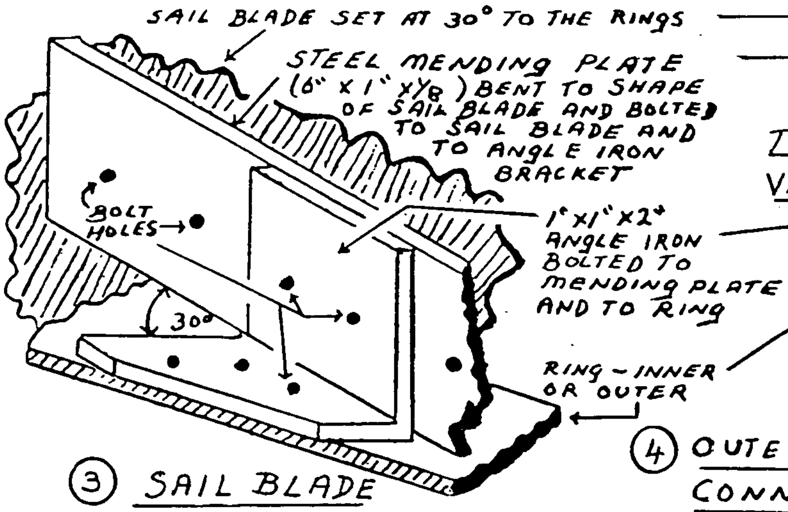
Note that the outer ring (only), passes through a hole in the mid point of the sail, (fig. 3).

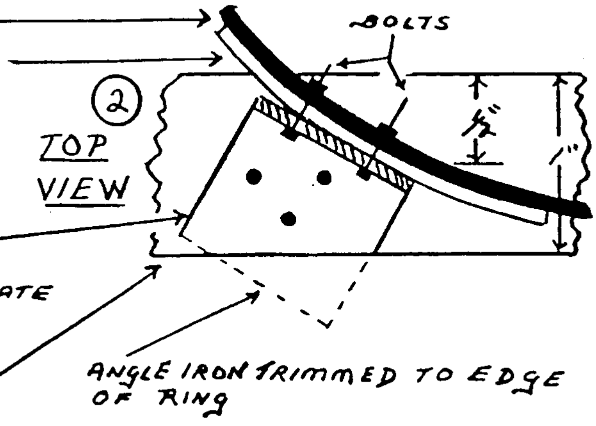
Take special note of the (cold), bending methods, illustrated in fig. 6. You will need one of these to make the inner and outer rings. The "E" method is the most widely accepted, though it requires more apparatus.

PLATE No. 34

–THE METAL MULTIBLADE–IV
–8-FOOT DIAMETER MULTIBLADE–II
–SAIL ATACHMENTS–
–RING BENDING METHODS–

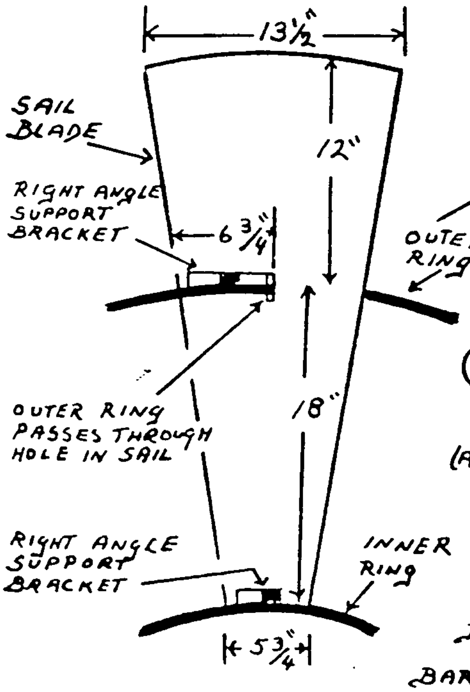
(1) RIGHT ANGLE SUPPORT BRACKET– SIDE VIEW–



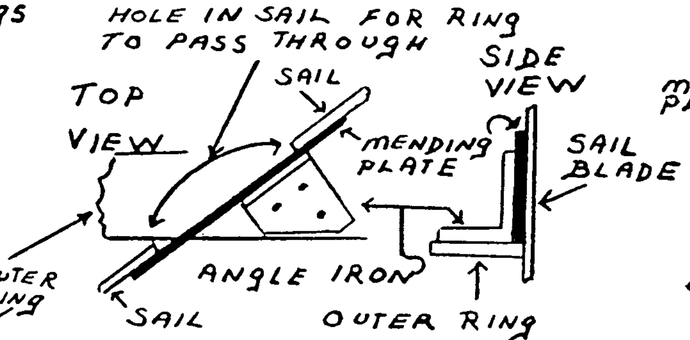


(3) SAIL BLADE

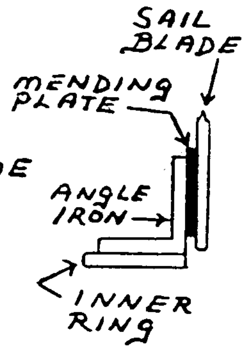
SET AT 30° TO THE RINGS



(4) OUTER RING CONNECTION



(5) INNER RING CONNECTION



(6) TWO METHODS OF BENDING IRON BAR IN RINGS

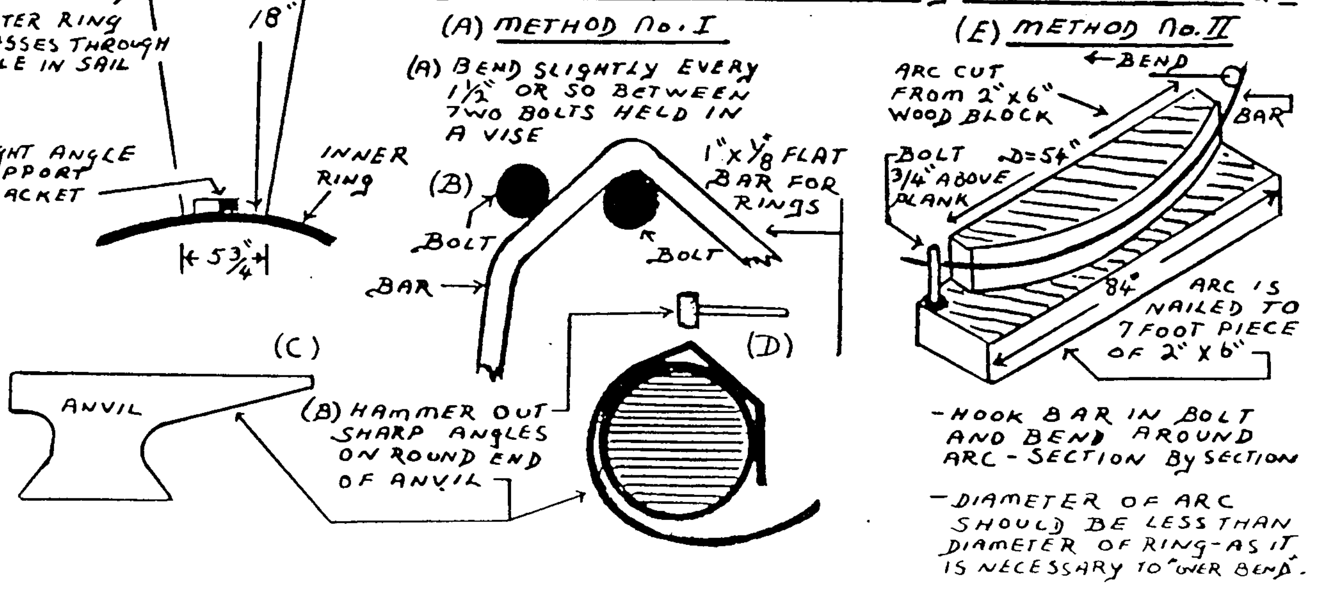


PLATE NO. 35

This is a very large and powerful design, and was mostly used for grinding grain and buzz sawing firewood, as well as for the pumping of water.

In Ontario, it was mostly used on a tower post over the barn roof, (see plate no. 81, fig. 1).

Note that the sections of steel drum have to be joined in the middle to form a 57" blade, (fig. 2). If you have to make your own rivets, you can use 3" nails cut down to 1/8" or so. Just put a washer over the small end and beat it down hard with a ball pen hammer on a stone or anvil until it “mushrooms” over.

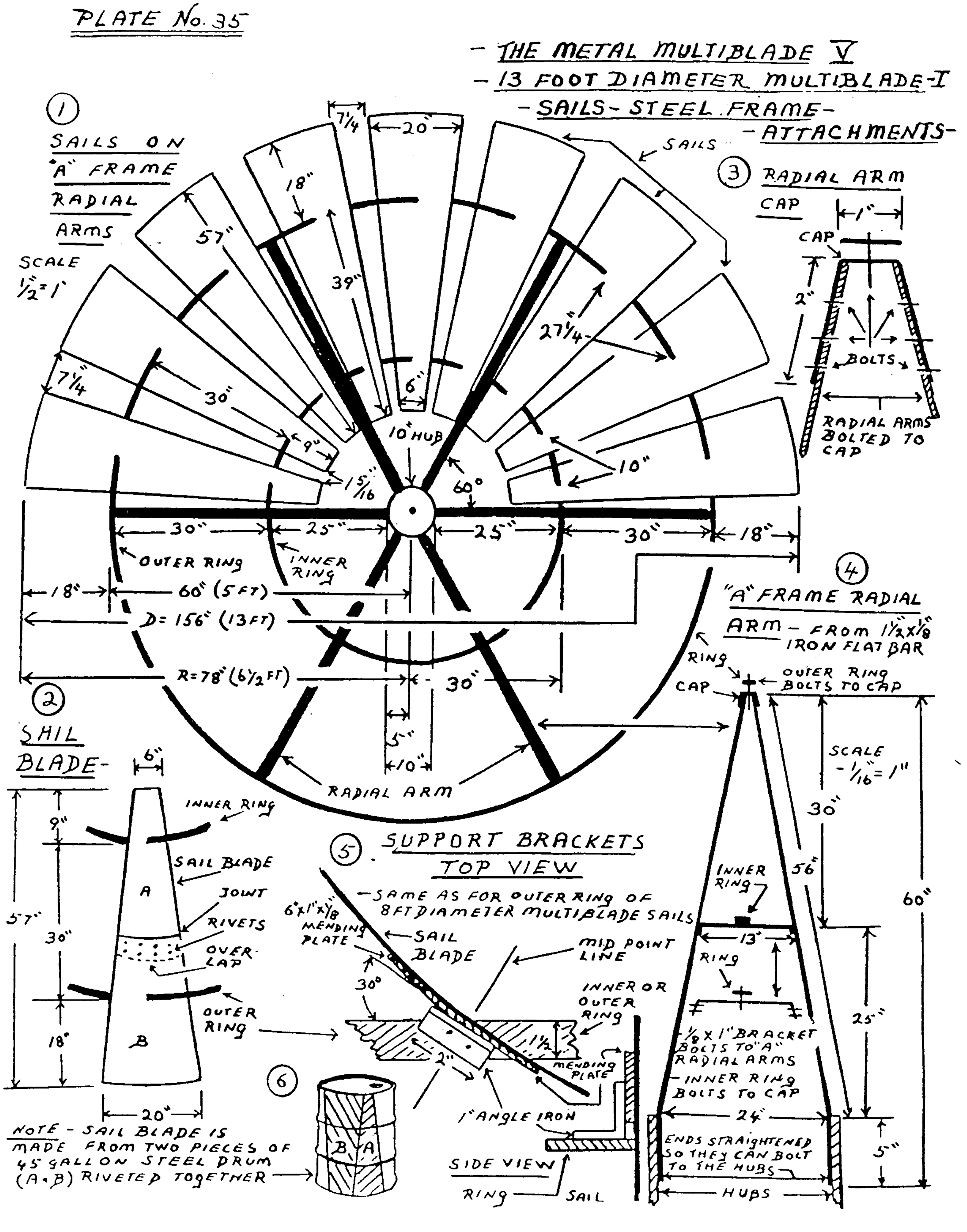


PLATE No. 35
- THE METAL MULTIBLADE V
- 13 FOOT DIAMETER MULTIBLADE-I
- SAILS- STEEL FRAME-
- ATTACHMENTS-
(1)
SAILS ON "A" FRAME RADIAL ARMS
SCALE 1/2"=1'
SAILS
7 1/4
20"
18"
57"
39"
27 1/4
7 1/4
30"
9"
6"
10" HUB
15/16
60°
10"
30"
25"
25"
30"
18"
OUTER RING
INNER RING
18"
60" (5 FT)
D= 156" (13 FT)
R=78" (6 1/2 FT)
30"
5"
10"
RADIAL ARM
(3)
RADIAL ARM CAP
1"
CAP
2"
BOLTS
RADIAL ARMS BOLTED TO CAP
(4)
"A" FRAME RADIAL ARM - FROM 1 1/2"X1/8" IRON FLAT BAR
RING
CAP
OUTER RING BOLTS TO CAP
SCALE - 1/16"=1"
30"
56"
60"
INNER RING
13"
RING
25"
1/8 X 1" BRACKET BOLTS TO "A" RADIAL ARMS
INNER RING BOLTS TO CAP
24"
5"
ENDS STRAIGHTENED SO THEY CAN BOLT TO THE HUBS
HUBS
(2)
SAIL BLADE-
6"
INNER RING
9"
SAIL BLADE
A
JOINT
RIVETS
57"
30"
OVER LAP
OUTER RING
18"
B
20"
NOTE - SAIL BLADE IS MADE FROM TWO PIECES OF 45 GALLON STEEL DRUM (A+B) RIVETED TOGETHER
(6)
B A
(5)
SUPPORT BRACKETS TOP VIEW
-SAME AS FOR OUTER RING OF 8 FT DIAMETER MULTIBLADE SAILS
6"X1"X1/8 MENDING PLATE
SAIL BLADE
MID POINT LINE
30°
INNER OR OUTER RING
1 1/2
2"
MENDING PLATE
1" ANGLE IRON
SIDE VIEW
RING
SAIL

PLATE NO. 36

Be sure to allow at least 12" between the outside of the sail diameter and the tail vane. This should be so on all systems to give the proper leverage to the tail vane.

PLATE No. 36

- THE METAL MULTIBLADE - VI
- 13 FOOT DIAMETER MULTIBLADE - II
- TAIL VANE

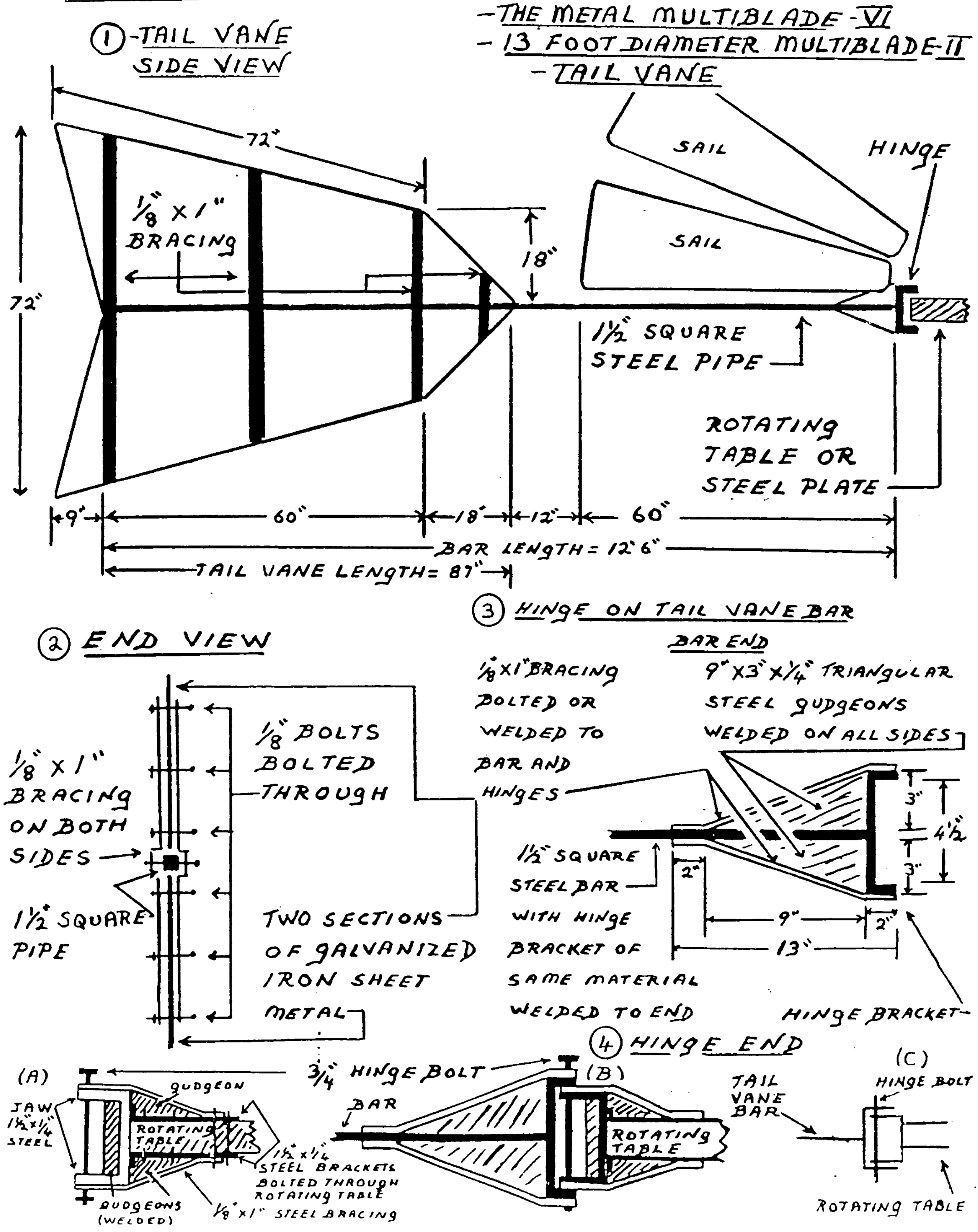


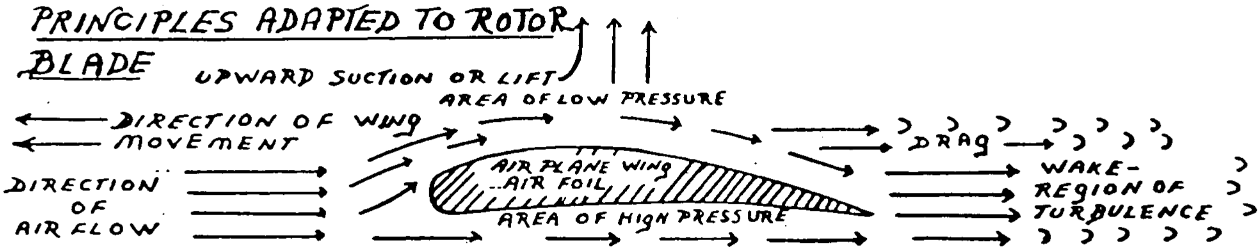
PLATE NO. 37

The illustrations are discussed with considerable detail in the first section on airfoils, (theory).

PLATE No. 37

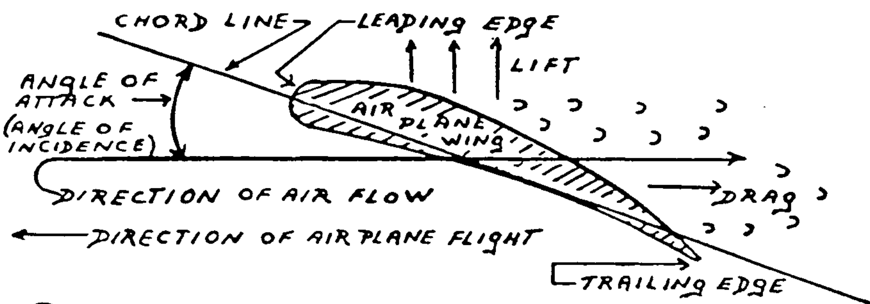
- THE AIR FOIL - ROTOR BLADE - I
- PRINCIPLES I

(1) AIR PLANE WING AIR FOIL PRINCIPLES ADAPTED TO ROTOR BLADE

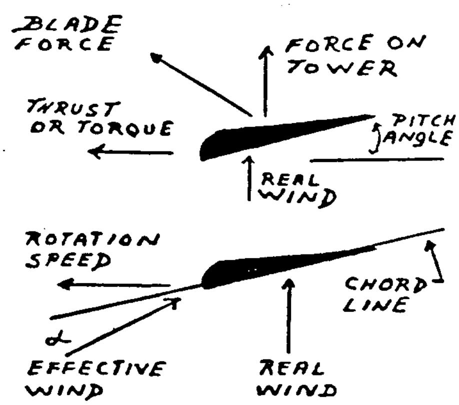


NOTE - AIR FOIL "SPLITS" AIR FLOW - PART THAT PASSES BENEATH WING TRAVELS THE SHORTEST DISTANCE, A STRAIGHT LINE. PART THAT PASSES OVER TOP TRAVELS A LONGER DISTANCE, A CURVED LINE, WHICH CAUSES AIR FLOW TO "STRETCH" OR THIN OUT WHICH CREATES THE VACUUM THAT CAUSES UPWARD SUCTION OR "LIFT." WAKE TURBULENCE FOLLOWING THE DOWNWARD CURVE, BEHIND THE TANGENT (HIGHEST) POINT, "PULLS BACK" OR IMPEDES THE FOREWARD MOTION. PROBLEM - TO MAXIMISE LIFT AND, AT THE SAME TIME, MINIMISE DRAG. WIND MACHINE USES LIFT TO TURN HIGH SPEAD ROTOR BLADES.

(2) AIR PLANE WING - AIR FOIL - PRINCIPLE



(4) ESSENTIAL ROTOR BLADE RELATIONSHIPS



(3) SAME PRINCIPLE - APPLIED TO ROTOR BLADE -

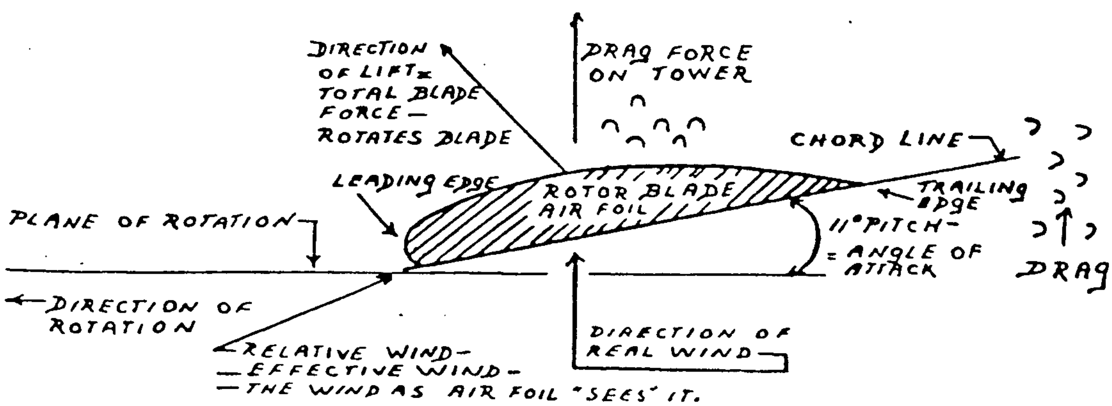


PLATE NO 38

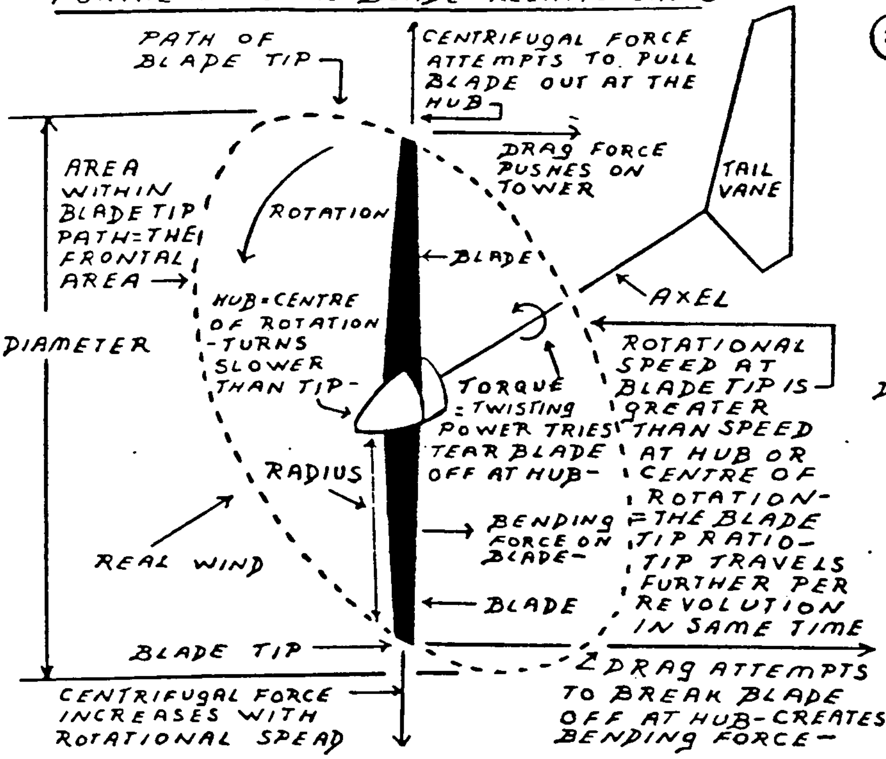
The illustrations are also discussed with considerable detail in the first section on airfoils, (theory).

- note the illustration of the torque principle in fig. 4.

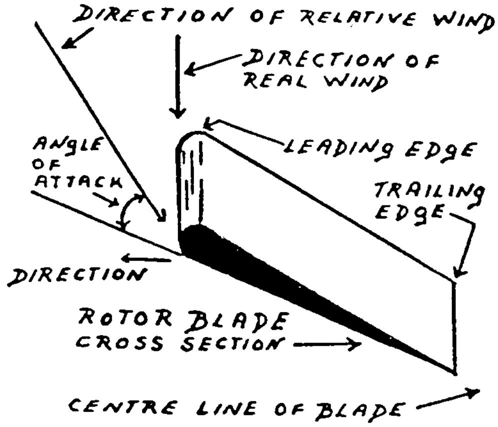
PLATE No. 38

—THE AIR FOIL—ROTOR BLADE—II
—PRINCIPLES—II

① FURTHER ROTOR BLADE RELATIONSHIPS



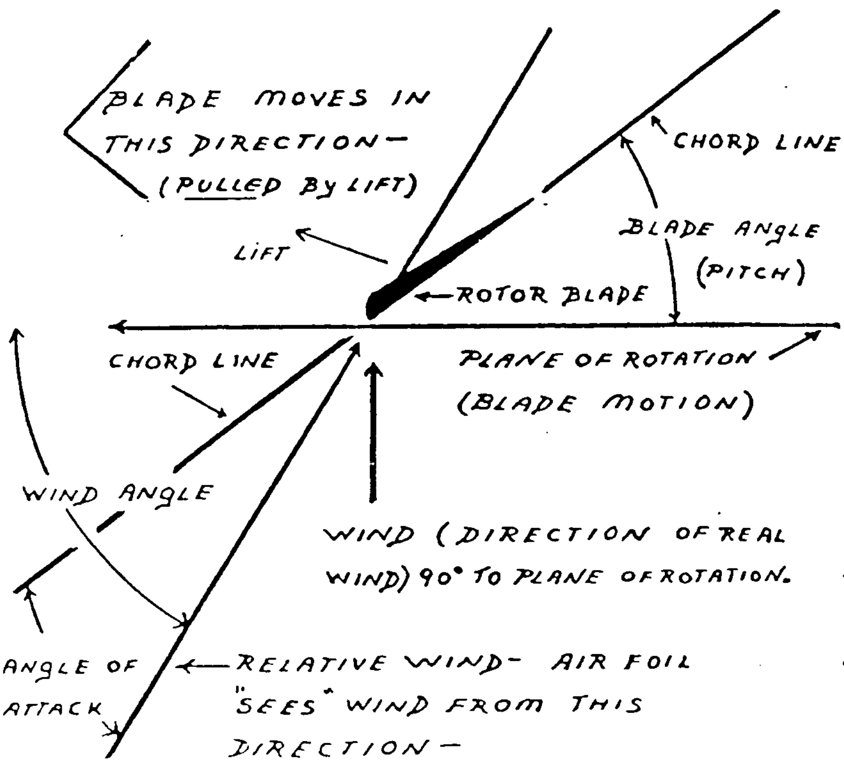
② THE SAME ROTOR BLADE IN CROSS SECTION



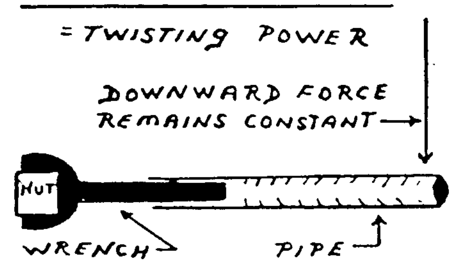
NOTE

- THE SMALLER THE ANGLE OF ATTACK (PITCH), THE FASTER THE ROTOR WILL TEND TO TURN - INCREASING THE ANGLE OF ATTACK SLOWS THE ROTOR DOWN - AS CHANGING THE SET OF A SAIL - I.E. THE POSITION OF THE SAIL - CHANGES THE SPEED OF A SAILING VESSEL.
- MAXIMUM ANGLE = 15°

③ ROTOR BLADE - PRINCIPLES APPLIED



④ PRINCIPLE OF TORQUE = TWISTING POWER



- WRENCH EXERTS TWISTING FORCE ON NUT - EXTEND LENGTH OF WRENCH BY ADDING PIPE - AND TWISTING POWER, OR TORQUE, IS INCREASED -

PLATE NO. 39

This blade is to be cut from a dressed piece of Douglas Fir, 2" X 6".

The flat bottom side is not touched. It remains as the flat surface of the original 2" X 6".

The curved back side is shaped with a draw knife, plane etc. Check the shape constantly with the metal template cut out.

Use the wedges to set the blades into the hub at the desired angle.

The strength of the airfoil is largely determined by its thickness at the tangent point. In this case it is 1 9/16".

Length to width ratio should 10:1, so the length of 5' 6" wide blade = 10 X 5.5 (inches) = 55" - 4 feet 6 inches or a diameter of 2 X 4' 6" = 9 feet plus 10" for the hub = 9' 10" or 10 feet. (Read both sections on airfoils very carefully).

PLATE No. 39

-THE AIR FOIL ROTOR BLADE- III
- NON TAPERED- 11°-15° PITCH-
-BLADES ANGLED BY WEDGES-I

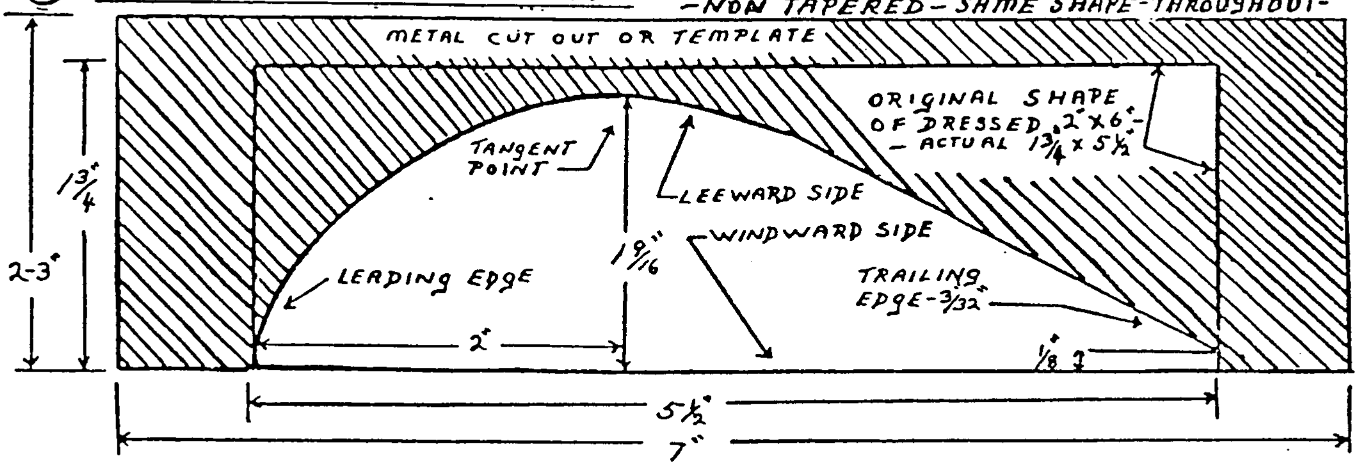
NOTES

(A) WEDGES-

-7" WEDGES - INSIDE THE HUB ON EACH SIDE OF THE ROTOR BLADE- -INSIDE THE HUB - ANGLE THE BLADES AT EITHER 11° OR 15° - OR ANY OTHER ANGLE DESIRED - BLADES CAN THEN BE CUT IN RADIAL LENGTHS - -IE- 7 FOOT DIAMETER ROTOR BLADES CAN BE CUT IN 3 FOOT 6 INCH LENGTHS- AND THEN JOINED AND ANGLED AT THE CENTRE HUB- THIS MAKES 3-BLADE ROTORS POSSIBLE- IT IS BY FAR THE BEST METHOD-

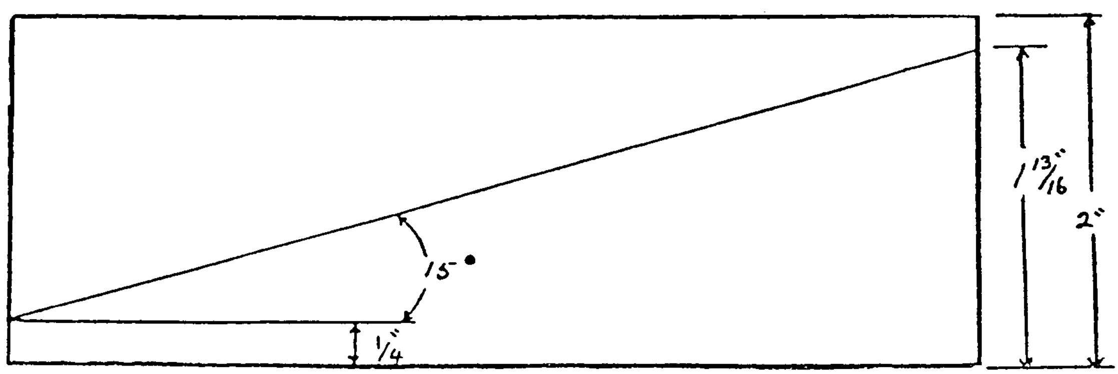
(B)-BLADES - BLADES CAN THEREFORE BE MADE FROM 2"X6" DRESSED LUMBER (1¾" X 5½") -FIR- USING MILLED SIDE OF PLANK AS WINDWARD SIDE OF BLADE-ONLY CURVED LEEWARD HAS TO BE SHAPED- -NON TAPERED- SAME SHAPE-THROUGHOUT-

(1) END VIEW-ACTUAL SIZE-



(2) END VIEW - 15° WEDGE ACTUAL SIZE- -FROM UNDRESSED 2"X6"-

- ONE ON EACH SIDE OF (HUB END OF) ROTOR BLADE - ANGLES BLADE TO 15° PITCH - ALL WEDGES ARE 7" LONG



(3) END VIEW

- 11° WEDGE ONE ON EACH SIDE OF HUB END - ANGLES ROTOR BLADE PITCH TO 11°

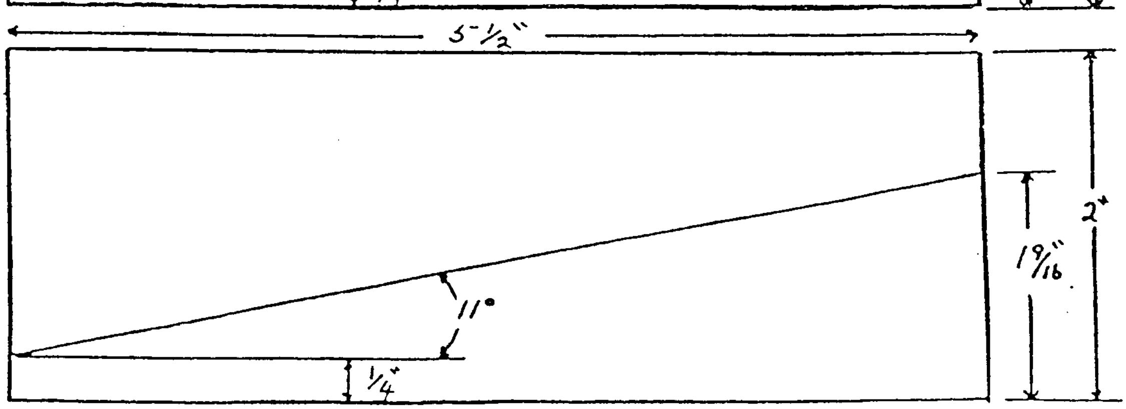


PLATE NO. 40

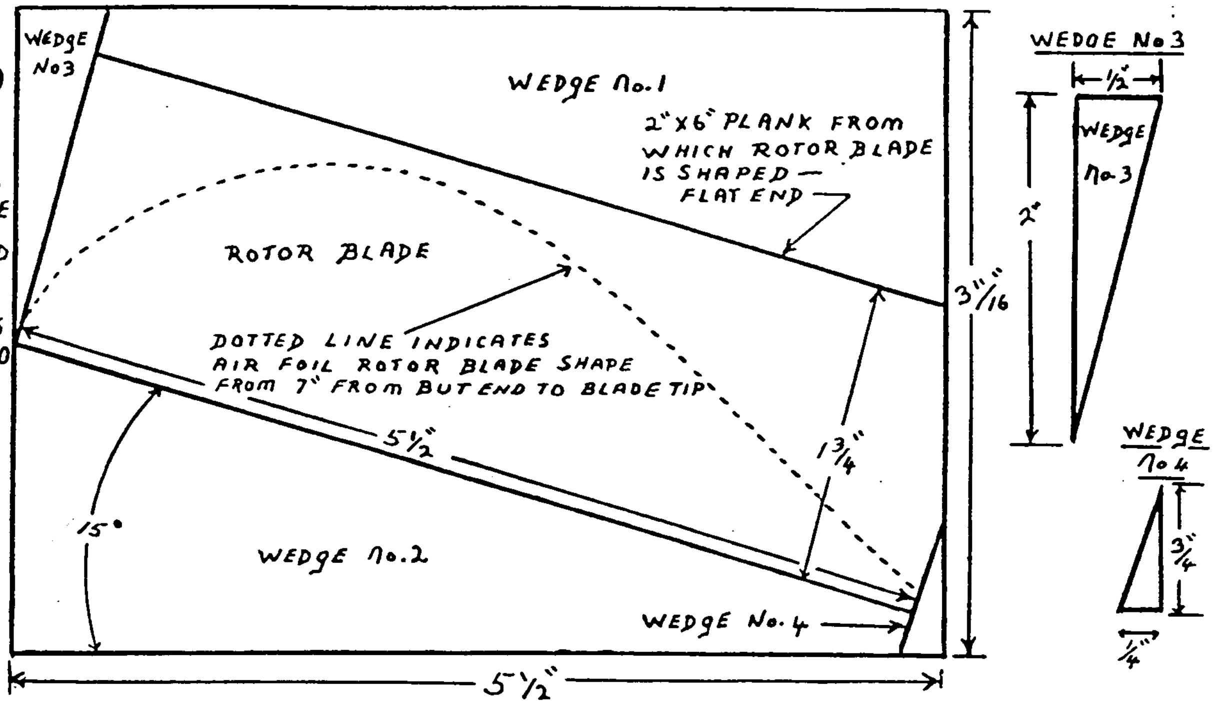
Shows the blade in plate no. 39 with the 7" wedges glued onto its butt, (root), end. Note that this blade is of the same shape from end to end. There is no taper or twist.

PLATE No. 40

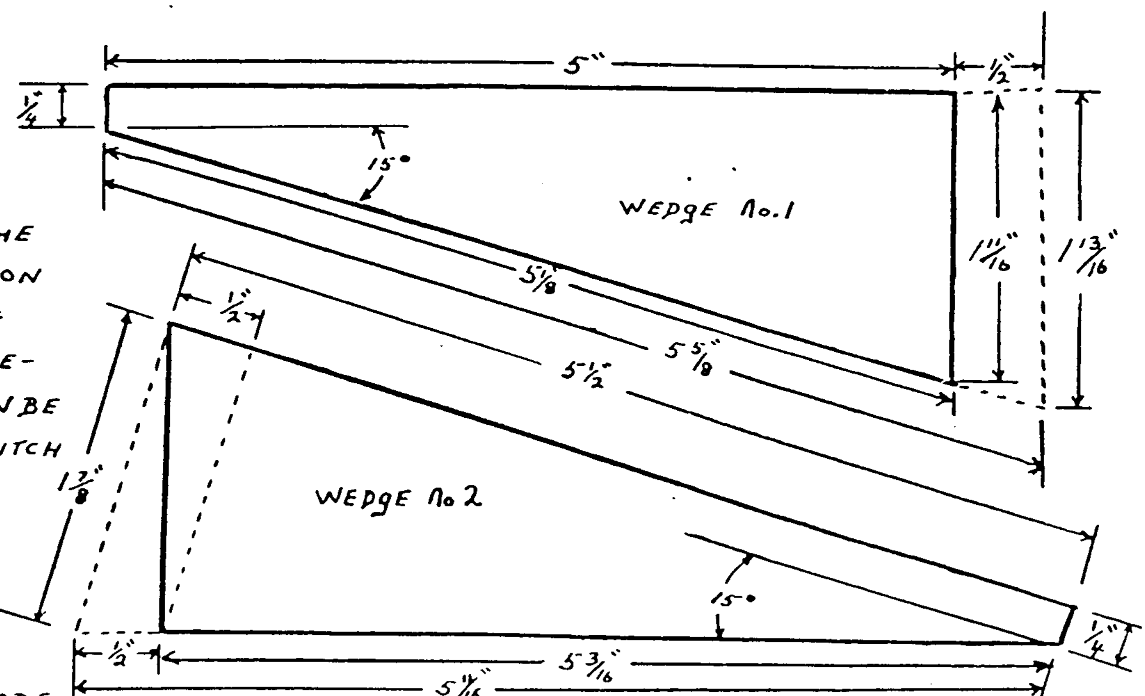
-NOTE- USE SAME CUT-OUTS TEMPLATES - AS IN PLATE No-37- ONLY CURVED SIDES ARE SHAPED - NO TAPER-

—THE AIR FOIL-ROTOR BLADE- IV
-NON TAPERED- 11°-15° PITCH-
-BLADES ANGLED BY WEDGES II
-METHOD OF ANGLING BLADES-

(1) (HUB) END VIEW OF BLADE END AND WEDGES — WEDGES GLUED TO 2"X6" PLANK- -ACTUAL SIZE



(2) (HUB) END VIEW OF WEDGES— EACH WEDGE IS 7" LONG TO COVER THE "FLAT AREA" ON HUB END OF ROTOR BLADE- WEDGES CAN BE MADE TO PITCH 11° OR 15°- -ACTUAL SIZE-



(3) SIDE VIEW OF ROTOR BLADE SHOWING POSITION OF WEDGES → AXLE →

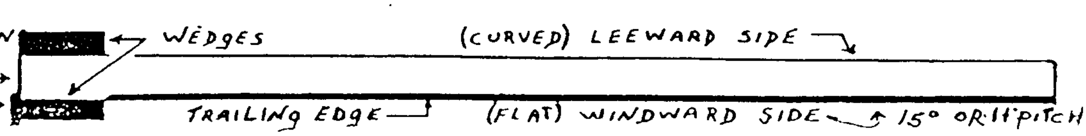


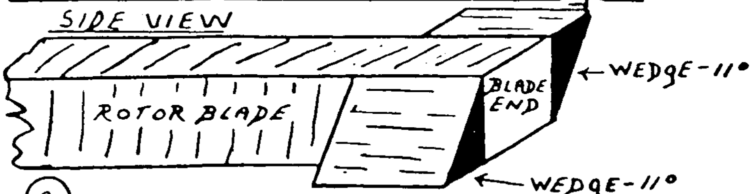
PLATE NO. 41

This is the same metal hub construction as is illustrated in plate no. 17.

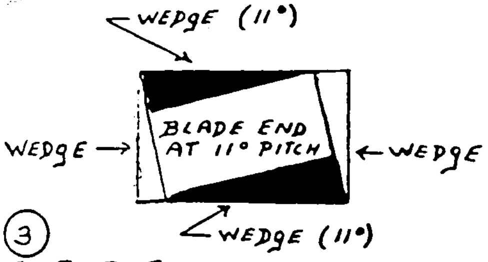
PLATE No. 41

- THE AIR FOIL - ROTOR BLADE V
- NONTAPERED - 11°-15° PITCH -
- 3-BLADE HUB CONSTRUCTION

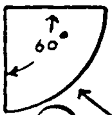
(1) THE ROTOR BLADE WITH WEDGES



(2) END VIEW - BLADE AND WEDGES

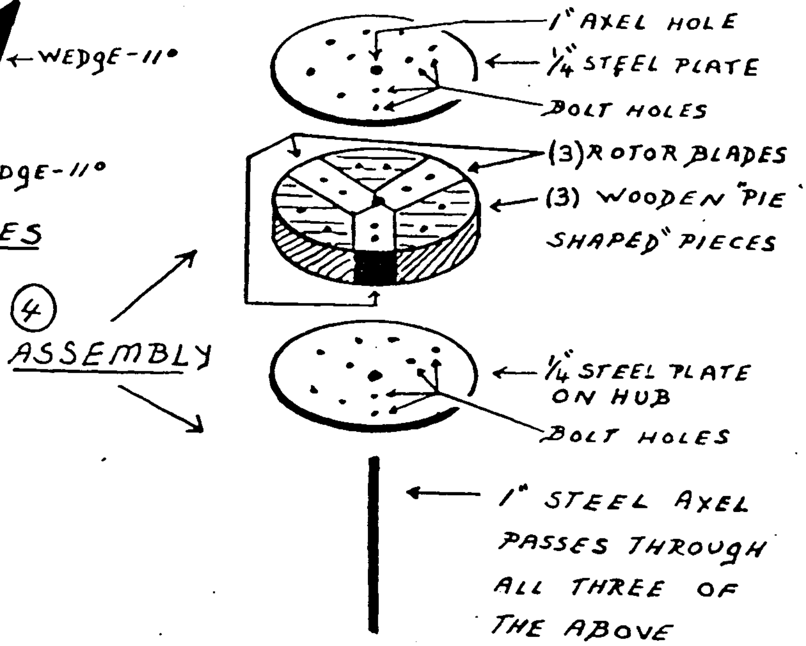


(3) THE PIE PIECE



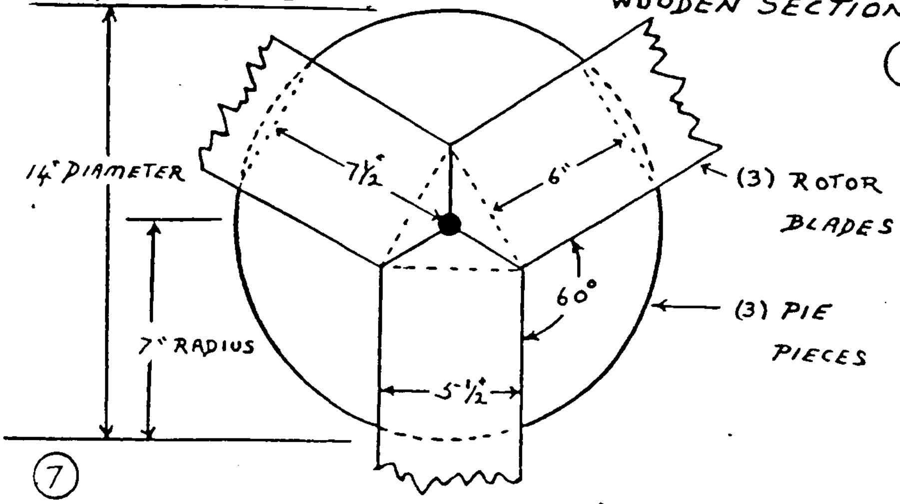
WOODEN "PIE" SECTIONS -SAME THICKNESS AS ROTOR BLADES-GLUED BETWEEN BLADES-

(4) ASSEMBLY

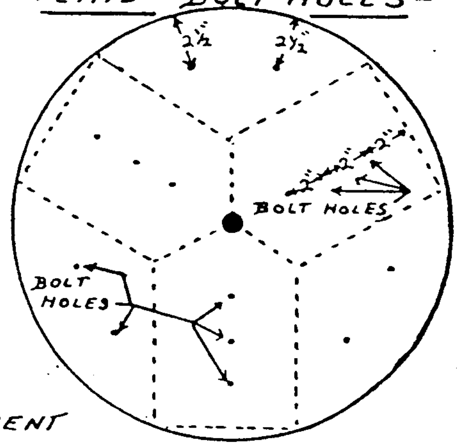


SECTIONS. IT IS ATTACHED BY MEANS OF THE HUB TO THE LOWER PLATE. THE UPPER PLATE IS BOLTED THROUGH THE WOODEN SECTIONS TO THE LOWER PLATE.

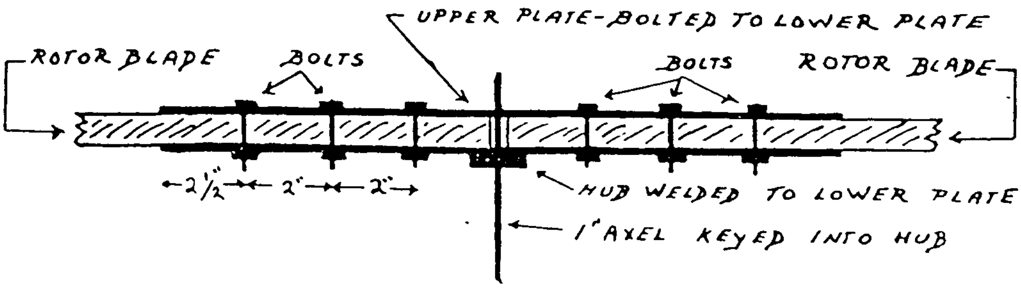
(5) THE UPPER PLATE - AND BLADES



(6) UPPER AND LOWER PLATE - BOLT HOLES -



(7) SIDE VIEW - SHOWING 3/16" BOLT PLACEMENT



- BOLT HOLES - 2½" FROM OUTER RIM
- 2" APART -
- 3 BOLTS IN EACH BLADE
- 2 BOLTS IN EACH PIE PIECE.

PLATE NO. 42

Note the difficulty in shaping tapered and twisted blades, especially if you have to make two, three or four blades, and they all have to be exactly the same. There is no scientific proof that such an effort is worthwhile, (fig. 1 and 2).

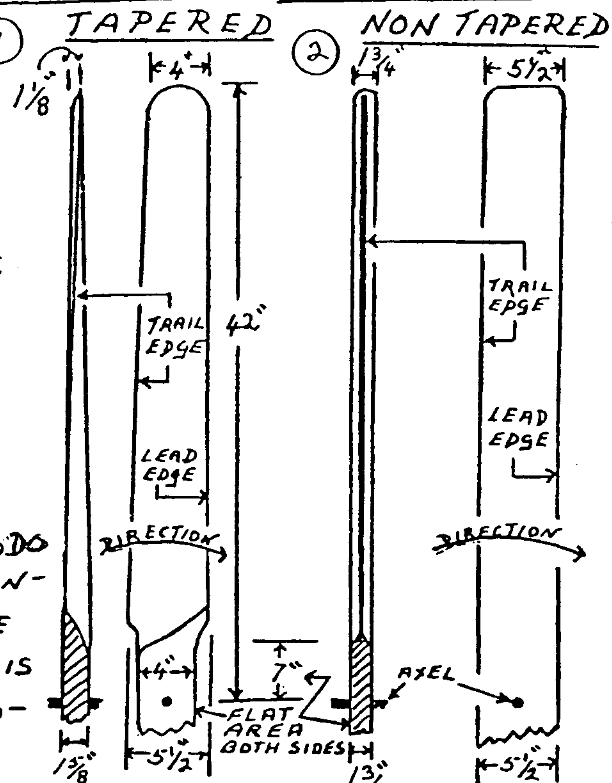
Fig. 4 is a cross section of a two blade rotor, cut from a single piece, and illustrates the difficulty of such a task.

PLATE No. 42

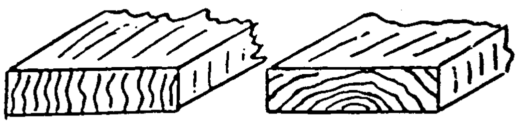
—THE AIR FOIL—ROTOR BLADE—VI
—COMPARE—NON TAPERED—TAPERED—
—CONSTRUCTION —7 FOOT ROTOR—

NOTES

- 7-FOOT ROTOR -(PROPELLER) BLADES - FOR ELECTRICAL GENERATION -
- FROM 7 FOOT PIECES OF 1"X6" FIR - OR SPRUCE WOOD -
- AIR FOIL SHAPES ARE INSPIRED BY THE SHAPE OF AIR PLANE WINGS - NOT BY THE SHAPE OF AIR PLANE PROPELLERS -
- **PITCH** - = 15° = THE ANGLE OF THE BLADE TO THE PLANE OF ROTATION - THE ANGLE OF THE BLADE FROM A POSITION FLAT AGAINST THE WIND -
- **TAPER** - IS NO LONGER CONSIDERED NECESSARY IN THE DESIGN OF ROTORS - ALSO - TAPER IS HARD TO DO

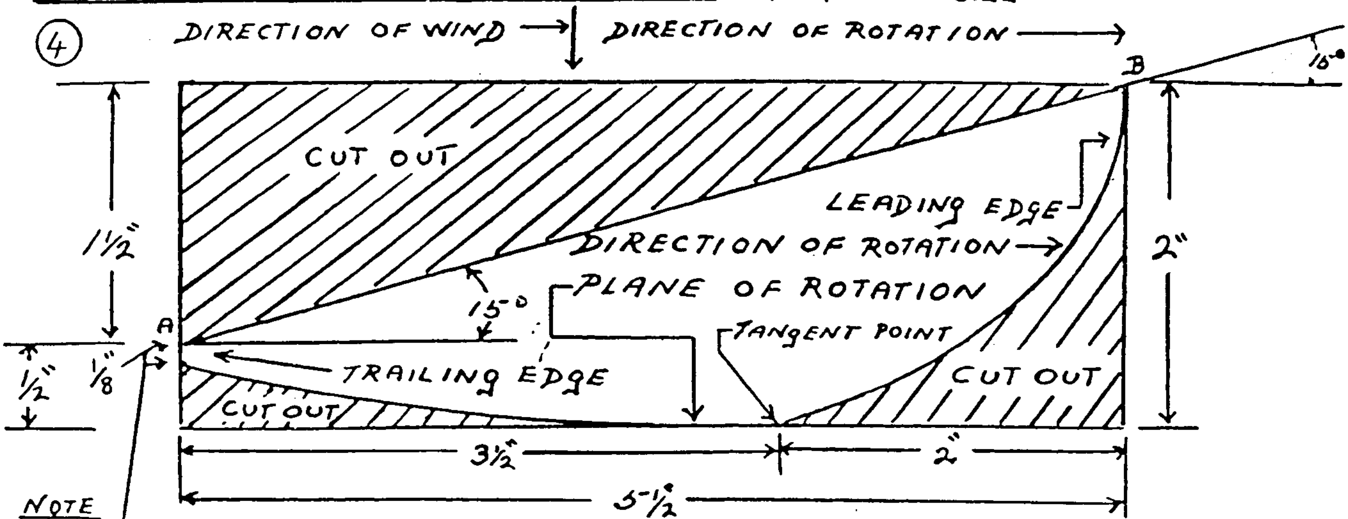


③ WOOD SELECTION - BY GRAIN FORMATION -



- BE SURE THAT WOOD IS KILN DRIED -

CROSS SECTION OF NON TAPERED BLADE - 7' - ACTUAL SIZE -



NOTE

TRAILING EDGE = 1/8" (THROUGHOUT) —

- UPPER (WINDWARD) SIDE - A-B - IS FLAT THROUGHOUT - AT 15° TO THE PLANE OF ROTATION - NOTE THAT POINT "A" IS 1/2" ABOVE (2"X6") PLANK BOTTOM - LINE RUNS DIAGONALY TO UPPER CORNER "B" = 15°
- BOTTOM SIDE CURVES CAN BE JUDGED BY THE EYE OR (BETTER) - MEASURED BY THE ILLUSTRATED GALVANIZED IRON CUT-OUTS.

PLATE NO. 43

Shows the templates necessary for making the blade illustrated in plate no. 42, that is the two blade, 15° pitch rotor cut from a single piece, a blade that has no need for wedges.

Make the two flat windward sides first as shown in fig. 1.

Then make the two curved back sides as shown in fig. 2.

In both cases, the thick dark lines at the bottom of the drawing, indicate the table top, along which the templates will slide to assure the accuracy of the shaping.

The 15° pitch is faster starting, but does not have the top rotational speed, (maximum R.P.M.), of the 11° pitched blade.

Fig. 3 shows the finished product, except in this case the blade is tapered, which is not advised.

PLATE No. 43

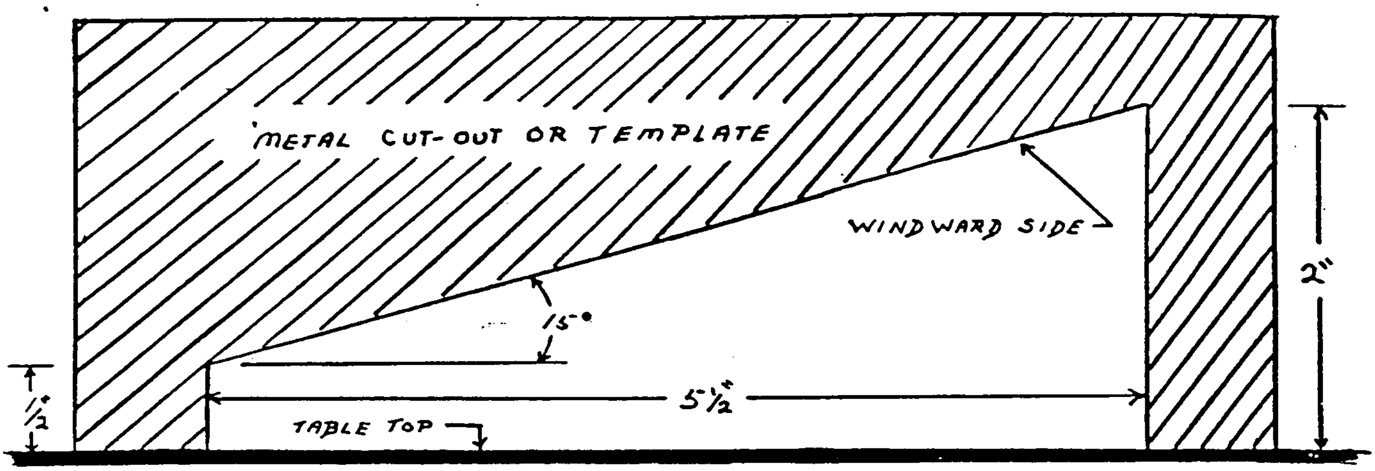
— THE AIR FOIL – ROTOR BLADE – VII
– TEMPLATES – 7' – SINGLE PIECE –

15° – PITCH – NON TAPERED

METAL CUT-OUTS – (GALVANIZED IRON) – TO MAKE 7' WOODEN ROTOR BLADES –
7' – DIAMETER – BOTH BLADES FROM A SINGLE 7' PIECE – NO WEDGES –

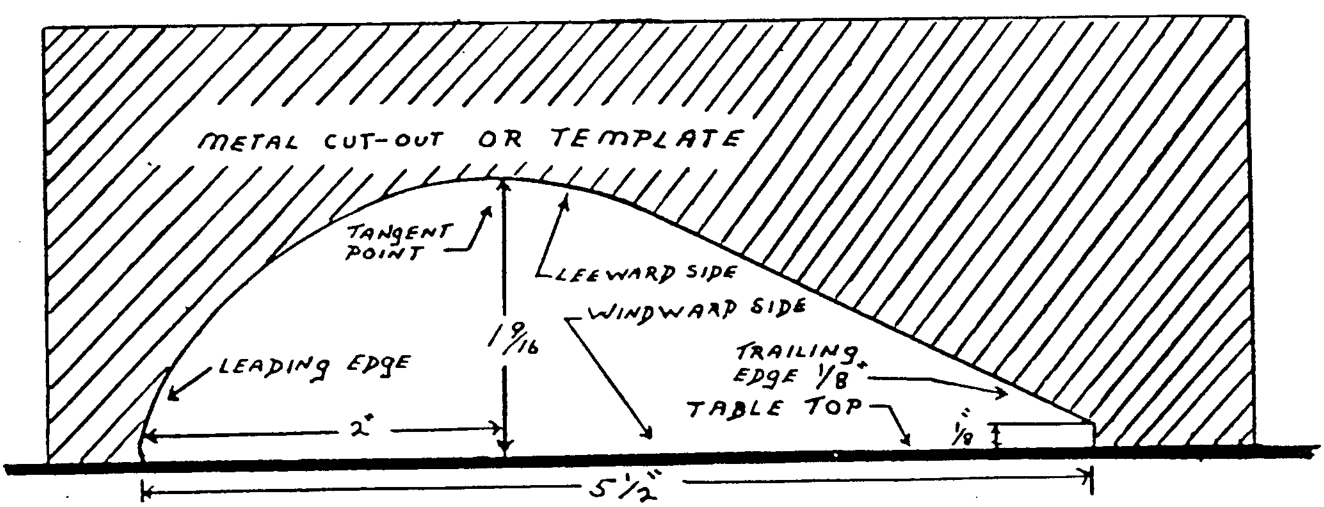
(1) FIRST – MAKE THE FLAT (WINDWARD) SIDE –
– MAKE THE CUT – WITH RIP SAW, PLANE AND RASP – THEN CHECK EXACTNESS AT ALL POINTS WITH CUT-OUT – WITH BLADE ON TABLE TOP –

CUT-OUT FOR WINDWARD SIDE – ACTUAL SIZE –



(2) SECOND – MAKE THE LEEWARD SIDE – SHAPE THE CURVES WITH DRAW KNIFE, RASP AND PLANE BY EYE JUDGEMENT THEN CHECK CURVES WITH CUT-OUT – BY PLACING (FINISHED) WINDWARD SIDE ON WORK TABLE.

CUT-OUT FOR LEEWARD SIDE – ACTUAL SIZE



(3) TWO BLADE – 7 FT – ROTOR – FROM SINGLE PIECE OF WOOD – TAPERED

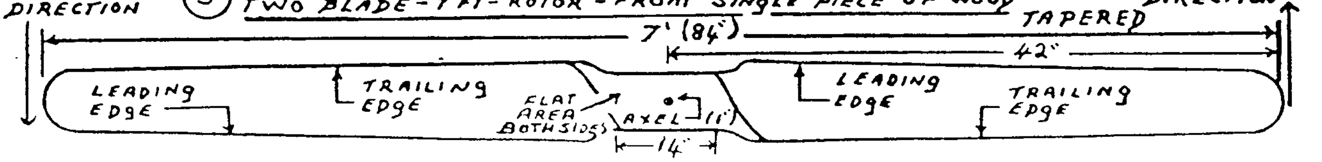


PLATE NO. 44

Shows the same two blade, single piece rotor construction as in plate no. 42 and 43, except that this blade has an 11° pitch.

This 11° pitch is a faster moving (rotating), airfoil, but somewhat slower in starting.

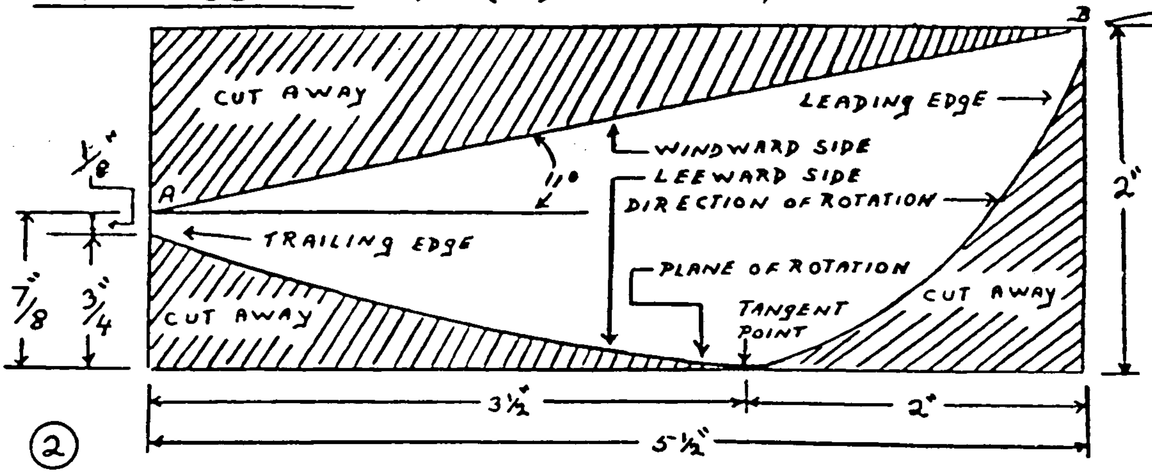
PLATE No. 44

- SAME METHOD AS PLATE No. 41 -
- DIFFERENT PITCH -
- 7' - TO - 14' - DIAMETER -

- THE AIR FOIL - ROTOR BLADE - VIII
- TEMPLATES - 7' - 14' - SINGLE PIECE -
- 11° PITCH - NON TAPERED -

(1)

CROSS SECTION - 42" (7' DIAMETER) BLADE - 11° PITCH



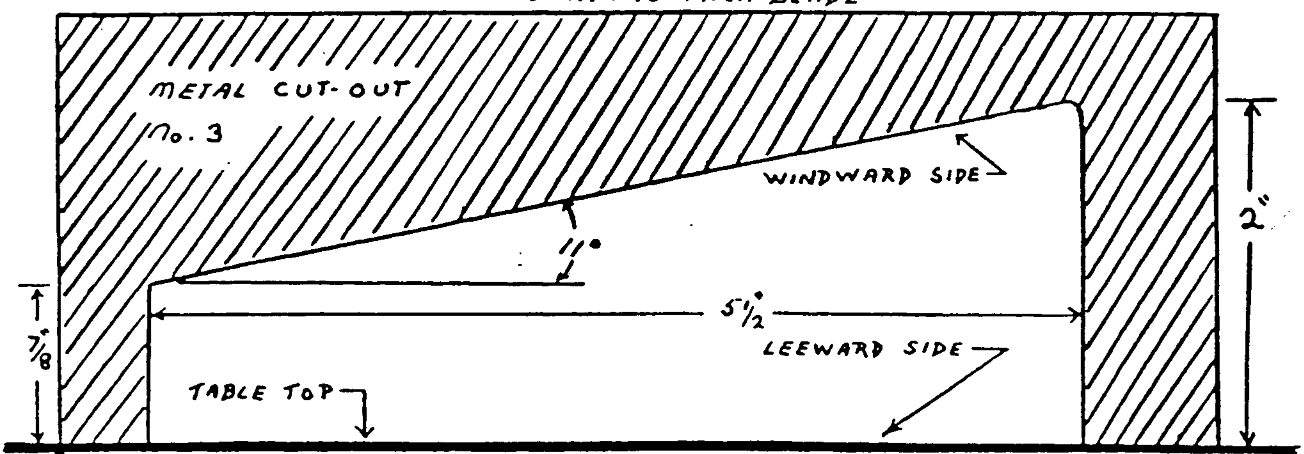
NOTE

- THE NON TAPERED BLADE - EITHER 15° OR 11° PITCH - CAN BE EXTENDED FROM 42" TO 84" - TO MAKE A (2 x 84") 14' DIAMETER ROTOR - 15° PITCH IS RECOMENDED FOR 25 MPH WINDS - 11° PITCH FOR 10 MPH WINDS -

(2)

STEP No. 1 - MAKE WINDWARD SIDE CUT-OUT - ACTUAL SIZE

- SAME INSTRUCTIONS AS WITH 15° PITCH BLADE -



(3)

STEP No 2 - MAKE LEEWARD SIDE CUT-OUT - ACTUAL SIZE

- SAME INSTRUCTIONS AS WITH 15° PITCH BLADE -

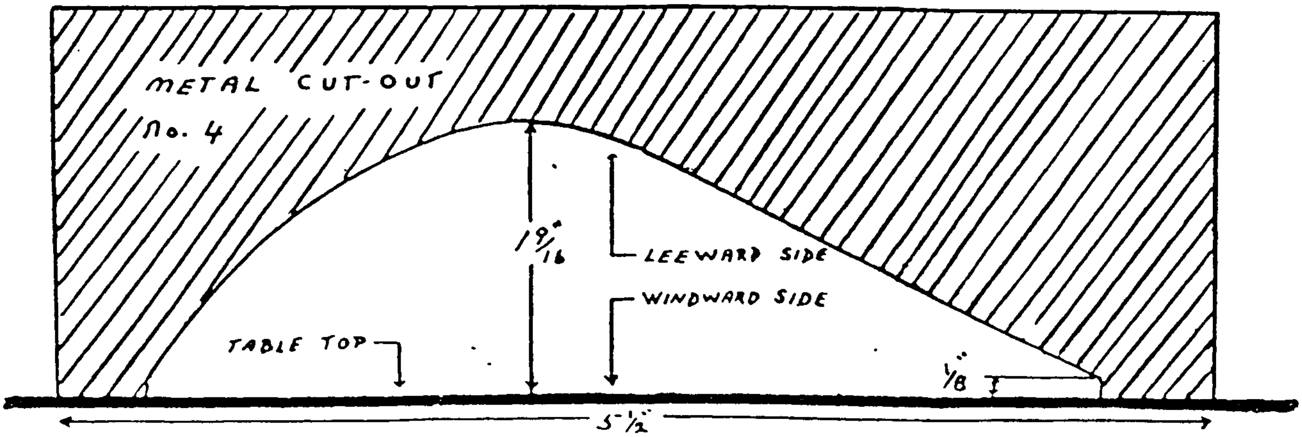


PLATE NO. 45

The wider 7" blade is designed for blade lengths of 6' to 7' 6", or maximum diameters of 14'.

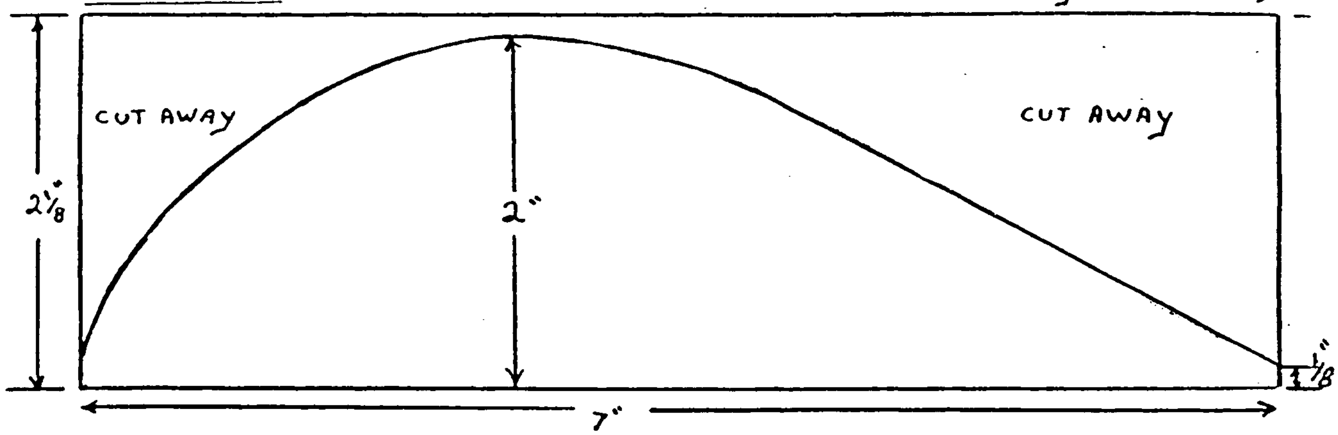
As the main strength is in the (2") tangent, the 6" butt end, (which is not shaped), can be reduced to a width of 6" so that it gets a better and stronger grip in the 12" (diameter), hub.

See notes on plates 43 and 44 (this section), for discussions on 11° and 15° pitches.

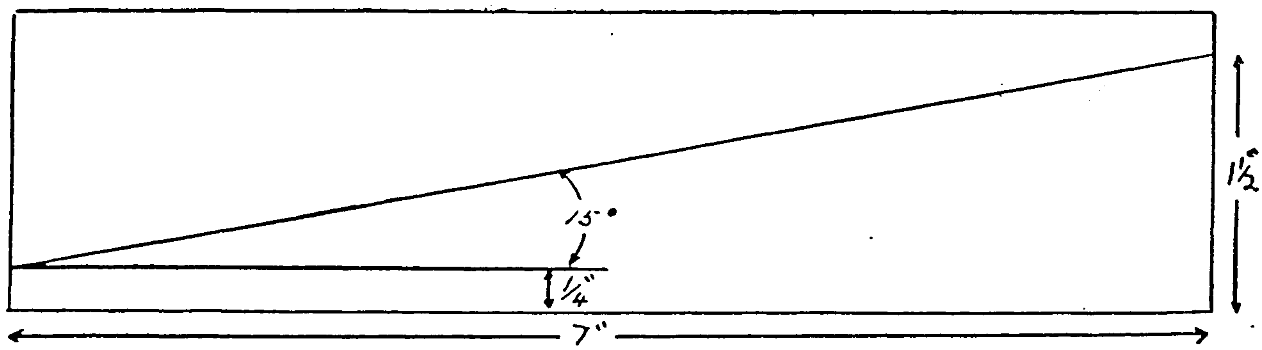
PLATE No. 45

- AIR FOIL - ROTOR BLADE - IX
- LARGER ROTOR BLADE
- MORE STRENGTH - LONGER BLADES - STRONGER WINDS -

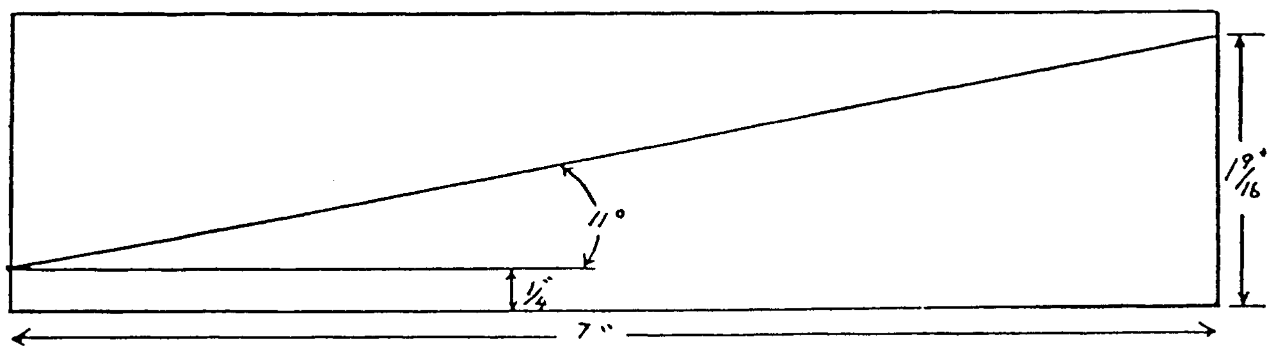
(1) END VIEW - ROTOR BLADE - FROM LAMINATED 1"X8" DRESSED PLANKS - ACTUAL SIZE - USE SAME METAL TEMPLATES AS PREVIOUSLY DESCRIBED -



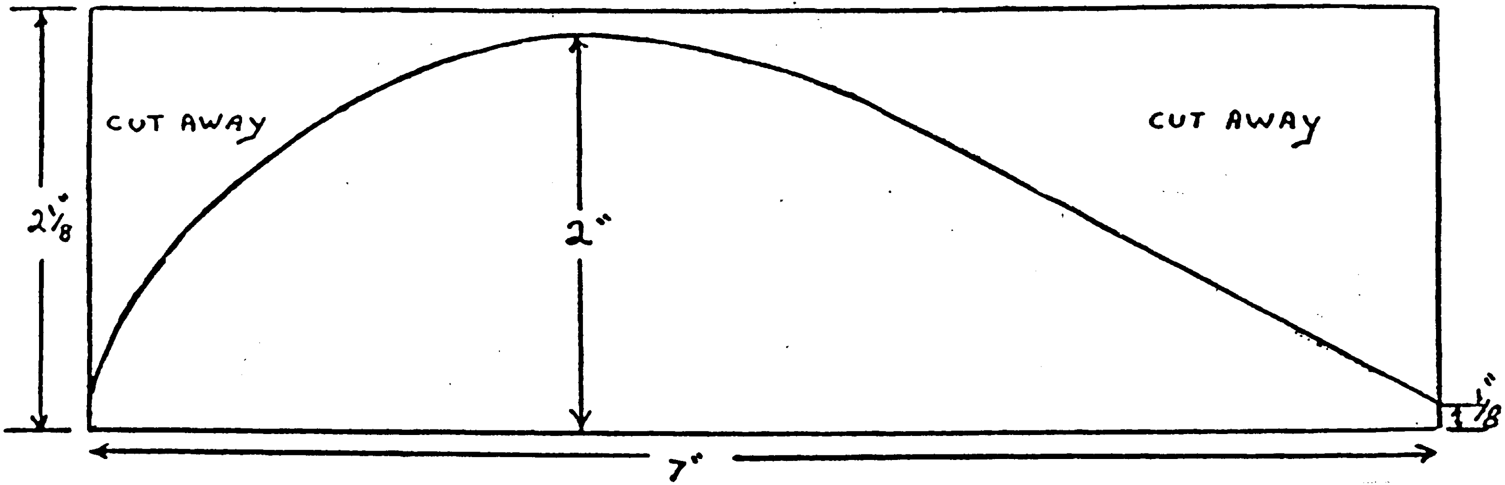
(2) END VIEW - ACTUAL SIZE - WEDGE - 15° - 10" LONG - USE TWO - AS IN PLATE IV - TO ANGLE BLADE 15° -



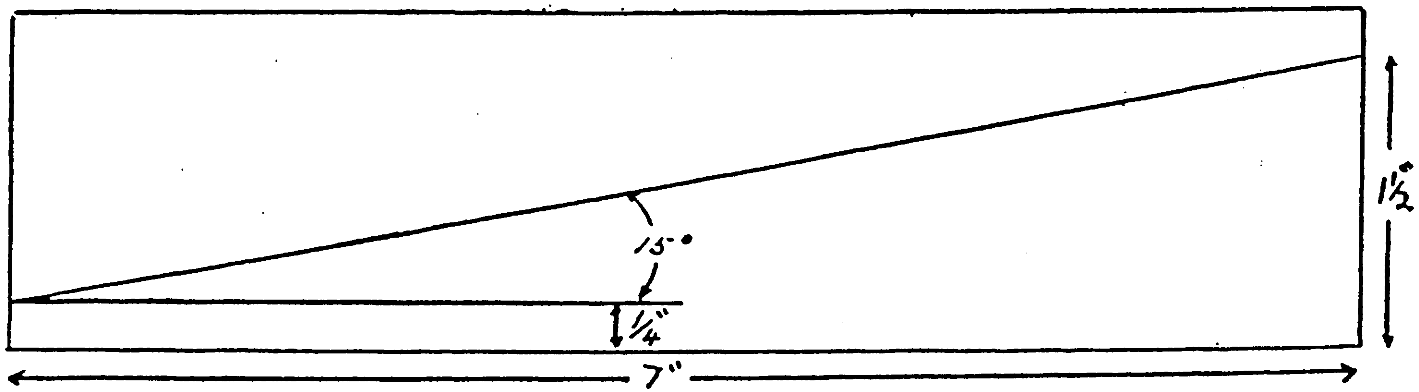
(3) END VIEW - ACTUAL SIZE - WEDGE - 11° - 10" LONG - USE TWO - AS IN PLATE IV - TO ANGLE BLADE 11°



(1) END VIEW - ROTOR BLADE - FROM LAMINATED 1"X8" DRESSED PLANKS - ACTUAL SIZE - USE SAME METAL TEMPLATES AS PREVIOUSLY DESCRIBED -



② END VIEW - ACTUAL SIZE - WEDGE - 15° - 10" LONG - USE TWO - AS IN PLATE IV - TO ANGLE BLADE 15° -



③ END VIEW - ACTUAL SIZE - WEDGE - 11° - 10" LONG - USE TWO - AS IN PLATE IV - TO ANGLE BLADE 11°

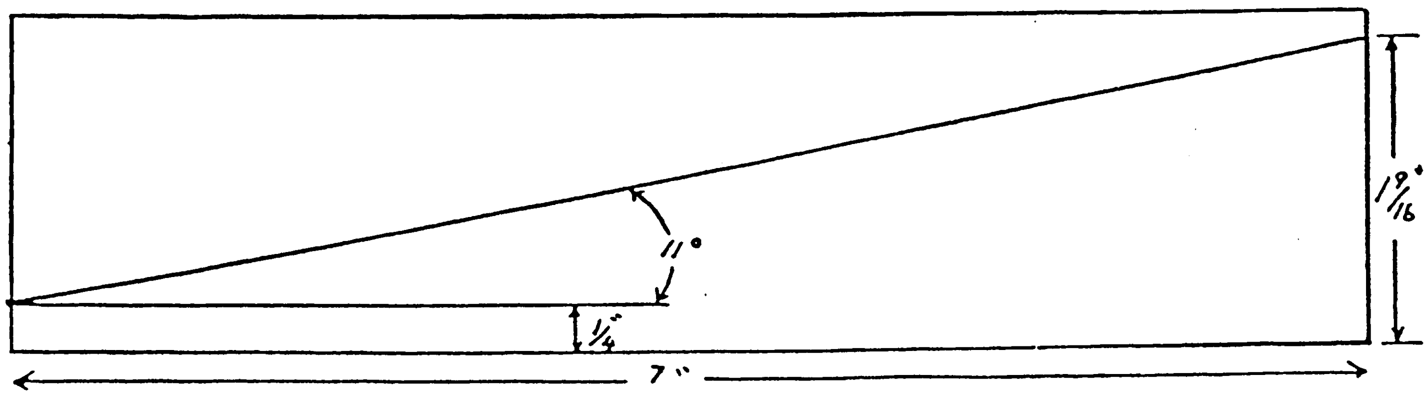


PLATE NO. 46

The butt end weight calculation in fig. 1 applies to all rotor blades.

The shaping methods in fig. 2, 3 and 4, apply only to tapered and twisted blades and only to the two blade single piece rotors, illustrated in plates 42, 43 and 44.

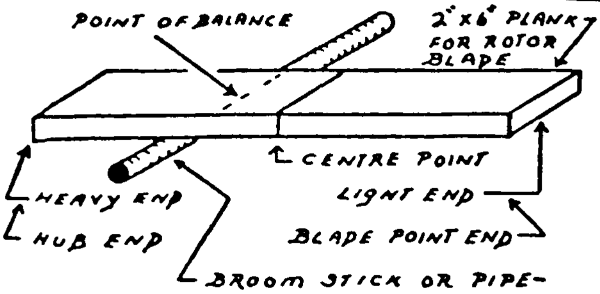
The flat centre section which fits into the hub, however, applies to all blades.

PLATE No. 46

- AIR FOIL-ROTOR BLADE-X
- TAPERED-I
- TWO BLADE-SINGLE PIECE-I
- CONSTRUCTION-

(1)

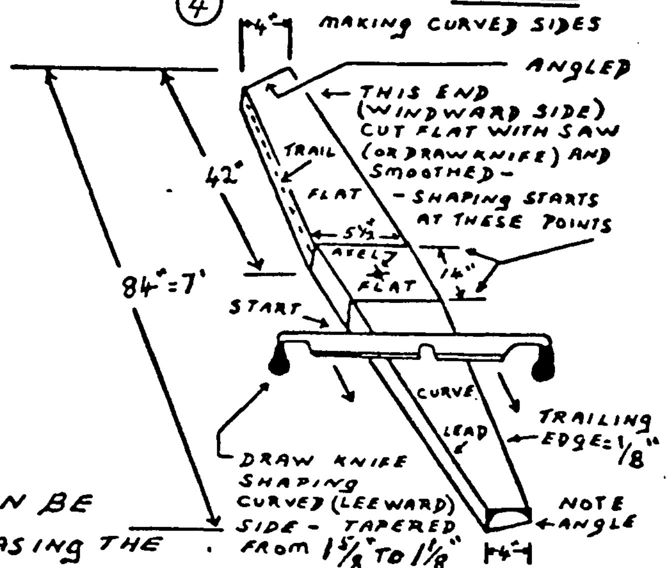
SELECT HEAVY END FOR HUB - STEP I



NOTE - PLACE BROOM STICK OR PIPE UNDER UNCUT PLANK TO SELECT HEAVY END FOR HUB.

-TEETER-TOTTER PRINCIPLE.

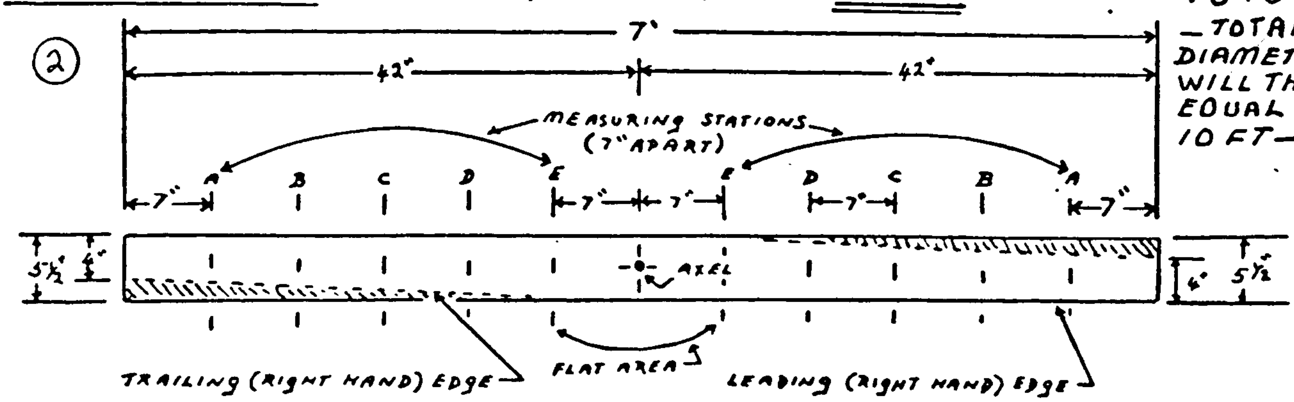
(4) FINISHING - STEP IV



NOTE - ROTOR BLADE LENGTH CAN BE EXTENDED FROM 42" TO 60" BY INCREASING THE DISTANCE BETWEEN THE STATIONS FROM 7" TO 10" AND THE FLAT AREA FROM 7" TO 10" — TOTAL DIAMETER WILL THEN EQUAL 10 FT—

TOP VIEW - SAW CUTS - 7 FT - TAPERED ROTOR BLADES - STEP II

(2)



SIDE VIEW - SAW CUTS - (RIGHT HAND SIDE) - 7 FT - TAPERED ROTOR BLADES - STEP III

(3)

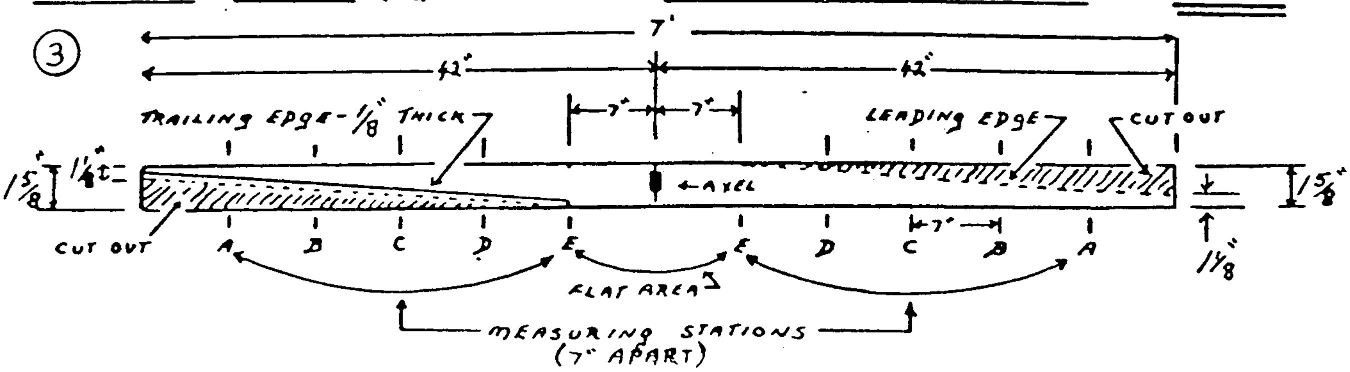


PLATE NO. 47

This is the standard tapered twisted blade that has been used for many years. The original was made of metal and shaped by machine. It is not worth the effort required for its construction. The only reason it is included is to provide a "yard stock" or basis of comparison.

To make a seven foot or seven foot six inch blade, you simply double the distance between the "stations" and keep everything else the same. The "root", or butt end, that fits into the hub, should have its width extended to no more than 6".

PLATE No. 47

AIR FOIL-ROTOR BLADE-XI

TWO BLADE-SINGLE PIECE MEASUREMENTS

-42" OR 60"-ROTOR BLADE-TAPERED-
-MEASUREMENTS-CURVED SHAPES-

-IF STATION MEASUREMENTS ARE INCREASED FROM 7" TO 10"-ALL OTHER MEASUREMENTS REMAIN THE SAME-

-TOP VIEW-SHOWS TAPER FROM TRAILING EDGE SIDE ONLY

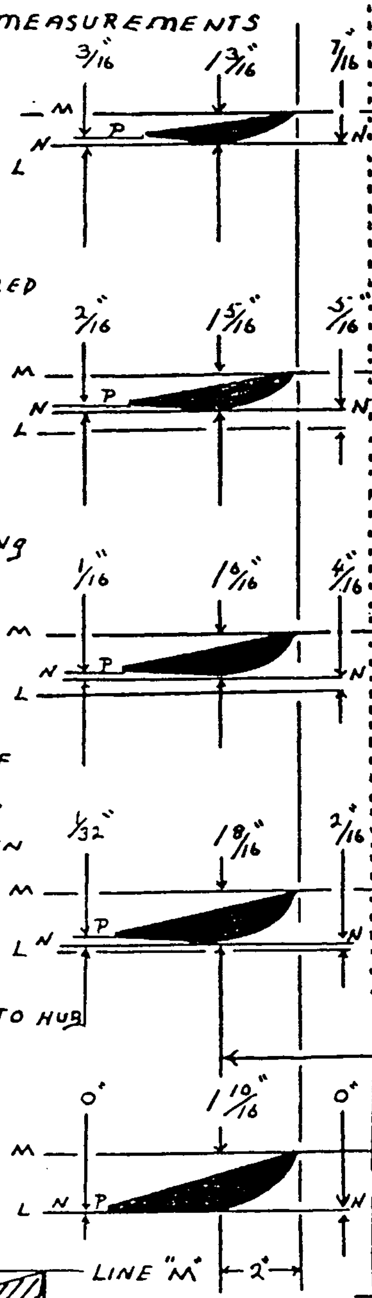
-SIDE VIEW-SHOWS PLANK THICKNES-L-M=1 5/8"-TAPERED TO 1 1/8 AT TIP SHOWN AT "N"-

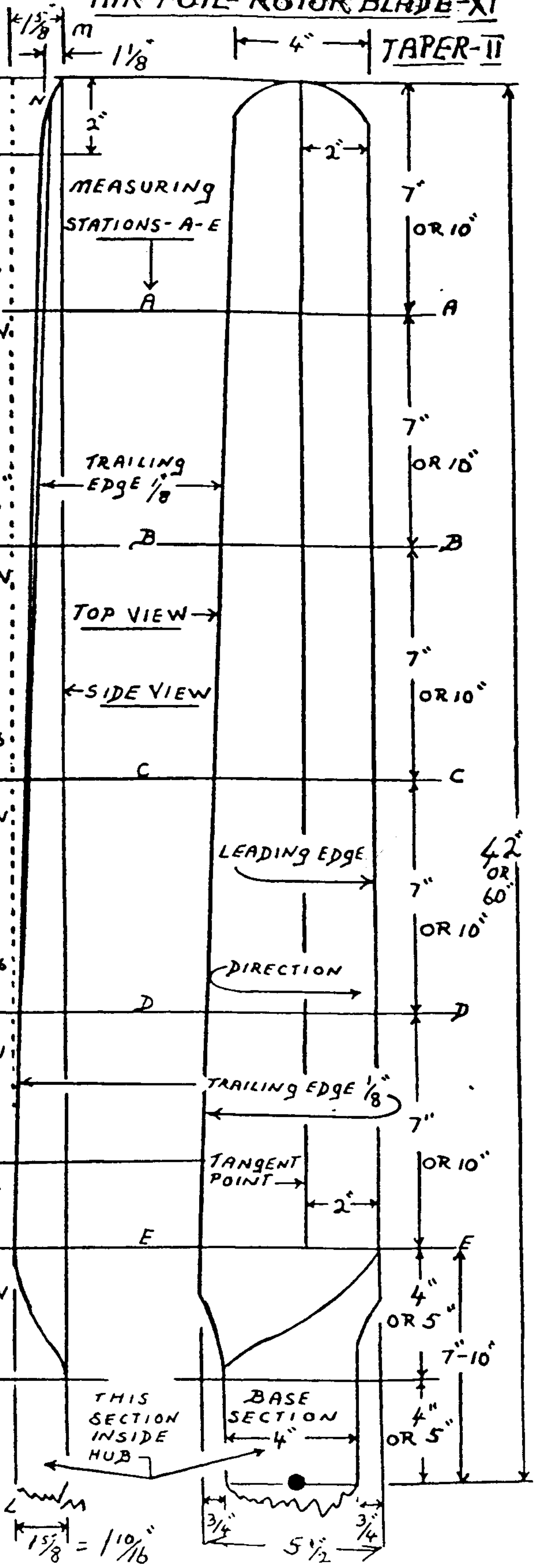
-TAPER IS SHOWN BY LINE "L-N" GETING CLOSER TO LINE "M"-

-AT TIP-DISTANCE FROM LINE "N" TO BOTTOM OF TRAILING EDGE "P"=N-P= 4/16"

NOTE-TO DOUBLE THE LENGTH OF BLADE FROM 42" TO 84" (TOTAL DIAMETER =14 FT)-JUST DOUBLE ALL OF THESE MEASUREMENTS-EG. MAKE THE DISTANCE BETWEEN THE STATIONS = 14" ETC.

-TRAILING EDGE REMAINS AT 1/8"-EASE SECTION CAN BE 7" OR 8" ACROSS-TO FIT INTO HUB





METHOD OF CONSTRUCTING METAL TEMPLATES FOR EACH MEASURING STATION-"A" TO "E"-

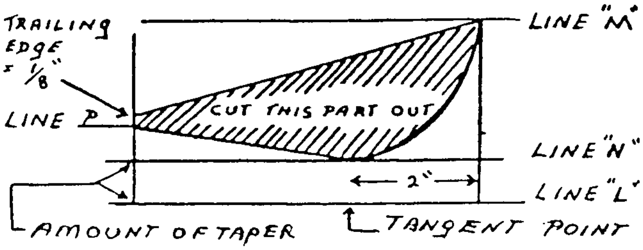


PLATE NO. 48

The sail windmill can be the most efficient of all wind machines if proper modern airfoil cut sails are used. A great deal of development money has been spent to perfect such sail designs for world class yacht races, like the Americas Cup.

It might even be a good idea to tailor your mast lengths to the size of the sails you can buy.

Home made sails will work, they just do not work as well.

If you use "store bought" sails, you should also use the masts that are designed to go with them. Tailor the hub thickness accordingly.

The disadvantage of the sail windmill is that the sails have to be taken down, or furled, (fig. 3), in foul weather. They are, therefore, not ideal for northern hemisphere winters.

The theory, or principle, is that the windmill sail operates in the same way as the jib sail on a yacht, (see 1, 2, 3 and 4). The jib sail in fig. 4 looks just like the windmill sail in fig. 1.

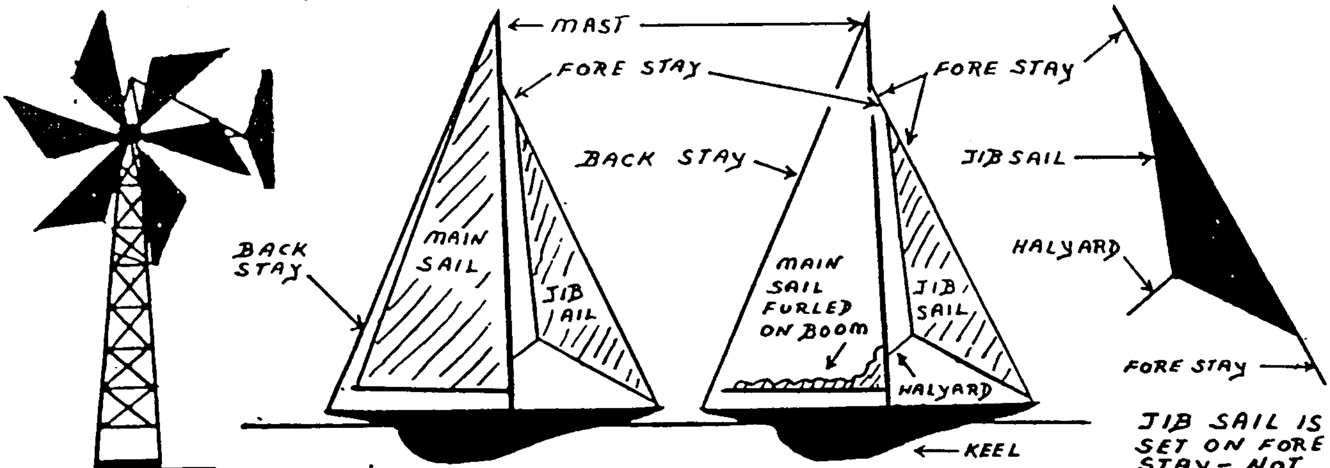
Fig. 5 and 6, show that the windmill sail works in the same way as the sail on a yacht when the yacht is sailing on a "beam reach".

A six sail windmill, therefore, has the same power as a yacht with six jib sails sailing on a beam reach.

PLATE No 48

- THE SAIL WINDMILL - I
- PRINCIPLES -

- WORKS LIKE JIB SAIL ON SAIL BOAT - WHEN BOAT IS SAILING ACROSS, OR AT RIGHT ANGLES TO THE WIND ON A "BEAM REACH" -



SAIL WINDMILL

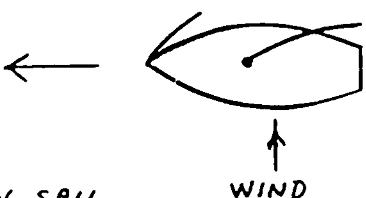
RACING YACHT - BOTH SAILS SET

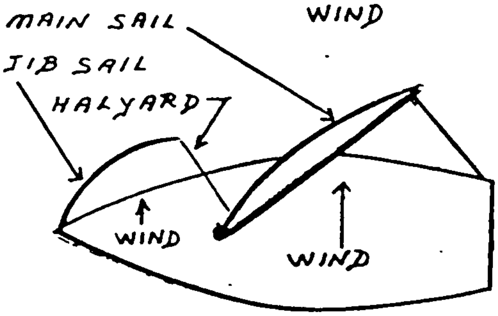
SAME YACHT WITH ONLY JIB SAIL SET

JIB SAIL IS SET ON FORE STAY - NOT ON THE MAST - AS IT IS WITH THE SAIL WINDMILL -

VESSEL SAILING ON BEAM REACH

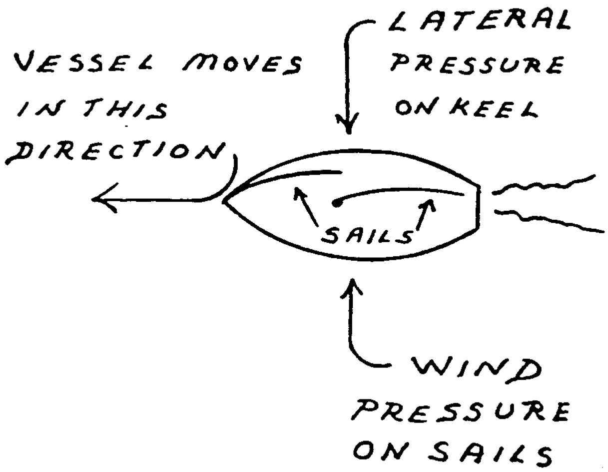
- WIND COMES OVER SHIPS SIDE (BEAM)





CORRECT SAIL SET FOR BEAM REACH - SAILING ACROSS THE WIND - AS FAR OUT AS SAILS WILL GO WITHOUT "LUFFING" - OR FLAPPING - AT THE FOREWARD

HOW VESSEL SAILS ON A BEAM REACH



NOTE - WIND DIRECTION IS 90° TO DIRECTION OF VESSELS MOVEMENT -

- SAIL WINDMILL WORKS IN THE SAME WAY - EXCEPT THAT TOWER RESISTANCE TAKES THE PLACE OF KEEL RESISTANCE OR PRESSURE -

EDGE CLOSE TO THE MAST OR FORESTAY - THE SAIL WINDMILL SHOULD BE SET IN THE SAME WAY - AIR FOIL PRINCIPLE -

PLATE NO. 49

These designs are all for 15' masts and 30' diameter sail areas, (see plate no. 2), which are most effective in areas having expected annual seasons of very light winds.

For areas where the expected norms are for winds of 10 m.p.h., or more, the mast lengths can be reduced to 7' 6" and the sail diameters to 15'. All given measurements will apply in terms of the reduced scale.

The mast thickness here recommended for all mast lengths is the dressed Douglas Fir or Pine, 2" X 2" which actually measures 1 1/2" X 1 1/2".

Fig. 1, 2 and 3 show how the sails in fig. 1 can be "furled" to reduce the sail areas so that they resemble the sails in plate no. 2.

Sail sizes are reduced in area by "reefing" for reasons of safety, when wind speeds indicate that they might increase to alarming proportions.

To reef a sail, you take the selected reef strings, hanging from the reef points (fig. 3), and tie them together around the long side of the sail. Be sure to use proper "reef knots", or the reefs will be impossible to untie when you want to increase the sail areas.

Fig. 3 and 4 shows how the stays and halyards work. "Stays" are permanent support wires, while halyards are working ropes that run through a pulley.

The "triadic" stay is a wire cable that runs from masthead to masthead, as it does on a schooner, and, thereby, creates the permanent unbreakable circle.

The "halyard" ropes work through the pulleys on the mastheads to pull the sails up and out. The halyard ends must be coiled and tied off, or cleated, at the bottoms or "feet" of the masts.

The sail windmill, especially with the 30 diameter sails, is designed to work on the wooden rotating table. Fifteen foot diameter sails, however, can be mounted on a metal rotating table, (see references in the "design relationships" section).

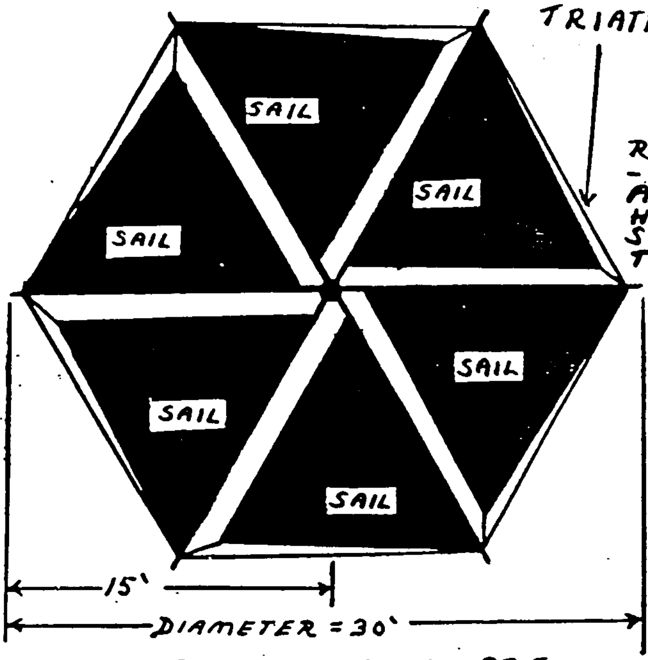
PLATE No. 49

THE SAIL WINDMILL II

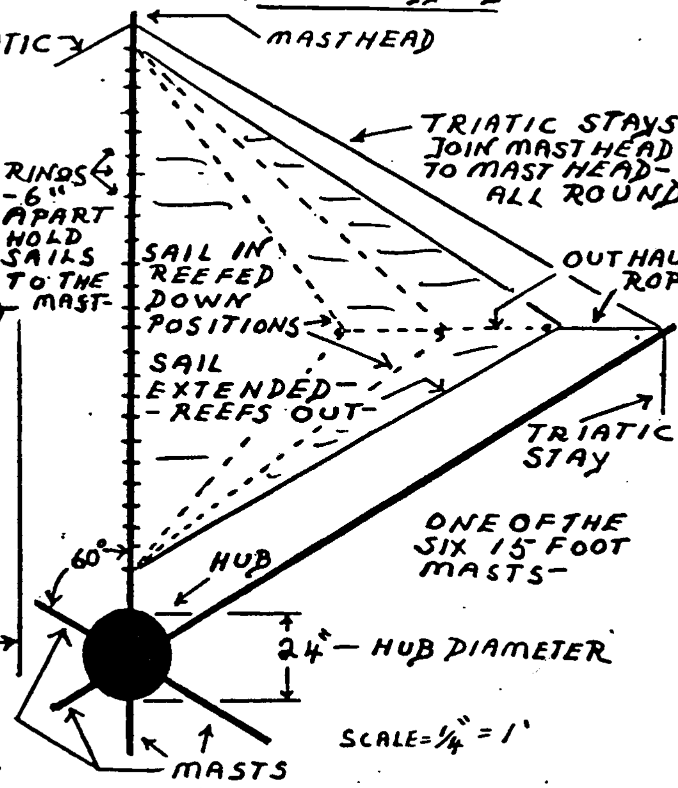
THE SAILS

- 30 FOOT DIAMETER WINDMILL — FOR AREAS WHERE WINDS ARE VERY LIGHT — OR TO CATCH DAILY ON SHORE BREESES AS IS DONE IN CRETE — TO MAKE SMALLER - 15 FOOT DIAMETER MACHINE - SIMPLY DIVIDE ALL DIMENSIONS BY 2 —

SAIL AREA - FRONT VIEW

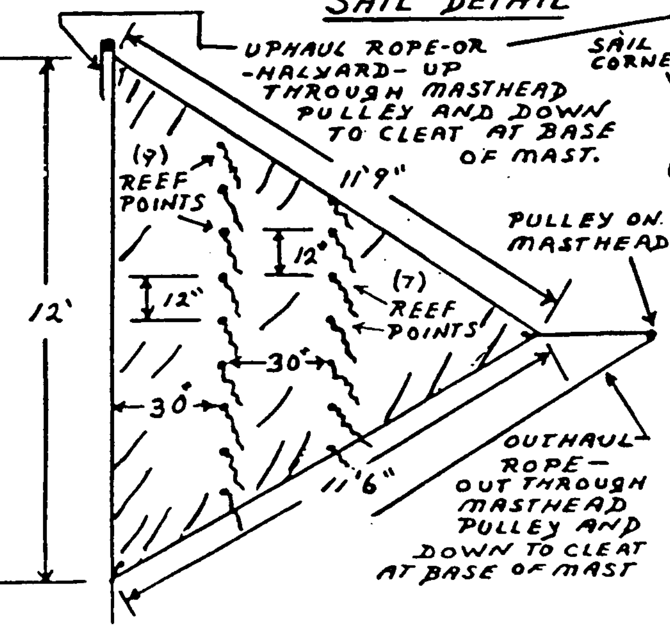


SAIL RIGGING



NOTE - ABOVE, ALL SALES ARE FULLY SET, FOR A VERY LIGHT BREESE - REEFS REDUCE SAIL SIZE TO DOTTED LINE AREAS.

SAIL DETAIL



RIGGING OVERVIEW

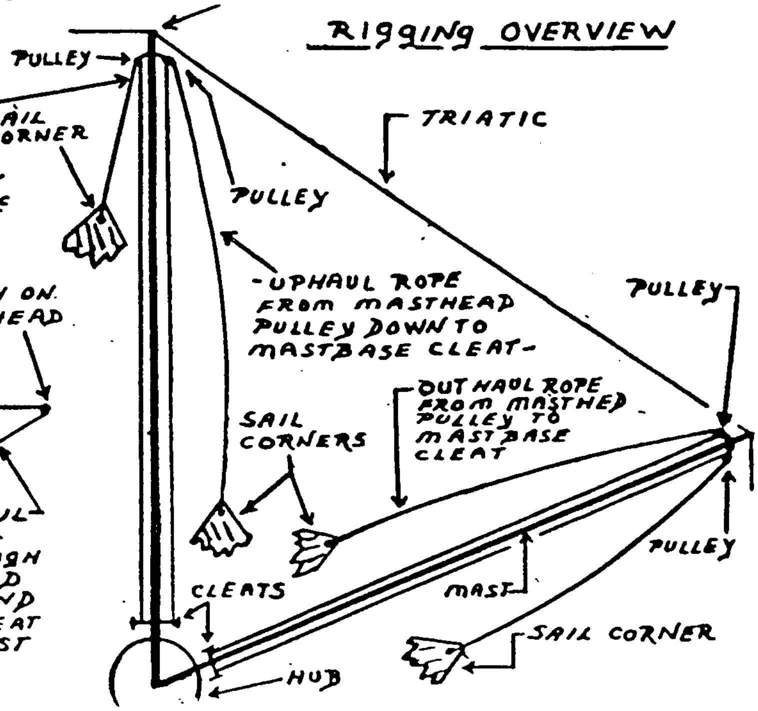


PLATE NO. 50

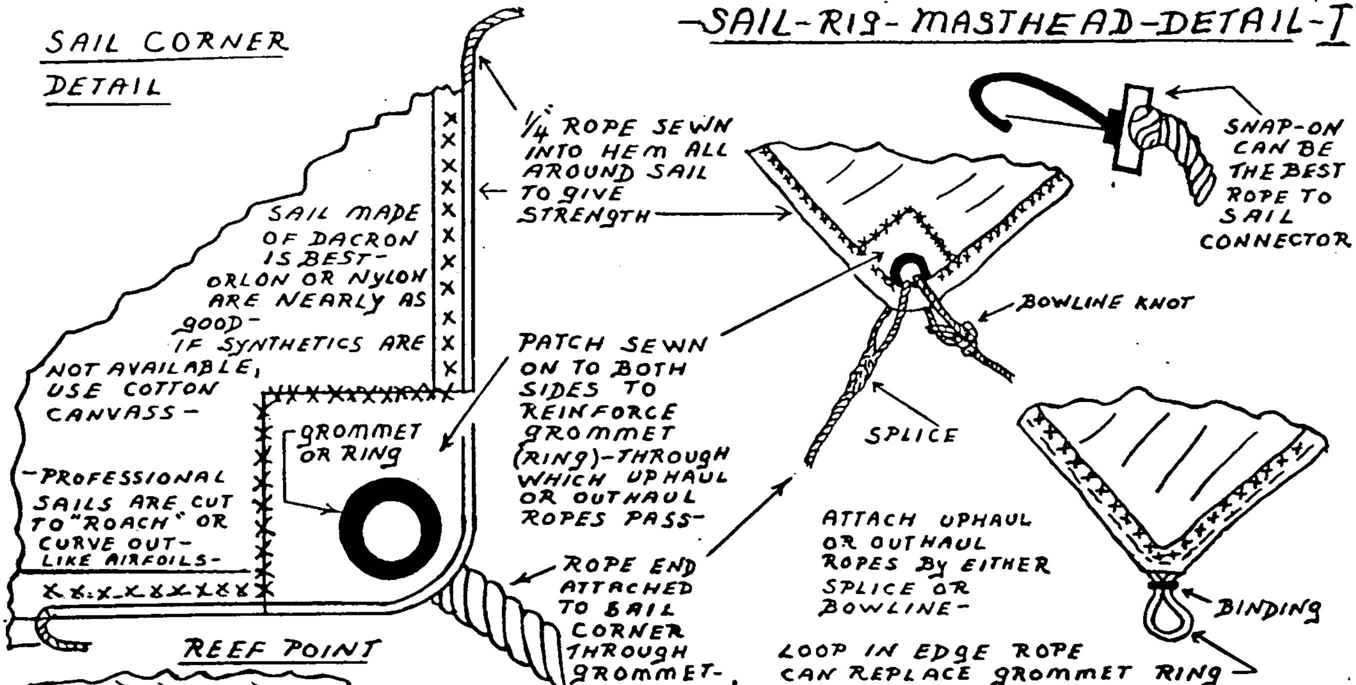
Fig. 1 to 6 show sail fittings that can be made at home or bought from marine supply stores.

Fig. 7, 8 and 9 show an easy to build masthead cap that will accommodate the stay cables and the cables that hold onto halyard pulleys.

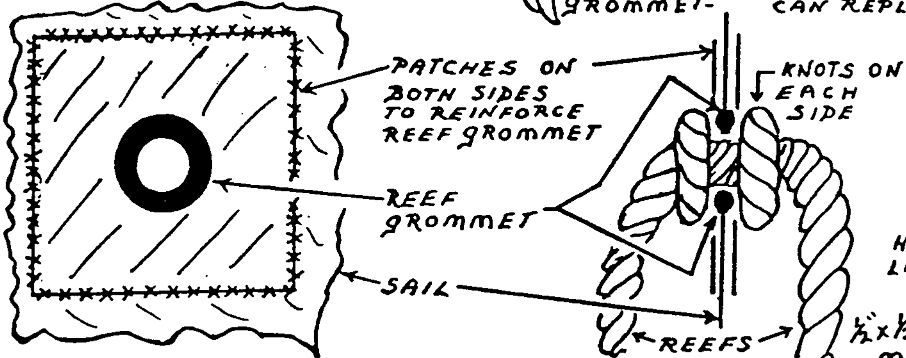
PLATE No. 50

-THE SAIL WINDMILL III
-SAIL-RIG-MASTHEAD-DETAIL-I

SAIL CORNER DETAIL



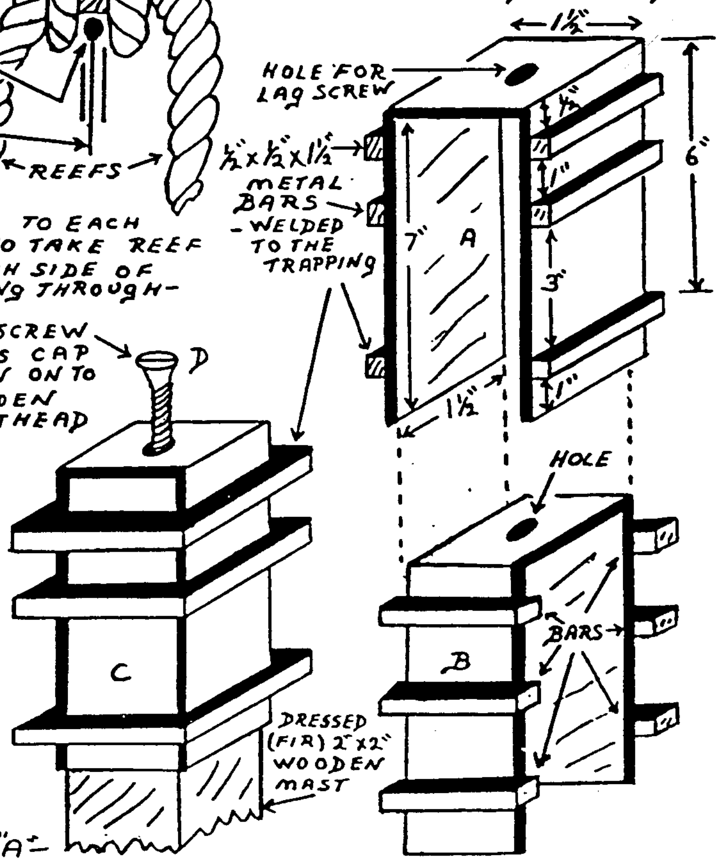
REEF POINT



NOTE - 12" REEFS HANG DOWN ON EACH SIDE OF SAIL - TO BE TIED TO EACH OTHER ON MAST SIDE OF SAIL - TO TAKE REEF OR TUCK IN SAIL - KNOTS ON EACH SIDE OF GROMMET PREVENT REEFS SLIPPING THROUGH-

MASTHEAD CAP

DETAIL-SHOWING RIDGES TO TO SECURE STAYS + PULLEYS



MASTHEAD CAP- (CONTINUED)

NOTE - "A" AND "B" ARE PIECES OF 1 1/2 X 1/8 METAL STRAPPING - 1/2" X 1/2" METAL BARS ARE WELDED TO THE STRAPPING TO FORM THE RIDGES TO GRIP THE STAY AND PULLEY CABLES.-

-"B" FITS INTO "A" TO FORM "C" AND IS HELD DOWN ONTO (FIR) WOODEN DRESSED 2"x2" MAST BY 2" LAG SCREW "D"-

-"B" DOES NOT HAVE TO BE WELDED TO "A"-

PLATE NO. 51

Fig. 5, 6 and 7, show ring fittings that hold sails to masts that can be made at home. The only problem is that as the rings have to run up and down the whole length of the mast, which means that you can only have one fore stay, you can not have a second fore stay running of the rings from the top to the bottom of the mast.

The car and rail systems, shown in figures 8, 9 and 10, allow for the second fore stay, as illustrated in plate no. 53, fig. 5. These systems can be purchased, in total, from marine supply stores.

Fig. 10 shows an alternative that can also be purchased from marine supply stores. It also permits the use of a second fore stay at the centre of the mast. Fore stays run foreword and support the mast against the force of the wind.

Note the masthead stay and halyard arrangements, illustrated in fig. 1, 2, 3 and 4.

Fig. 11 shows the cleat arrangement at the base of the mast for tying off the halyards. The cleats can also be placed on the hub at the base of each mast, (see plate no. 52, fig. 3).

PLATE No 51

—THE SAIL WINDMILL IV
—MAST HEAD AND RIG DETAIL—II

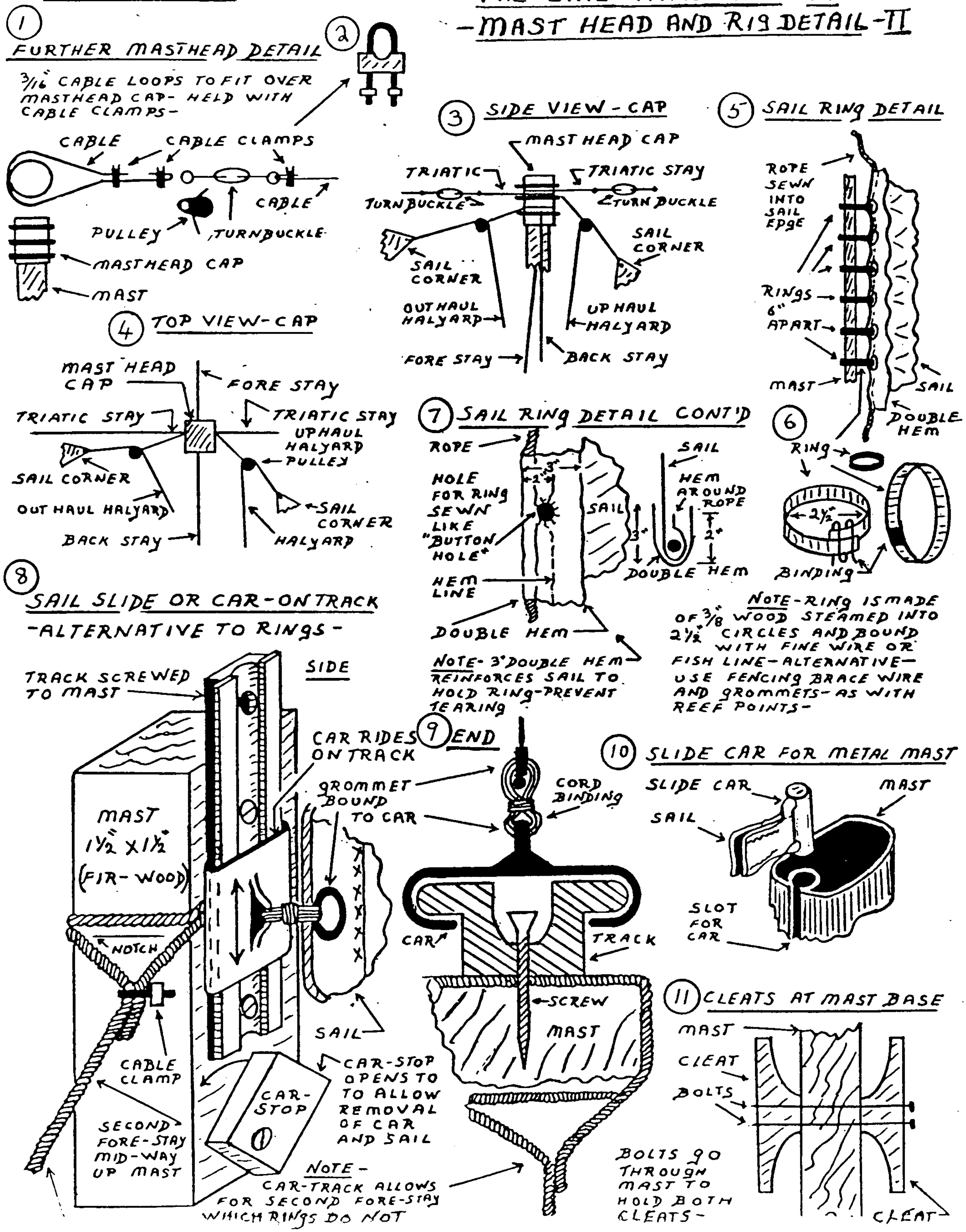


PLATE NO. 52

The hubs in fig. 1, 2, 3 and 4, work in the same way as the metal hub in plate no. 17. Take special note of plate no. 17, fig. 3.

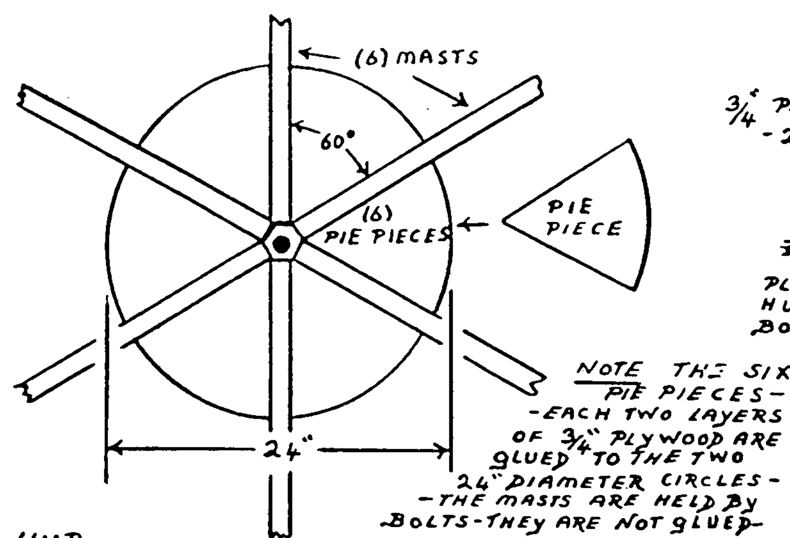
Fifteen foot diameter sails can have a 12" diameter hub, but 30 foot diameter sails should have a 24" diameter hub. This is a question of properly “stepping” the mast.

Fig. 5 shows the need for the four leg metal tower to give proper support to the cable that supports the 18' tail vane for the 30 foot diameter sails. This tower will not be needed on 15' diameter sails. They can use the tail vane system illustrated in plate no. 36.

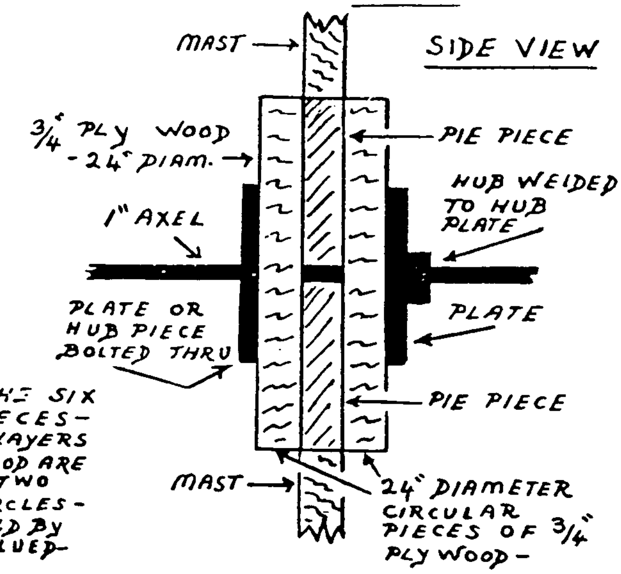
PLATE No. 52

-THE SAIL WINDMILL V
-THE HUB - TAIL VANE - ROTATING TABLE -

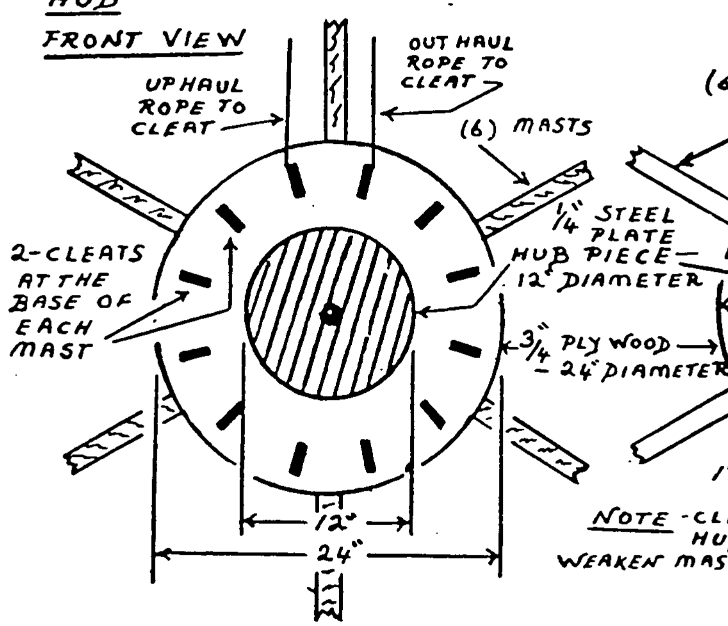
THE HUB
FRONT VIEW



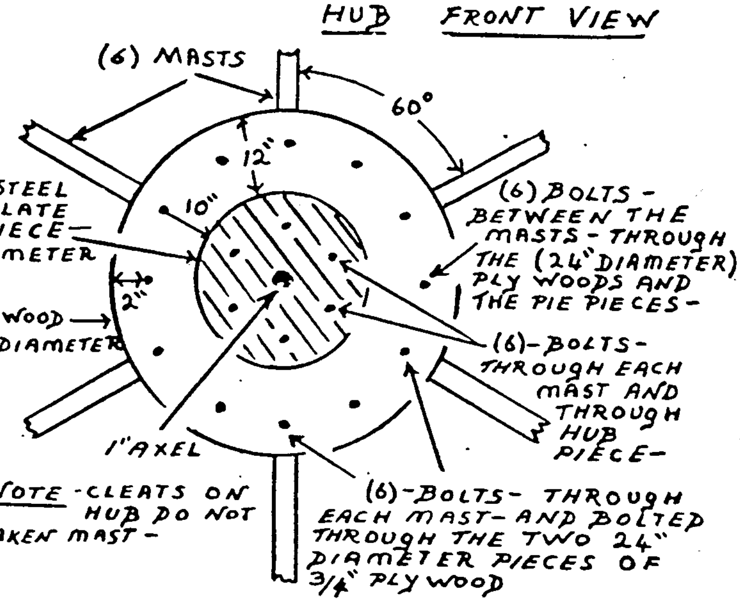
SIDE VIEW



HUB
FRONT VIEW



HUB FRONT VIEW



TAIL VANE AND TOWER

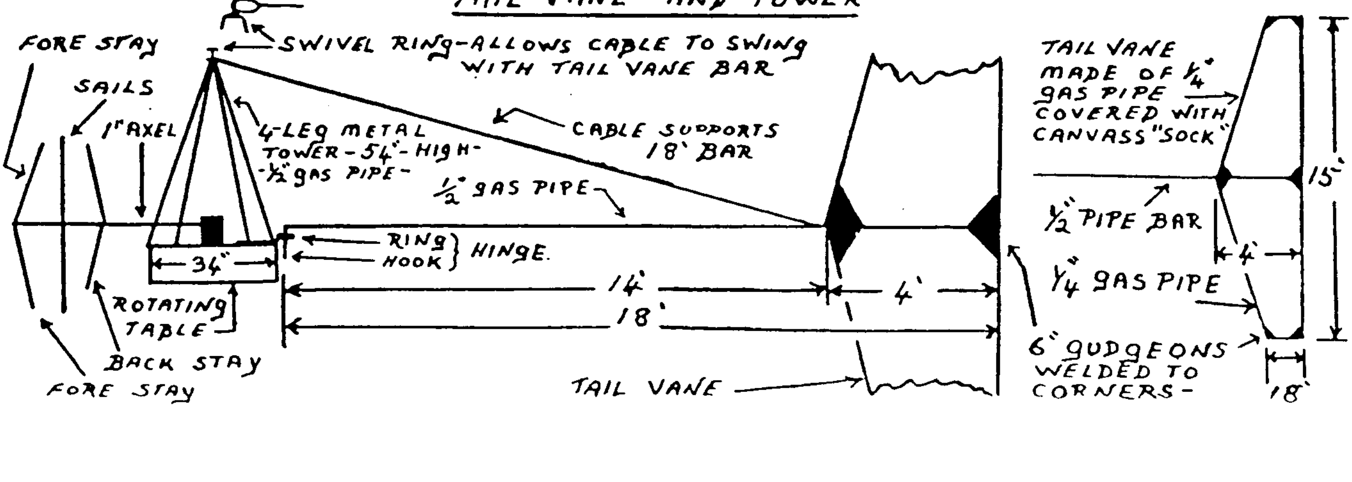


PLATE NO. 53

Fig. 1 and 2, show the "sock type" tail vane in which a canvas "sock" is sewn over a light (1/4" gas pipe), metal frame and then given a few coats of paint to make it stiff. The advantage of the "sock" type is its lightness, a necessary factor on an 18' tail vane bar.

Fig. 3 and 4 show how the fore stays hook onto the nose ring. The nose ring is constructed in the same way as the metal hub, illustrated in plate no. 17.

The nose ring is placed on the axle, 4' ahead of the main hub (fig. 5), in order to give proper support to the fore stays. If possible, you should use two fore stays because the wind force is always on the front side of the masts. Good support is necessary, especially if you use masts of 2" X 2" Douglas Fir or Pine.

Note also, the "back up hub", 4' behind the main hub. The purpose of the back up hub is to give proper support to the (wire cable) back stays.

This means that the main hub must be at least 4' 6" ahead of the thrust bearing on the rotating table. To take this strain, the axle should be at least 1 1/2" diameter. A 2" diameter axle would be better.

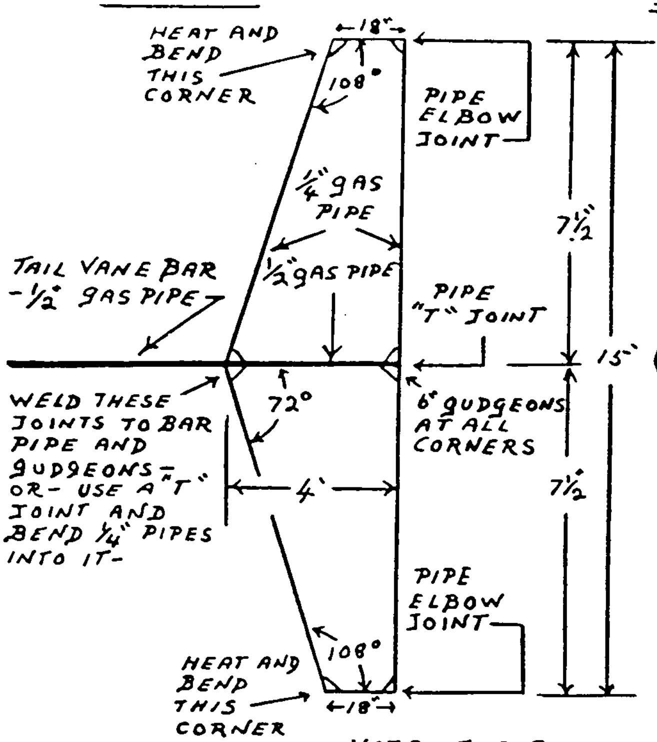
The 4' distance between the back up hub and the main hub also puts a lot of leverage, (upward pressure), on the second (ball bearing), pillow block. Make sure everything is very secure. This is a good argument for the wider, (wooden), rotating table that is possible on the concrete block tower, illustrated in plate no. 2.

Always make a scale drawing to make sure that the sail tips will not strike the tower legs.

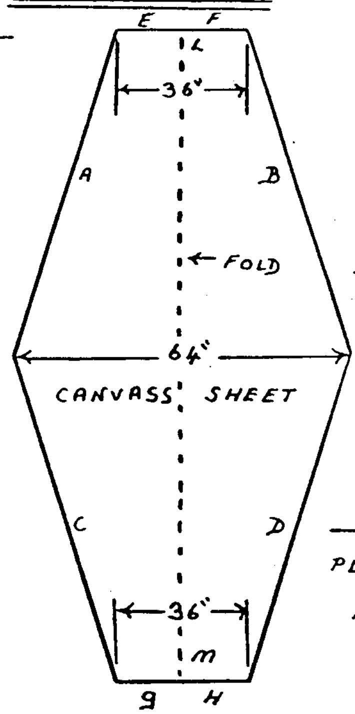
PLATE No. 53

-THE SAIL WINDMILL VI
-THE TAIL VANE II
-FORE AND BACK STAYS- HUBS-

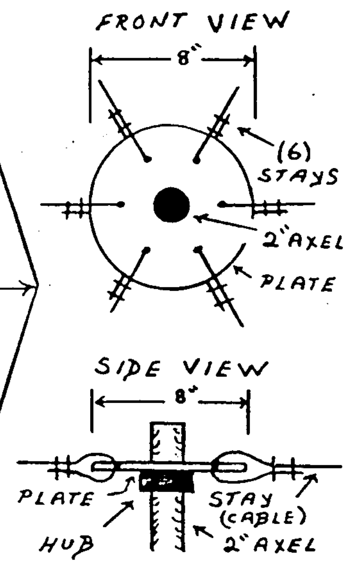
TAIL VANE



TAIL VANE SOCK



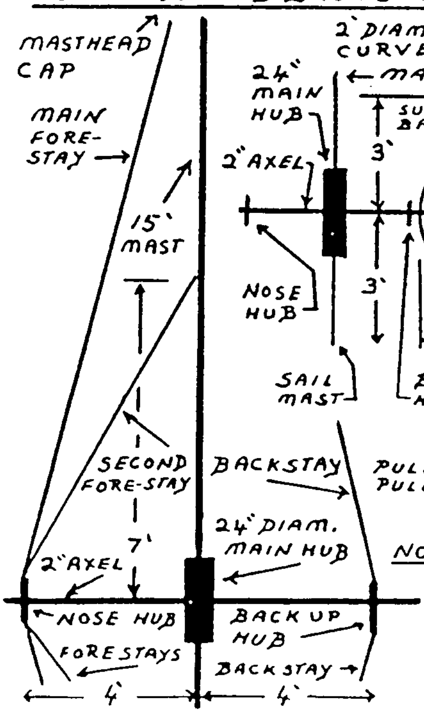
BACK UP HUB - OR NOSE RING



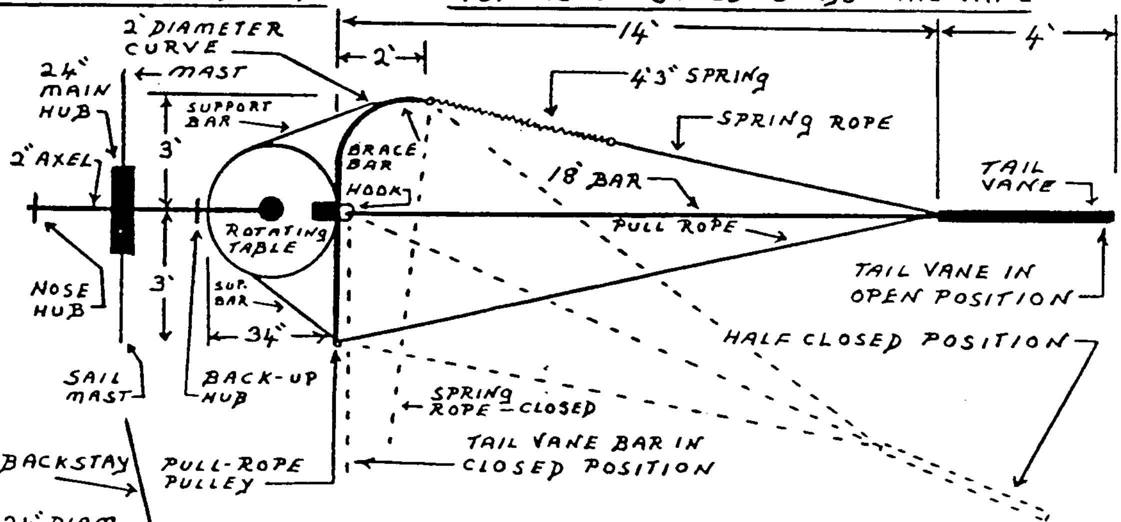
NOTE - THE BEST METHOD IS TO DRAW ACTUAL SIZE TAIL VANE ON SHOP FLOOR - BEND PIPES ACCORDINGLY TO ASSURE THAT ALL ANGLES -TOP AND BOTTOM- ARE THE SAME-

CANVASS SOCK- CUT TO SHAPE- FOLD ALONG DOTTED LINE -L- M- FIT OVER TAIL VANE PIPES- SEW; E TO F- G TO H- A TO B- C TO D-

FORESTAYS AND BACK STAYS-SIDE-



TOP VIEW SAILS-STAYS-TAIL VANE



NOTE - SECOND FORESTAYS CAN ONLY BE USED WITH SLIDE CARS AND MAST TRACK- NOT WITH SAIL RINGS-

NOTE - 1 1/4" OR 1 1/2" DIAMETER ALUMINUM PIPE CAN BE SUBSTITUTED FOR 2" x 2" FIR FOR THE MAKING OF MASTS - IN SOME COUNTRIES BAMBOO IS USED-

NOTE - MAST LENGTH CAN BE REDUCED TO 10' OR 5' WITH SIMILIAR REDUCTIONS TO ALL OTHER MEASURENTS EXCEPT ROT. TABLE-

PLATE NO. 54

It is recommended that the fan of a tractor trailer type truck, a "Mack", or a Detroit or a Cummins diesel engine be used.

The fans of stationary caterpillar diesel engines are also very good, but they tend to be expensive, even if they are second hand.

Whatever second hand or junk yard fan you choose, make sure that it is in perfect condition. A bent fan that you take home and straighten yourself is not a good idea because the aeronautical curve will not be perfect.

Remember, the wider the blade tip, the sooner it will start and the greater the bottom end torque will be. A narrower tip, however, will turn faster. In other words, it will achieve a higher tip end R.P.M.

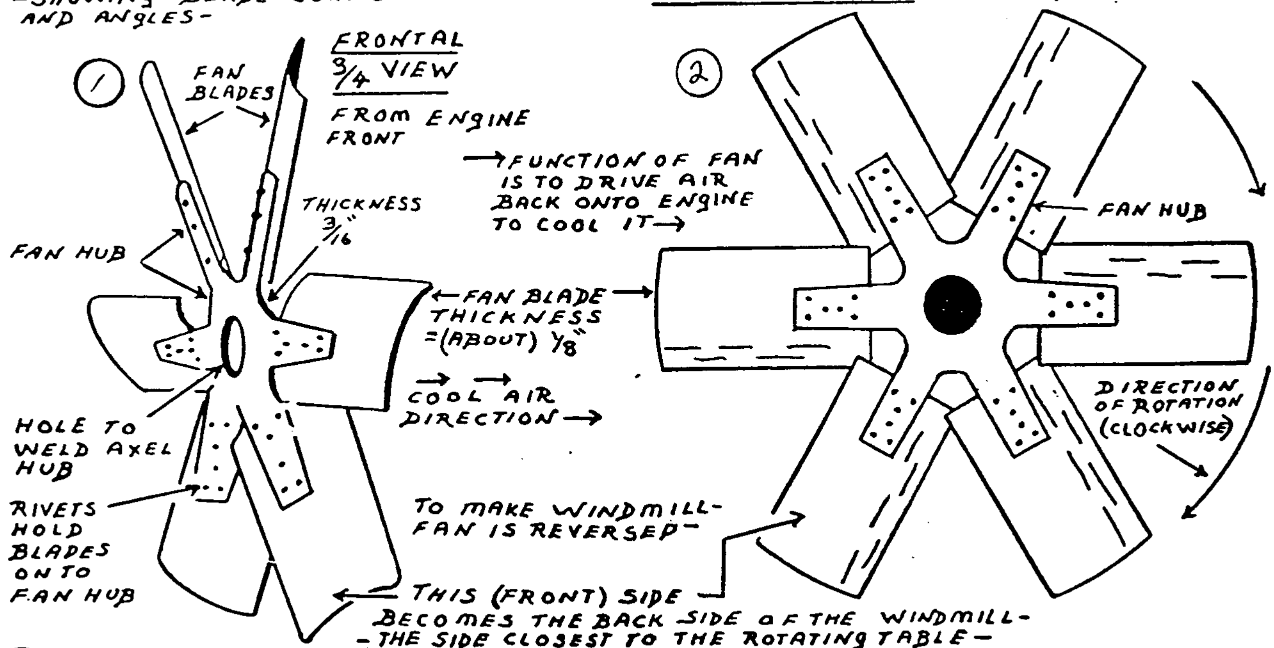
PLATE No. 54

DESIGN ALTERNATIVE I
BIG TRUCK FAN BLADE
STEEL DRUM SAILS

-6 BLADE FAN

(ALLIS-CHALMERS HIGH SPEED DIESEL) -SHOWING BLADE CURVES AND ANGLES-

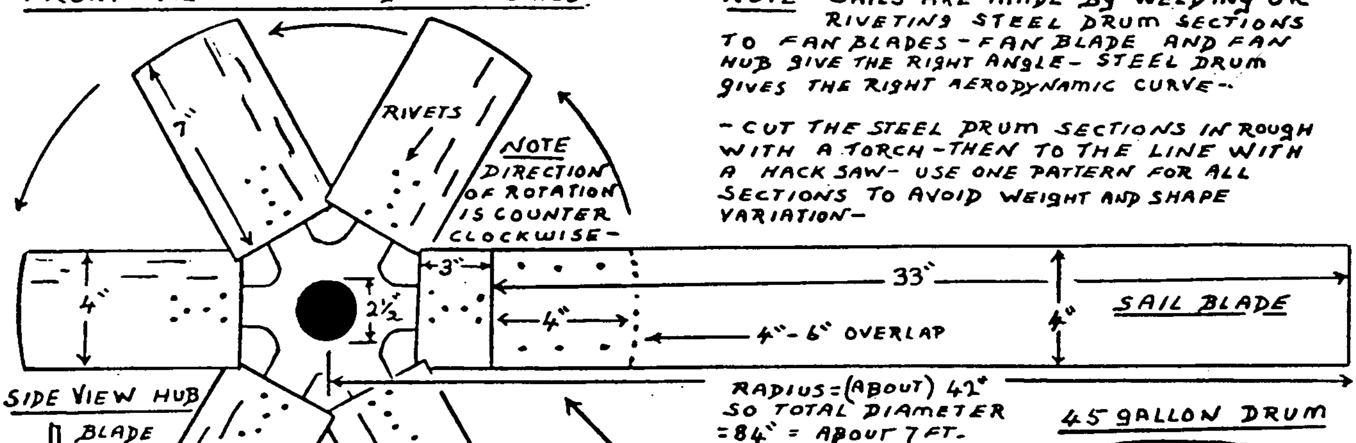
FULL FRONT VIEW - FROM ENGINE FRONT

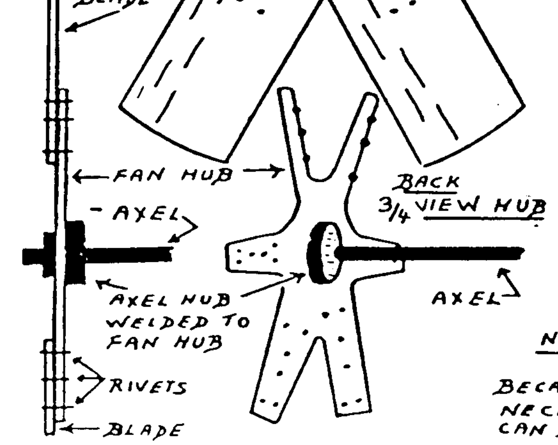


3 BACK VIEW OF ENGINE FAN = FRONT VIEW OF WINDMILL SAILS

NOTE- SAILS ARE MADE BY WELDING OR RIVETING STEEL DRUM SECTIONS TO FAN BLADES - FAN BLADE AND FAN HUB GIVE THE RIGHT ANGLE- STEEL DRUM GIVES THE RIGHT AERODYNAMIC CURVE-

- CUT THE STEEL DRUM SECTIONS IN ROUGH WITH A TORCH - THEN TO THE LINE WITH A HACK SAW - USE ONE PATTERN FOR ALL SECTIONS TO AVOID WEIGHT AND SHAPE VARIATION-





STEEL DRUM SECTION SAILS ARE RIVETED TO FAN BLADES-

-DOUBLE THICKNESS OF STEEL DRUM SECTION CAN BE USED FOR ADDED STRENGTH - THEY CAN BE JOINED IN SUCH A WAY AS TO GIVE EXTRA LENGTH OF SAIL-

NOTE - NO BACK UP HUB OR BACK BRACING IS SHOWN, BECAUSE PROBABLY IT WILL NOT BE NECESSARY- ¼" IRON BARS, HOWEVER, CAN BE WELDED UP BACKS OF SAILS-

45 GALLON DRUM

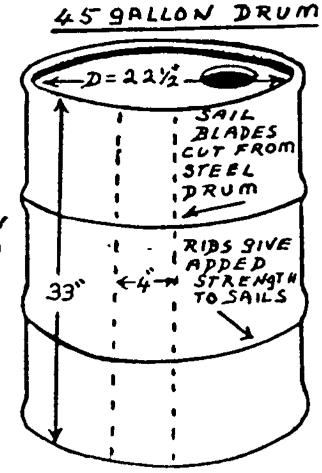


PLATE NO. 55

This design can use the big truck fan blade (plate 54), or just about any other sail blade design that takes your fancy, (see "Design Relationships - "T").

The same can be said of bearing and hub types, (see plates no. 15 and 16 for wood and metal bearings, and plates 6 and 17 for wood and metal hubs).

It can, in fact, be set up to do any kind of wind machine work you desire.

It is multidirectional, in that it has no tail vane. You just have to pick it up by hand, and face it into the wind. The weights are necessary to hold it down.

Note the gas pipe axle crank shaft, illustrated in plate no. 60, fig. 4. To use this, you will have to "break" the axle in the middle and place two extra bearings, one on each side of the crank shaft.

See also the "pump plans", illustrated in plate no. 61 through to 65.

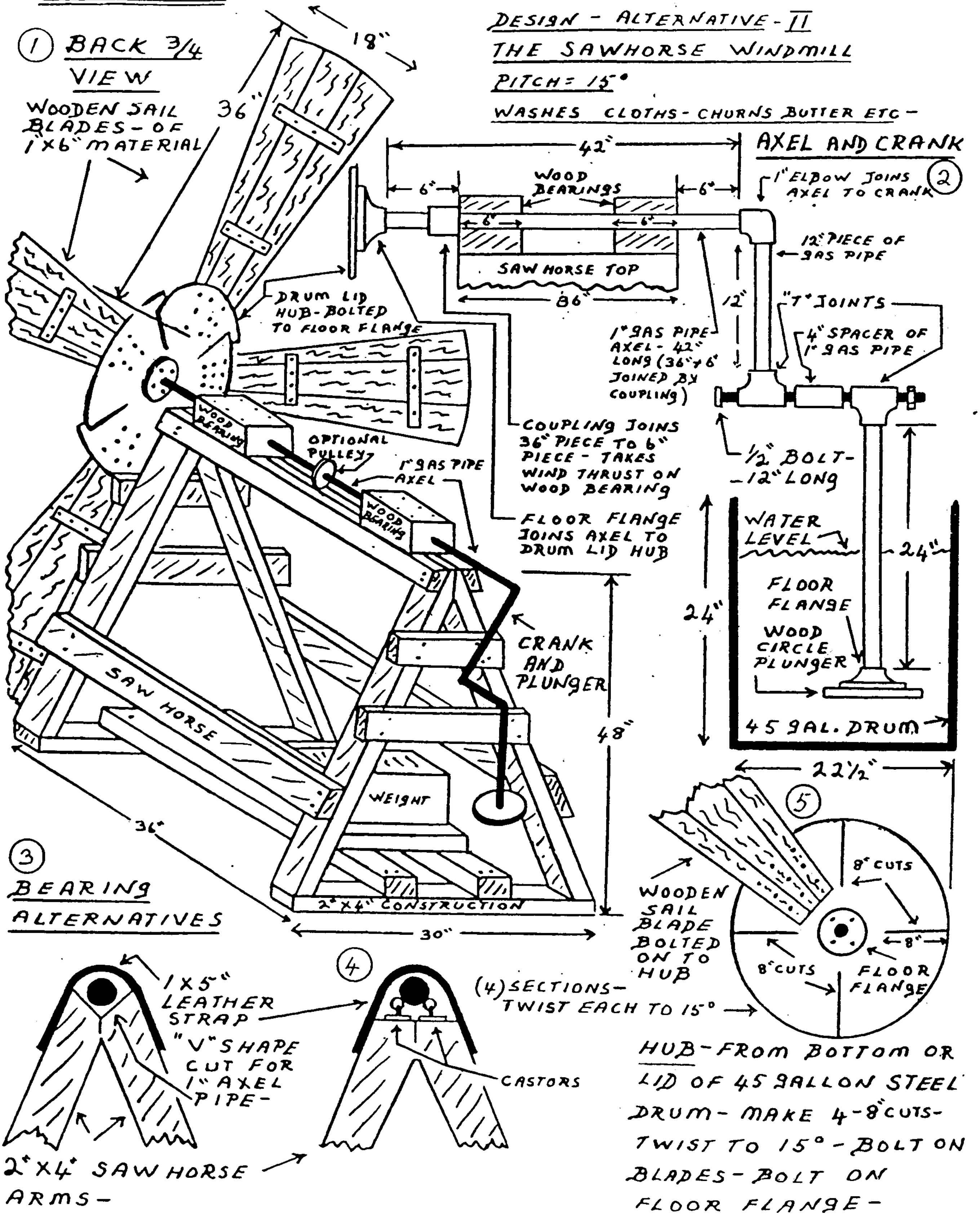
PLATE No. 55

DESIGN - ALTERNATIVE - II

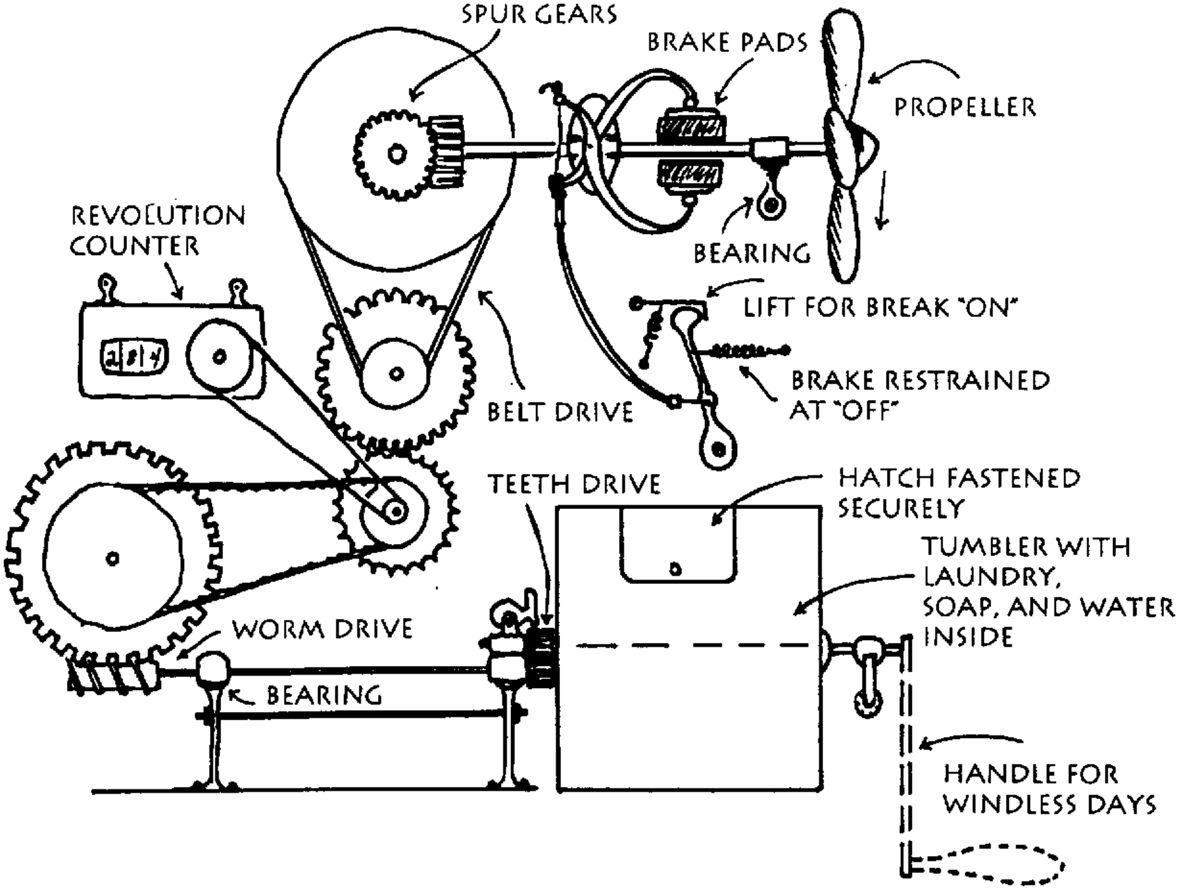
THE SAWHORSE WINDMILL

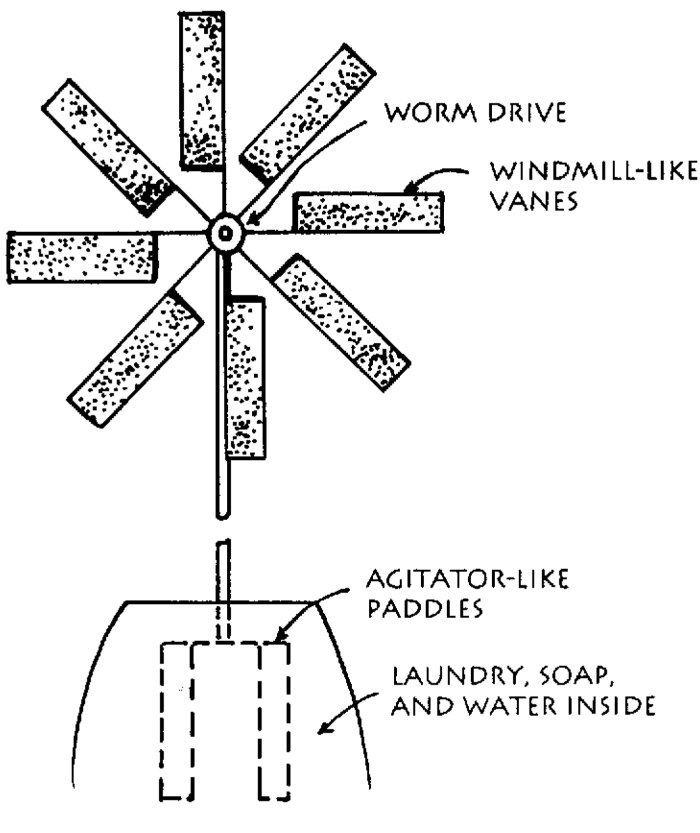
PITCH = 15°

WASHES CLOTHS - CHURNS BUTTER ETC -



HUB - FROM BOTTOM OR LID OF 45 GALLON STEEL DRUM - MAKE 4 - 8" CUTS - TWIST TO 15° - BOLT ON BLADES - BOLT ON FLOOR FLANGE -





WASHING MACHINES

PLATE NO. 56

Fig. 1 shows the lever crank system in place on the saw horse windmill, as illustrated in plate no. 55.

Notice that the axle end has been flattened and welded into a squared hole in the crank bar. It is important that the surface be flat so that it does not conflict with the connecting bar as it revolves, (see metal hub alternative, illustrated in plate no. 17, fig. 6).

The pivot connecting the crank bar to the connecting bar can be a steel bolt welded into the crank bar, passing through a hole in the connecting bar. Hold it loosely with a washer and two nuts. The second nut will hold the first nut tight, while still allowing free movement. In other words, you will not have to screw the first nut down tight onto the connecting bar.

The upper end of the connecting bar should fit into a "fork" on the end of the lever arm. A steel bolt, then passes through the fork and the connecting bar end.

The "fulcrum" end of the lever arm should fit into another fork between the two fulcrum arms. (There is only one side of the fulcrum arm fork shown).

If possible, use brass bushings on the pivot point steel bolts.

Cut the arms from 1/2" steel plate.

Note that the pump rod comes to the mid point of the lever arm. This reduces the effort by 50% which means that the same effort can produce twice as much work.

Fig. 2 illustrates the mathematics of the class two lever which is what this lever crank is. A class two lever is one in which the weight is exerted at some point between the fulcrum and the effort. A wheel barrow is a good example of a class two lever. The wheel acts as the fulcrum; the load on the wheel acts as the weight and the man holding the handles produces the upward effort. The closer the load is placed to the wheel, the less will be the need for upward effort by the man on the handles.

This formula will work with all three classes of levers. Its purpose is to calculate effort required to lift a stipulated weight or to overcome a stipulated amount of resistance.

The trick is to remember that the effort arm is always the distance between the fulcrum and the lifting effort; the resistance arm is always the distance between the fulcrum and the gravity centre point of the load.

Fig. 3, shows the measurements and detail of this particular lever crank. Note that the lift distance at "A" is half the distance of the vertical lift at the point "C" where the lever arm joins the connecting bar, which is equal to the diameter of the circle described by the pivot point of the crank bar. The lift effort at "A" is half that at "C". A 10 pound effort at "C" will lift a 20 pound weight at "A".

The vertical lift distance at "B" is half that at "A" and a quarter of that at "C". A 10 pound lift effort at "C" will raise a 40 pound weight at "B".

The vertical lift distance at "C" is equal to twice the length of the crank bar on the axle.

The length of the connecting bar is of no significance in lift measurement. It's purpose is to push the end of the lever bar through an arc described by the point "C".

The crank bar itself, exerts leverage effort and increases power.

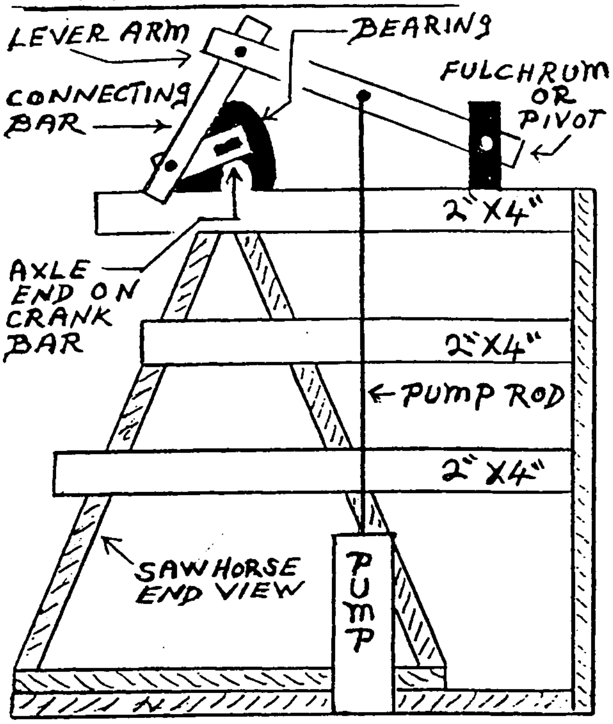
Curved pump handles are measured at straight lines between points, for purposes of calculation.

The pitman, illustrated in plate no. 57, fig. 5, is also a lever, (class three), to which the same formula applies.

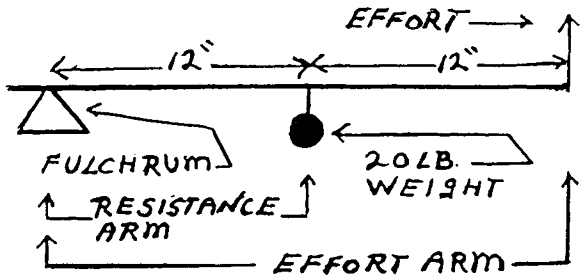
PLATE No. 56

– DESIGN ALTERNATIVE – III
– THE SAWHORSE WINDMILL – II
– LEVER CRANK –
– INCREASES POWER –

(1) END VIEW
SAWHORSE WINDMILL WITH LEVER-CRANK



(2) THE PRINCIPLE OF THE CLASS-TWO LEVER



FORMULA $= \frac{L}{l} = \frac{R}{E}$

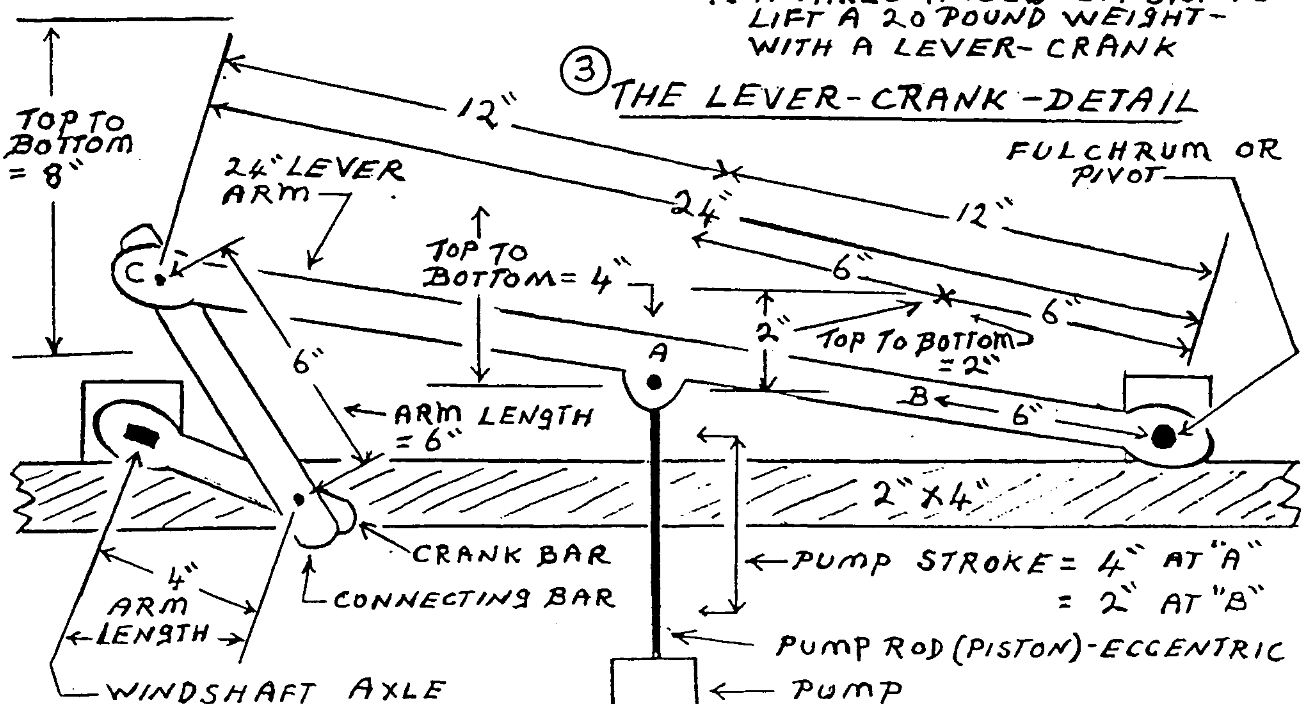
WHERE:
- L = LENGTH OF EFFORT ARM –
- l = LENGTH OF RESISTENCE ARM
- R = RESISTENCE WEIGHT-FORCE
- E = EFFORT FORCE

$= \frac{24}{12} = \frac{20}{E} = 24E = 240$

$\therefore E = 240 \div 24 = 10$ LB.

$\therefore$ IT TAKES A 10LB EFFORT TO LIFT A 20 POUND WEIGHT – WITH A LEVER-CRANK

(3) THE LEVER-CRANK-DETAIL



NOTE – ARMS ARE MEASURED FROM PIVOT TO PIVOT SO ADD AT LEAST 2" TO EACH END –

NOTE – POINT "A" MOVES IN AN ARC – SO PUMP ROD WILL MOVE FROM SIDE TO SIDE AT TOP ("A")

PLATE NO. 57

The biggest advantage of this design is that it is multidirectional and, thus, requires no tail vane. No matter what the direction of the wind, it just keeps on turning. The only way to stop it is to either tie it down or block it from the wind.

By increasing the length of the arms, and by adding quarter sections of steel drums to the half drums on the ends of the arms, you will increase the torque.

The set up for adapting the auto rear end (fig. 4), is described in plate no. 29 and its accompanying verbal text.

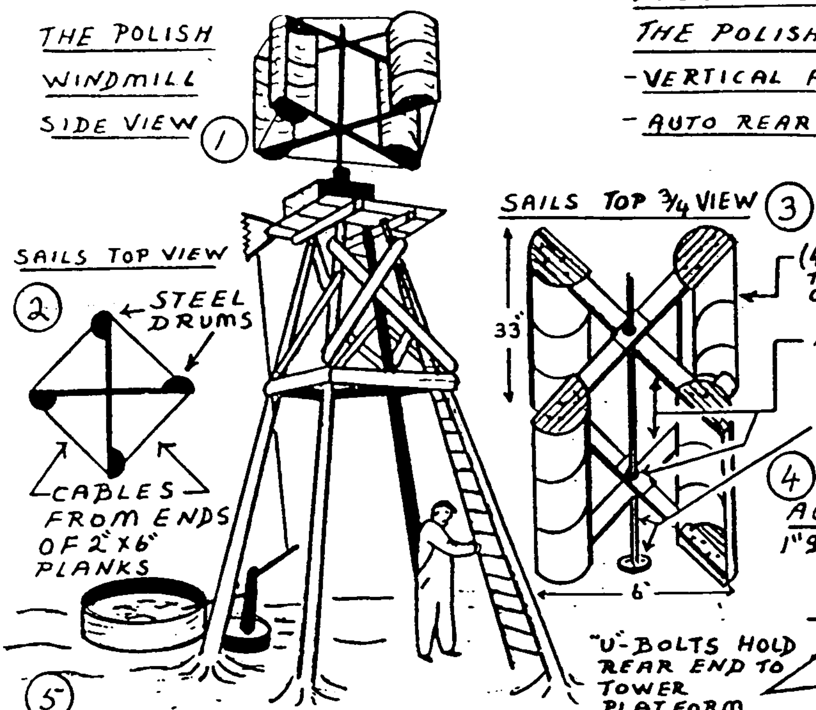
The pitman (fig. 5, 6 and 7), is a wooden or metal peg on a wooden or metal wheel, which is bolted to a metal disc, which is bolted to the auto rear end axle flange.

The 1", (or 2"), gas pipe sail axle is welded to a 1/4" thick steel plate disc, which bolts to the auto rear end drive shaft flange, (see fig. 3, 4 and 8).

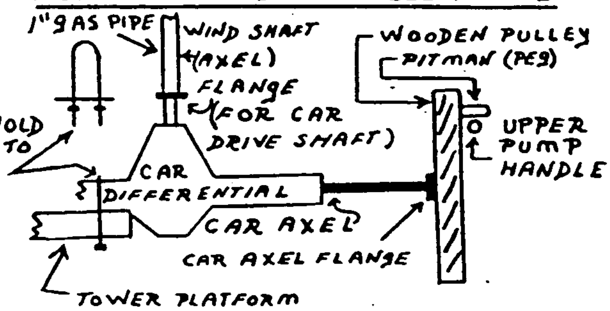
PLATE No. 57

DESIGN ALTERNATIVE III
THE POLISH WINMILL I
-VERTICAL AXIS - STEEL DRUM SAILS-
- AUTO REAR END DRIVE - MULTIDIRECTIONAL
- NEADS NO TAIL VANE

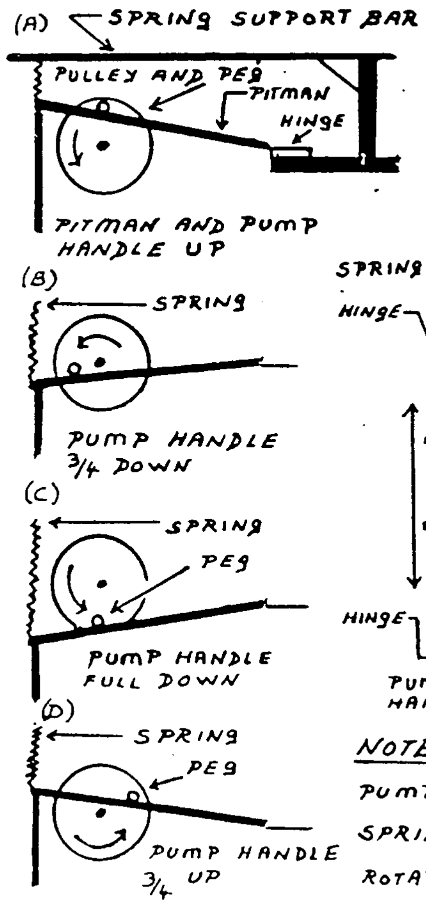
THE POLISH WINDMILL SIDE VIEW (1)



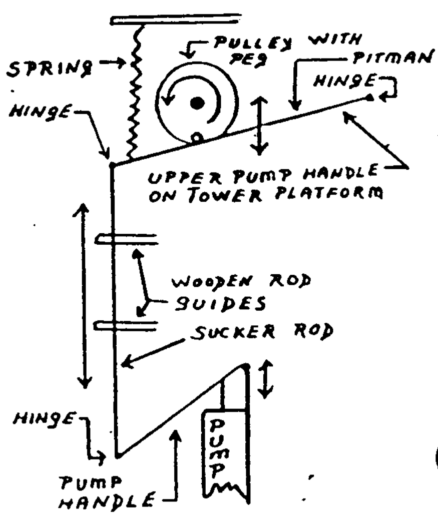
(4) SIDE VIEW
AUTO REAR END RT. ANGLE DRIVE



(5) ECCENTRIC PIN ON WOODEN PULLEY DRIVES PITMAN.

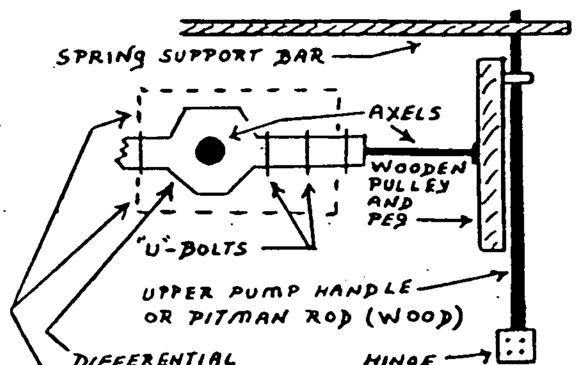


(6) PITMAN CONNECTED TO PUMP HANDLE WITH SUCKER ROD



NOTE - PEG PUSHES PUMP HANDLE DOWN - SPRING RAISES IT UP - ROTARY → VERTICAL MOTION-

(7) TOP VIEW
AUTO REAR END AND PITMAN



BLOCKS HOLD DIFFERENTIAL (REAR END) UPRIGHT - SO WIND FORCE CAN NOT PUSH IT OVER-

(8) STEEL VERTICAL AXEL FLANGE

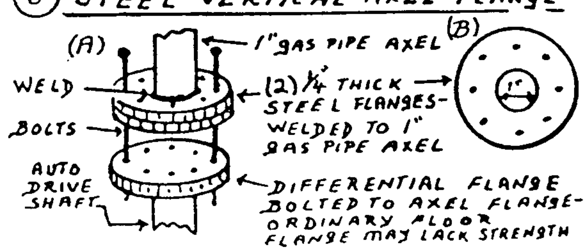


PLATE NO. 58

Note the counter weight replacing the spring in fig. 1. The counter weight is simply a plastic tub filled with the proper amount of sand. A counter weight will not wear as a spring will. A spring, however, will last a long time if it is not extended beyond its proper stretching limit.

Note the important concept, illustrated in fig. 2, 3, 4, 5, 6 and 7.

Left alone, the wind blows at the same time on both sides of the machine, the open sail going as well as on the back side of the returning sail coming back.

If the returning sail side is blocked off, the speed and power of the machine will increase dramatically. This can be done in a number of ways as illustrated. A good alternative is the replacement of the doors (fig. 5), with venetian blind type louvre boards which can be opened or closed at will.

A more simple solution is to erect canvas or wooden barriers which can be easily raised or taken down.

PLATE No. 58

DESIGN ALTERNATIVE - IV
THE POLISH WINDMILL II
- VARIATION - USING MANUFACTURED RIGHT ANGLE DRIVE AND ENCLOSURE

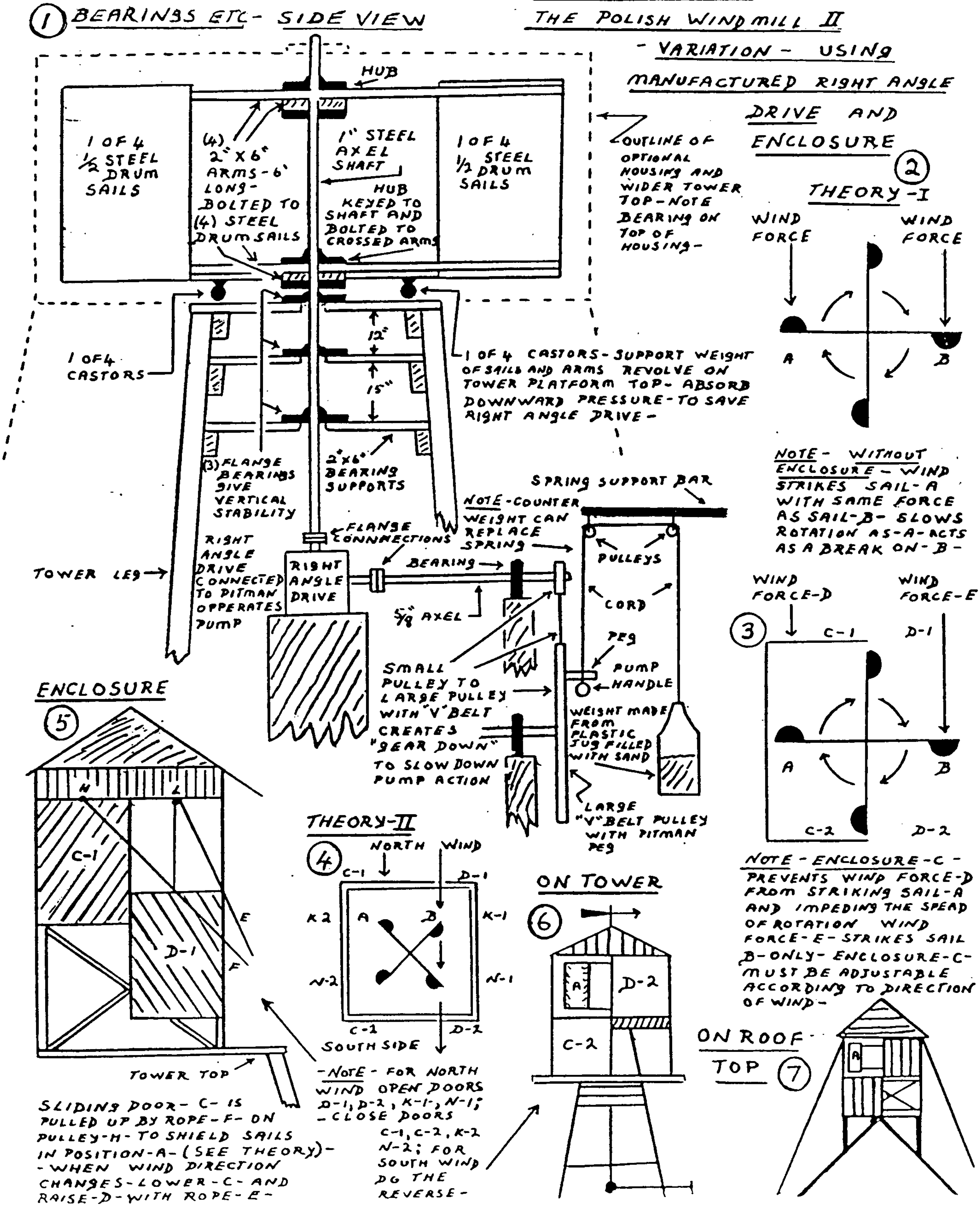


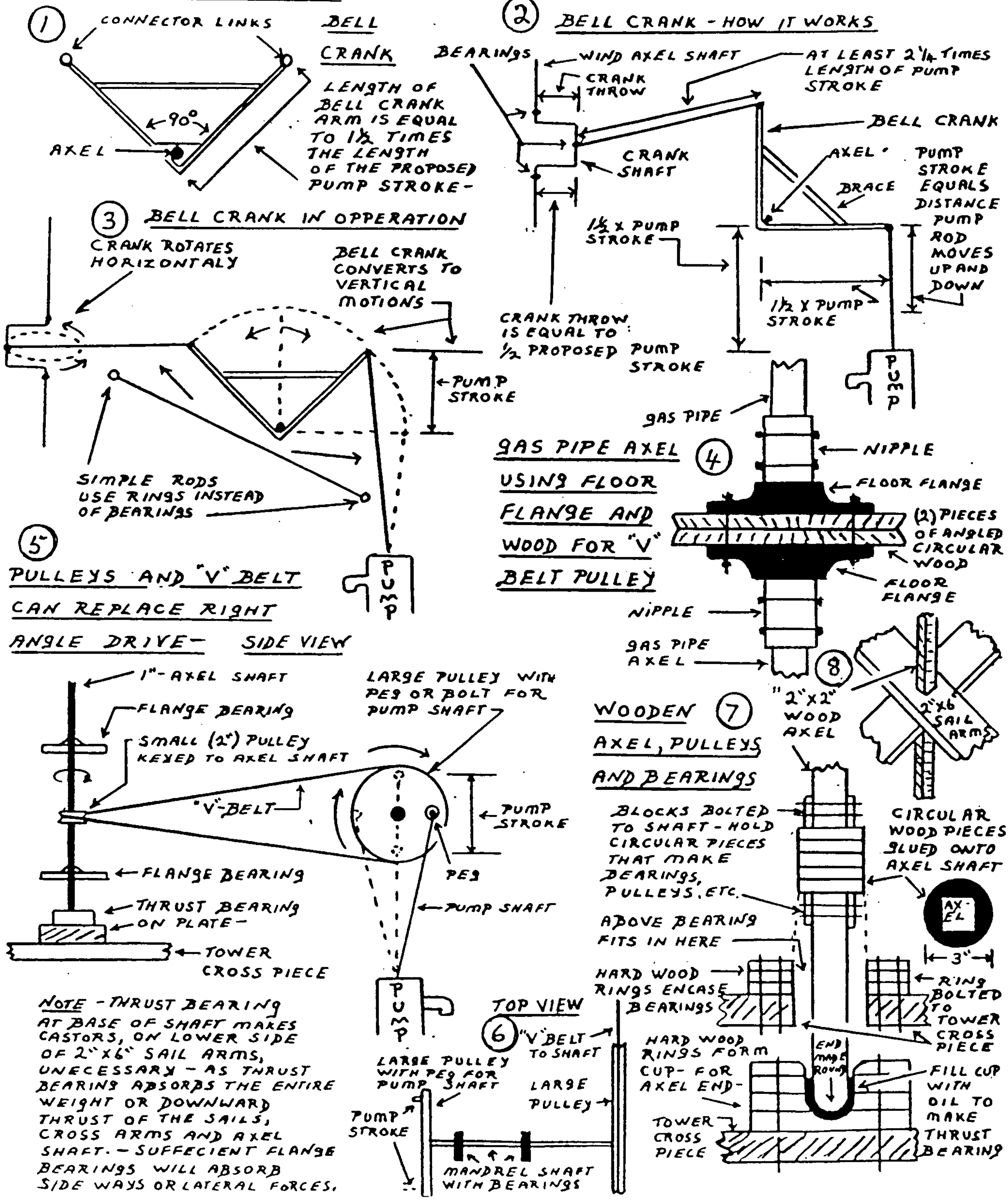
PLATE NO. 59

The methods of power direction change, illustrated here, can be applied to all designs, (see the section on "Design Relationships").

PLATE No. 59

HORIZONTAL MOTION CONVERTED TO VERTICAL MOTION BY BELL CRANK-

DESIGN ALTERNATIVE - V
THE POLISH WINDMILL - III
POWER CONNECTIONS



NOTE - THRUST BEARING AT BASE OF SHAFT MAKES CASTORS, ON LOWER SIDE OF 2"x6" SAIL ARMS, UNECESSARY - AS THRUST BEARING ABSORBS THE ENTIRE WEIGHT OR DOWNWARD THRUST OF THE SAILS, CROSS ARMS AND AXEL SHAFT. - SUFFECIENT FLANGE BEARINGS WILL ABSORB SIDE WAYS OR LATERAL FORCES.

PLATE NO. 60

The wooden bearings here illustrate all work in the same way as those shown in plate No. 15. Vertical bearings should have cups, (widening of the hole), at the top, so that used crank case oil can be poured in from time to time for lubrication.

Bearings and pulleys must be of hardwood, while the vertical shaft can be of either hard or soft wood.

PLATE No. 60

WOODEN SHAFT, BEARINGS, POWER CONNECTIONS CONTINUED

DESIGN ALTERNATIVE - VI
THE POLISH WINDMILL - IV
POWER CONNECTIONS (CONT'D)

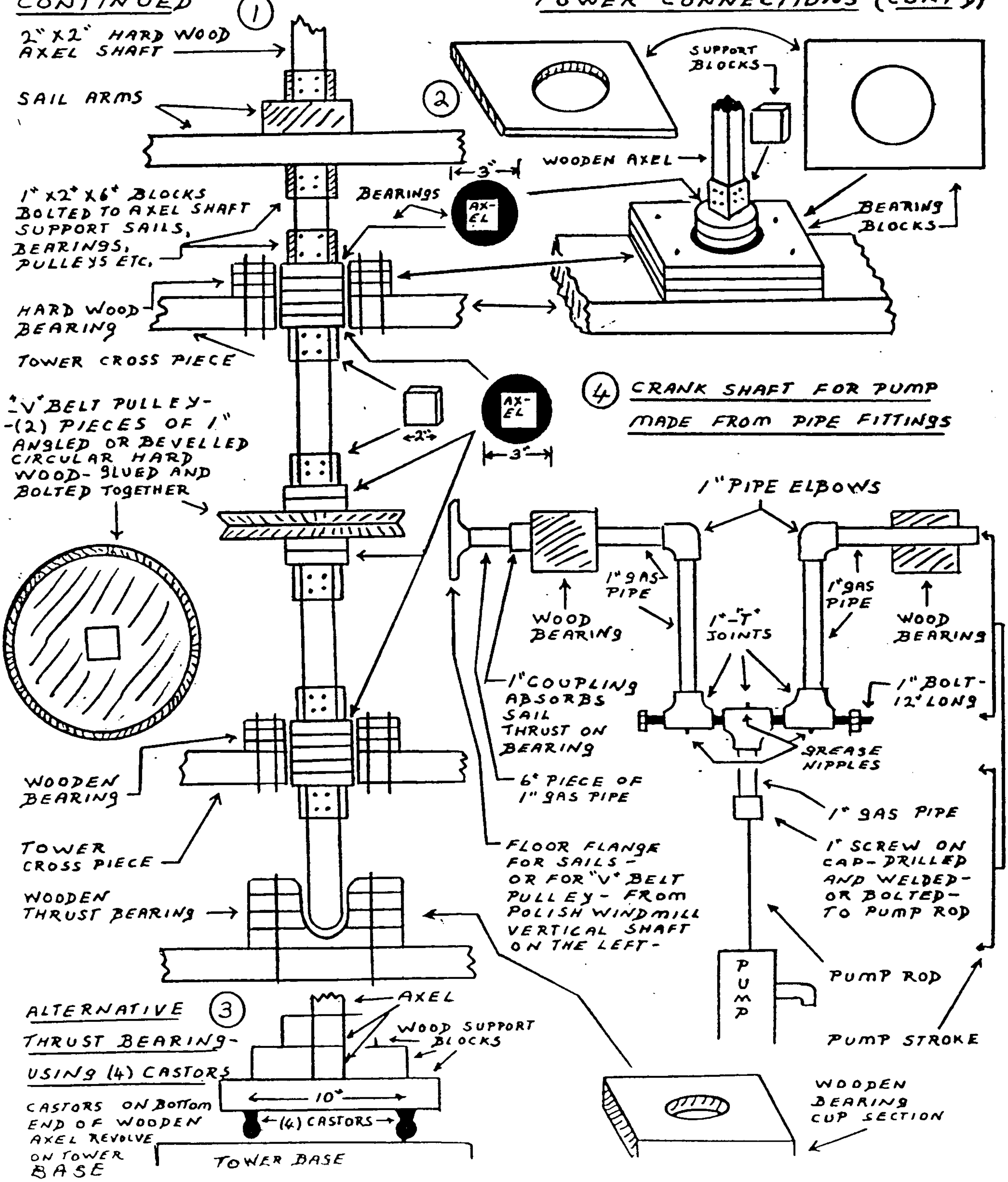


PLATE NO. 61

Fig. 1 and 2 are pressure pumps, because they are capable of driving water from their outlet pipes with considerable force.

They can push water over a considerable distance or up to a considerable height. They can, therefore, motivate water fountains and overhead irrigation systems.

Pressure is volume of water pushed through a smaller aperture like a hose nozzle.

Volume is the amount of water running through a pipe. It is determined by the size of the pipe and the power of the engine behind the pump.

The pumps, illustrated in plates 62, 63, 64 and 65 are pressure pumps.

Fig. 3 and 4 are "lift pumps", such as are found at the well heads of most family farms. They are usually thought of as "hand pumps", because they make use of the leverage principle, (see plate no. 56), so that people can operate them by hand. A lift pump simply raises the water up. It does not provide pressure.

The principle on which the pressure pump works is this:

The piston is motivated by the eccentric of the wind machine, (see plate no. 19, et. al.), which makes it go up and down.

When the piston moves up, it sucks water into the chamber through the intake valve which rises up to let the water through. "Suck" is, perhaps, the wrong word. What really happens is that the raised piston creates a kind of vacuum, or low pressure area in the chamber and the water is pushed into it by the atmospheric pressure on the surface of the outside water. This downward atmospheric pressure is enough to drive the water 20 or 25 feet up the pipe. Beyond that distance, you will have trouble.

The moving up of the piston also draws the outlet valve closed so that water is unable to run back into the chamber or cylinder from the outlet pipe.

When the piston comes down on the next stroke, it forces the intake valve to close, and at the same time, forces the outlet valve to open. The water then passes out into the outlet pipe.

When the piston goes up again, the section closes the outlet valve and opens the intake valve. The cycle then begins over again.

It will be seen that as more and more water is forced through the outlet valve into the outlet pipe, more and more pressure will build up in that pipe. If this water is forced through a small hole like a nozzle, it will squirt or spray over quite a long distance.

It can, therefore, be definitely stated, that water can be pushed by a pump over a much greater distance than it can be pulled by the same pump.

The distance that water can be pushed is determined by how much pressure is being exerted on the down stroke of the piston. This will depend on the amount of power that can be developed by the wind machine.

It is a good idea, therefore, to consider the lever crank, illustrated in plate no. 56, because it will increase the power of the eccentric rod's down stroke by two of four times. It will also reduce the length of that stroke by the same amount.

PLATE No. 61

-PUMP PLANS-I- THEORY

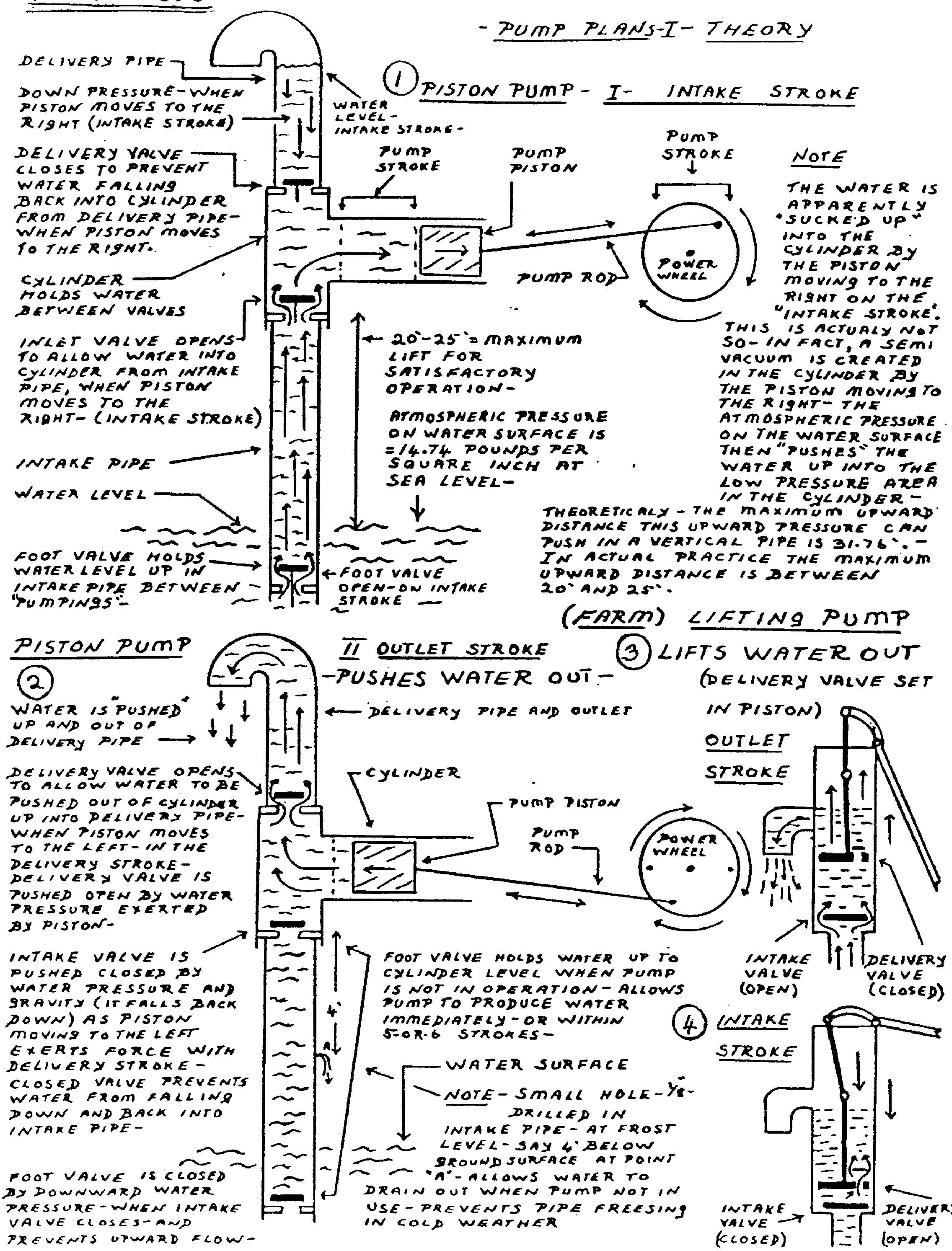


PLATE NO. 62

This pressure type pump is made almost entirely from ordinary pipe fittings that can be purchased from a local hardware store.

The exception could be the piston rod which can be of ordinary cold steel rod, though brass is better, as it won't rust.

An important change that can be made to this design is to make all of the pump fittings of the same size. That is to say, that instead of a reducer coming out of the left side of the "T" joint, you use another 1 1/4" nipple and 1 1/4" coupling, etc.

In this way, the outlet valve will be exactly the same as the intake valve in both size and shape.

This will not only make the outlet valve easier to construct, it will cause it to work better, (see plate 64, fig. 3 and 4).

The outlet pipe should still be reduced to 1/2" diameter to maintain pressure.

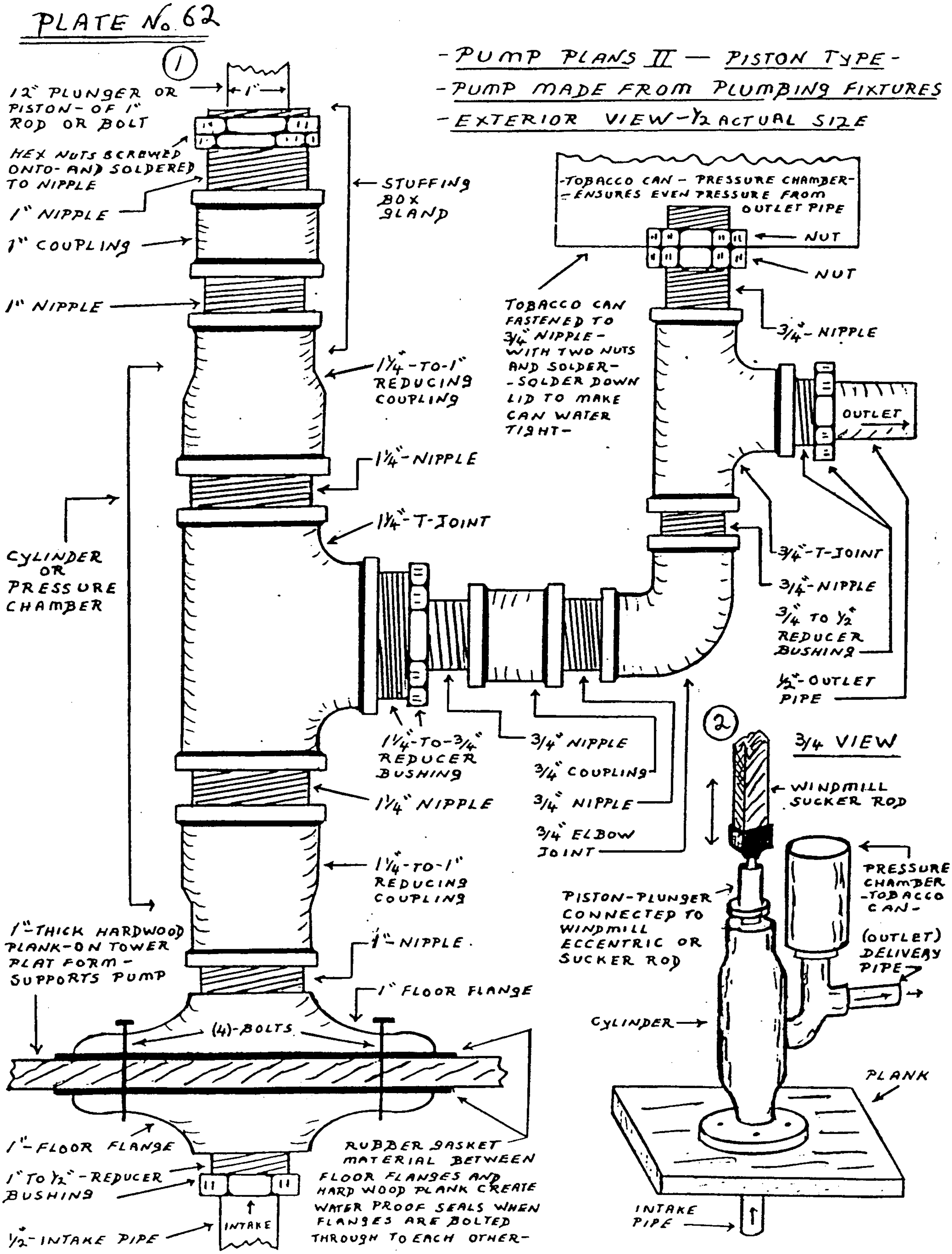


PLATE No 62
- PUMP PLANS II — PISTON TYPE -
- PUMP MADE FROM PLUMBING FIXTURES
- EXTERIOR VIEW - ½ ACTUAL SIZE
1
12" PLUNGER OR PISTON - OF 1" ROD OR BOLT
1"
HEX NUTS SCREWED ONTO - AND SOLDERED TO NIPPLE
STUFFING BOX GLAND
1" NIPPLE
1" COUPLING
1" NIPPLE
1¼-TO-1" REDUCING COUPLING
1¼"-NIPPLE
1¼"-T-JOINT
CYLINDER OR PRESSURE CHAMBER
1¼"-TO-¾" REDUCER BUSHING
1¼" NIPPLE
1¼-TO-1" REDUCING COUPLING
1"-NIPPLE.
1"-THICK HARDWOOD PLANK - ON TOWER PLATFORM - SUPPORTS PUMP
1" FLOOR FLANGE
(4)-BOLTS
1"-FLOOR FLANGE
1" TO ½"-REDUCER BUSHING
½"-INTAKE PIPE
INTAKE
RUBBER GASKET MATERIAL BETWEEN FLOOR FLANGES AND HARD WOOD PLANK CREATE WATER PROOF SEALS WHEN FLANGES ARE BOLTED THROUGH TO EACH OTHER -
-TOBACCO CAN - PRESSURE CHAMBER - ENSURES EVEN PRESSURE FROM OUTLET PIPE
NUT
NUT
TOBACCO CAN FASTENED TO ¾" NIPPLE - WITH TWO NUTS AND SOLDER - - SOLDER DOWN LID TO MAKE CAN WATER TIGHT -
¾"- NIPPLE
OUTLET
¾"-T-JOINT
¾"-NIPPLE
¾" TO ½" REDUCER BUSHING
½"-OUTLET PIPE
¾" NIPPLE
¾" COUPLING
¾" NIPPLE
¾" ELBOW JOINT
2
¾ VIEW
WINDMILL SUCKER ROD
PISTON-PLUNGER CONNECTED TO WINDMILL ECCENTRIC OR SUCKER ROD
PRESSURE CHAMBER - TOBACCO CAN -
(OUTLET) DELIVERY PIPE
CYLINDER
PLANK
INTAKE PIPE

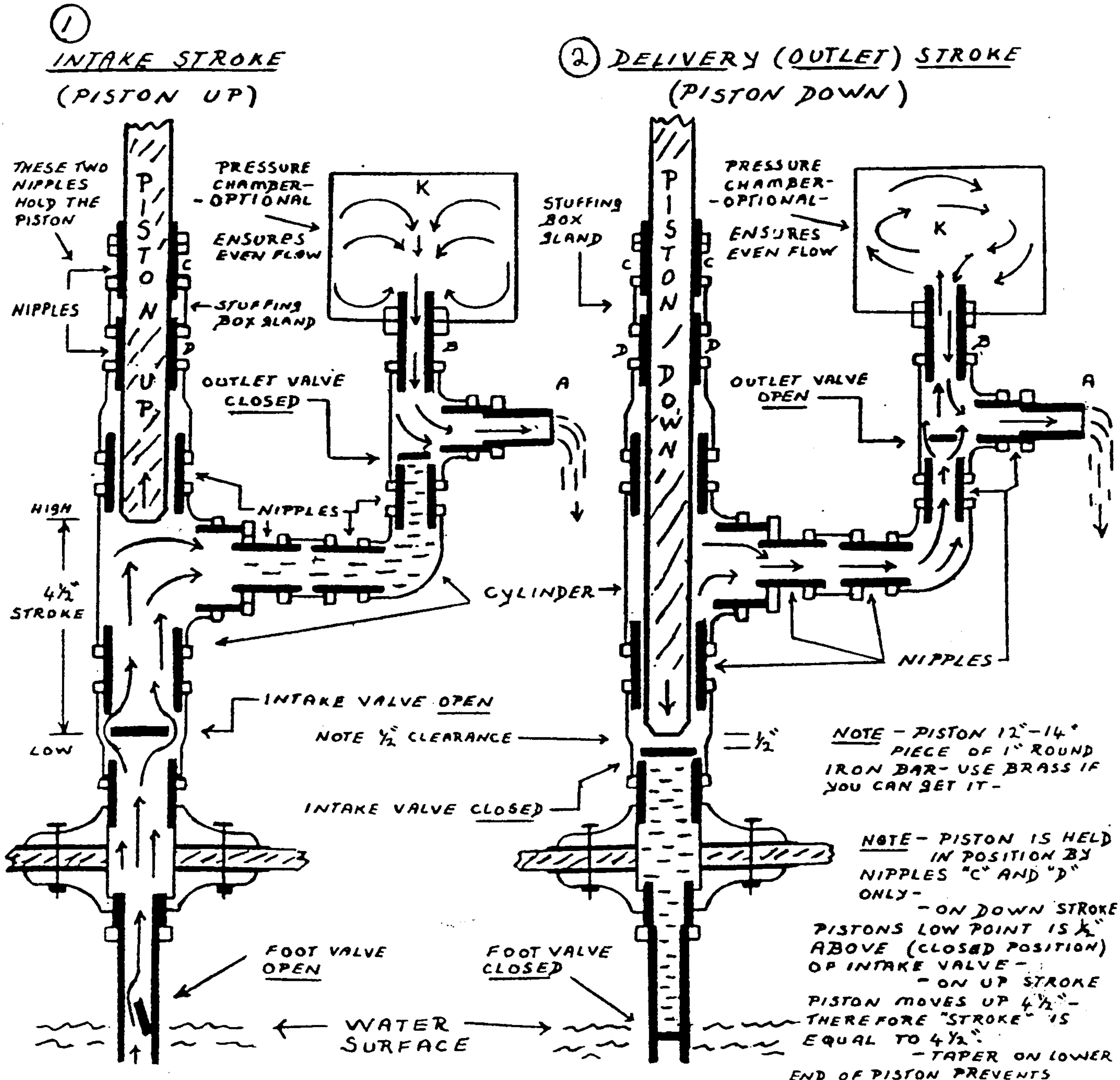
PLATE NO. 63

See the text note on plate no. 63, about removing the reducer from the "T" joint to the outlet valve, and replacing it with a 1 1/4" nipple.

This will mean that both the intake and outlet valves will be seated on 1" nipples.

PLATE No. 63

— PUMP PLANS III — PISTON TYPE —
— PUMP MADE FROM PLUMBING FIXTURES
— INTERIOR VIEW — ABOUT ⅓ ACTUAL SIZE



NOTE — PISTON 12"–14" PIECE OF 1" ROUND IRON BAR — USE BRASS IF YOU CAN GET IT —

NOTE — PISTON IS HELD IN POSITION BY NIPPLES "C" AND "D" ONLY —
— ON DOWN STROKE PISTONS LOW POINT IS ½" ABOVE (CLOSED POSITION) OF INTAKE VALVE —
— ON UP STROKE PISTON MOVES UP 4½" — THEREFORE "STROKE" IS EQUAL TO 4½".
— TAPER ON LOWER END OF PISTON PREVENTS "KNOCKING" ON LOWER NIPPLES.

NOTE —
"K" — TOBACCO CAN PRESSURE CHAMBER IS OPTIONAL — IT SIMPLY ENSURES EVEN FLOW FOR IRRIGATION SYSTEMS AND FOUNTAINS — WITHOUT IT THERE WOULD BE NO OUTPUT AT "A" ON THE INTAKE STROKE — ONLY ON THE DELIVERY STROKE — HENCE A PULSATING "UP AND DOWN" FLOW — ALTERNATIVE — REMOVE ("K") CHAMBER — SCREW A CAP ON TO NIPPLE "B".

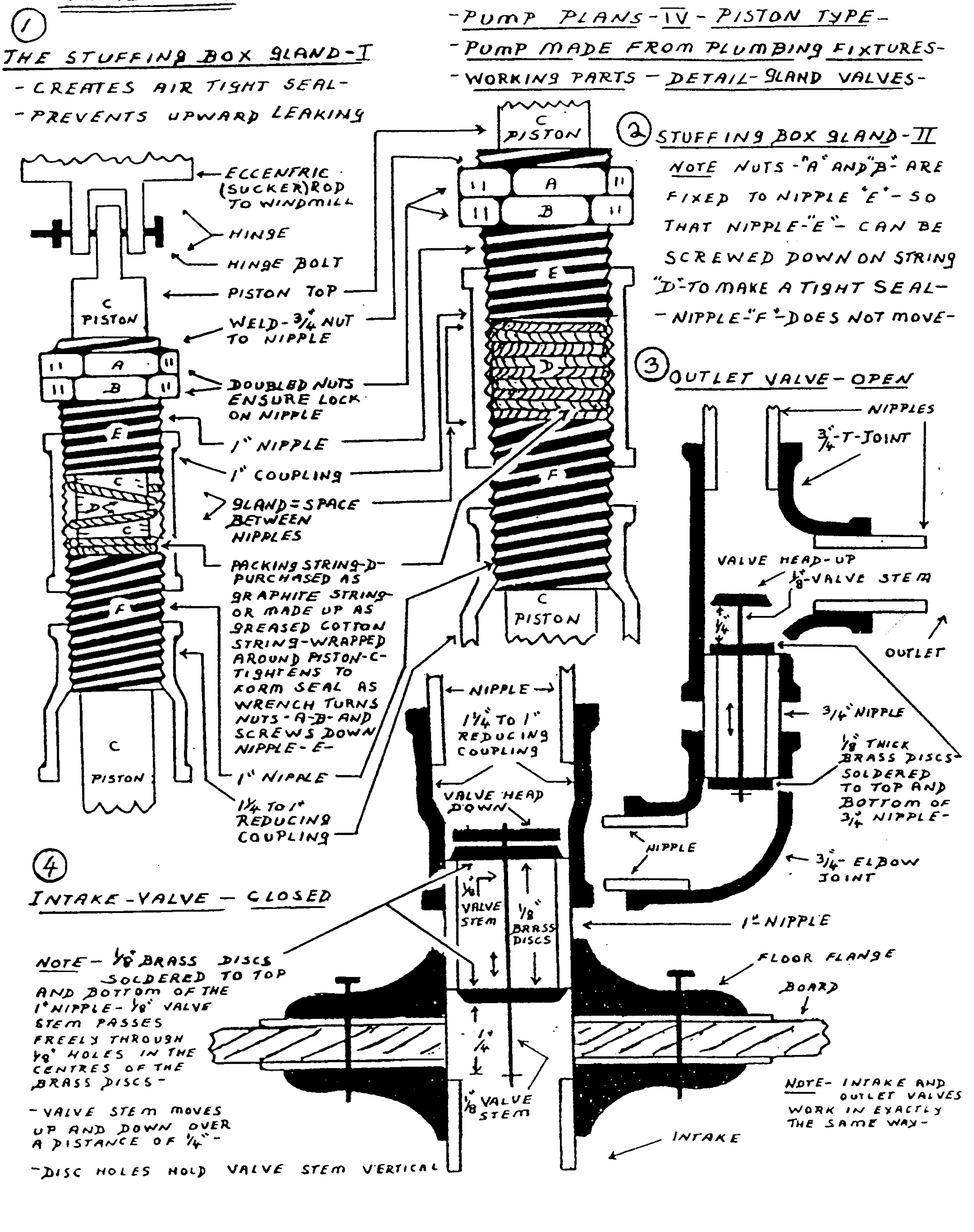
PLATE NO. 64

The idea of the stuffing box gland, (fig. 1 and 2), is that the top, (A and B), can be screwed down, when necessary, to keep the greased string tight as it wears against the piston, in order to maintain a perfect seal. Graphite string from a plumbing supply store is better than greased string. The idea of the double nuts is that the top one will always hold the bottom nut on tight.

Note, again, the advantages of making the outlet valve (fig. 3), the same size as the intake valve, (fig. 2).

The outlet pipe itself, must still be reduced in size to 1/2", (as in plate no. 62, fig. 1), to create the necessary pressure. The outlet and intake pipes will then be the same.

PLATE No. 64



-PUMP PLANS-IV-PISTON TYPE-
-PUMP MADE FROM PLUMBING FIXTURES-
-WORKING PARTS - DETAIL-GLAND VALVES-
(1) THE STUFFING BOX GLAND-I
-CREATES AIR TIGHT SEAL-
-PREVENTS UPWARD LEAKING
ECCENTRIC (SUCKER) ROD TO WINDMILL
HINGE
HINGE BOLT
PISTON TOP
C PISTON
WELD-3/4" NUT TO NIPPLE
A
B
DOUBLED NUTS ENSURE LOCK ON NIPPLE
E
1" NIPPLE
1" COUPLING
C
D
C
GLAND=SPACE BETWEEN NIPPLES
PACKING STRING-D- PURCHASED AS GRAPHITE STRING OR MADE UP AS GREASED COTTON STRING-WRAPPED AROUND PISTON-C-TIGHTENS TO FORM SEAL AS WRENCH TURNS NUTS-A-B-AND SCREWS DOWN NIPPLE-E-
F
1" NIPPLE
C PISTON
1¼ TO 1" REDUCING COUPLING
(2) STUFFING BOX GLAND-II
NOTE NUTS-"A" AND "B"- ARE FIXED TO NIPPLE "E" - SO THAT NIPPLE-"E"- CAN BE SCREWED DOWN ON STRING "D"-TO MAKE A TIGHT SEAL-
-NIPPLE-"F"-DOES NOT MOVE-
C PISTON
A
B
E
D
F
C PISTON
(3) OUTLET VALVE-OPEN
NIPPLES
3/4"-T-JOINT
VALVE HEAD-UP
1/8"-VALVE STEM
1/4"
OUTLET
3/4" NIPPLE
1/8" THICK BRASS DISCS SOLDERED TO TOP AND BOTTOM OF 3/4" NIPPLE-
NIPPLE
3/4"-ELBOW JOINT
(4) INTAKE-VALVE - CLOSED
NIPPLE
1¼ TO 1" REDUCING COUPLING
VALVE HEAD DOWN
1/8" VALVE STEM
1/8" BRASS DISCS
1" NIPPLE
FLOOR FLANGE
BOARD
1¼"
1/8" VALVE STEM
INTAKE
NOTE- 1/8" BRASS DISCS SOLDERED TO TOP AND BOTTOM OF THE 1" NIPPLE- 1/8" VALVE STEM PASSES FREELY THROUGH 1/8" HOLES IN THE CENTRES OF THE BRASS DISCS-
-VALVE STEM MOVES UP AND DOWN OVER A DISTANCE OF 1/4"-
-DISC HOLES HOLD VALVE STEM VERTICAL
NOTE- INTAKE AND OUTLET VALVES WORK IN EXACTLY THE SAME WAY-

PLATE NO. 65

See again the advantages of making the outlet valve, (fig. 6), exactly the same as the intake valve, (fig. 3 and 4), otherwise you will find the brass rings on the small outlet valve very hard to make. The same amount of water has to pass through both the intake and the outlet valve. It is more sensible to make them the same size and in exactly the same way.

The stationary top and bottom brass disc plates (fig. 1, 2 and 5), are brazed or soldered to the top and bottom of the 1" nipple. Brazing is better, because it will be stronger in face of the pressure of the moving water. The disc to nipple joints must be made carefully and filed down so the nipples can still screw into the couplings.

Both the top and bottom stationary disc plates must allow the same amount of water to pass through their holes, as passes through the 1/2" diameter intake and outlet pipes.

In other words, the total area of the holes in the upper disc plate and the total area of the holes, (crescent shape openings), in the lower disc plate, must each equal the area of the inner diameter of both the intake and outlet pipes. In fact, it won't hurt if the disc plate hole areas are a little larger than the pipe hole areas, because of the increased friction encountered when passing through smaller holes. Increased friction slows the movement of any fluid.

Note that the moving valve disc (fig. 4), has no holes in it. This disc must be able to totally cover the five small holes in the upper stationary disc plate, because water can not be allowed to pass back once the valve is closed.

The valve disc, (without holes), must be small enough in diameter, (11/16"), to enable it to move freely up and down in a 1" diameter pipe. It must also be small enough in diameter to allow the moving water to pass around it when the valve is open, (see plate no. 63, fig. 1, The Intake Valve).

It must also be large enough to totally block off the holes in the top stationary disc plates when the valve falls down and closes.

The 1/8" bolt, (fig. 4), passes freely through the 1/8" centre holes, (fig. 1, 3 and 5), of the stationary upper and lower disc plates.

The nut on the bottom of the bolt prevents the bolt from moving more than 1/4" upward.

The valve disc is brazed or soldered to the top of the bolt.

When the piston moves up creating a suction or vacuum, the valve disc moves up on the bolt and allows water to pass through the holes in the stationary valves.

When the piston moves down, it creates a water pressure that forces the intake valve down and shut.

This same downward pressure from the piston also causes the water in the cylinder, or chamber, to force the outlet valve open, and water is forced through it into the outlet pipe. When this pressure stops, that is, when the piston reaches to bottom of its stroke, the outlet closes, (falls closed), and the cycle begins again.

A more simple valve system can be made by simply setting a ball bearing, (of the same diameter as the valve disc in fig. 4, i.e. 11/16"), in a 1/2" diameter ring, or cup, brazed into the bottom end of the nipple. Two small holes can be drilled at the proper place in the nipple. If two wires are strung through these holes, they will prevent the ball bearing from rising too far on the piston's up stroke. If the ball bearing rises too far, it may have trouble falling back in time to shut off the intake pipe. Solder the holes tightly shut when the wires are in place.

The outlet valve can be made in the same way and of the same size. The ball bearing will be pushed up to let the water through on the piston's down stroke. On the piston's up stroke, the ball bearing will fall back to make a tight seal and prevent the water from running back into the chamber.

Larger pumps can be made by increasing all of the measurements in proportion, a larger piston, larger pipe and larger valves, or larger ball bearings.

Do not forget the crank lever system in plate no. 56.

PLATE No. 65

-PUMP PLANS -V- PISTON TYPE
-PUMP MADE FROM PLUMBING FIXTURES
-VALVE DETAIL- ETC

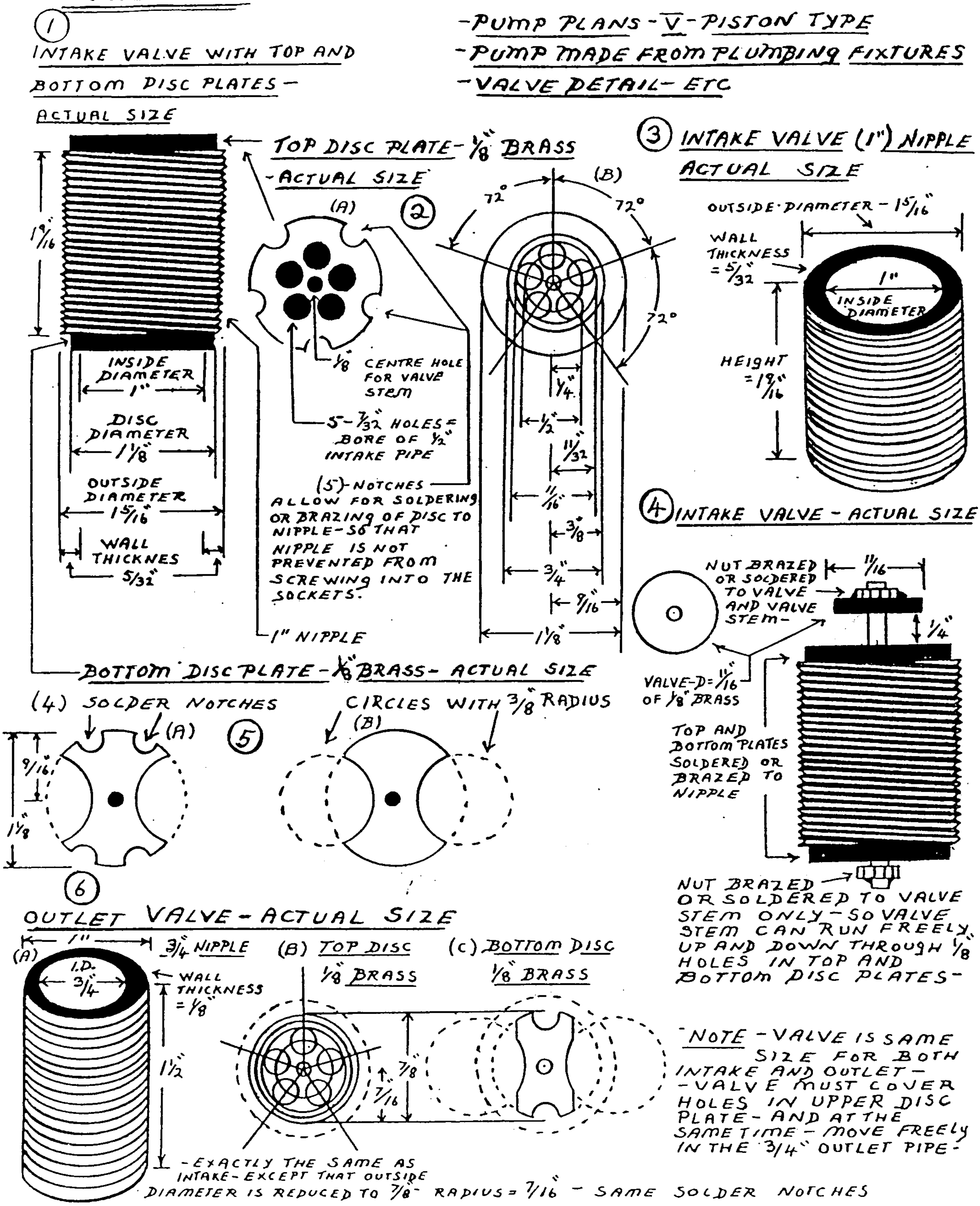


PLATE NO. 66

"Gear up" is discussed thoroughly in the section on theory. The purpose is to increase the R.P.M. from the wind shaft axle to a R.P.M. capable of running a generator or alternator.

Note that with a "gear up", as opposed to a "gear down", the wind shaft axle is at the bottom with the gear up axles and generator above it. (See also the "V"-belt gear up principles", plate no. 67, fig. 1).

"Slip rings" are discussed thoroughly in the section on electrical connections. The purpose of the slip ring is to convey the current from the moving rotating table to the stationary tower.

A generator requires two slip rings, one for each of the positive and negative wires.

An alternator requires three slip rings, one for each of the positive, negative and field wires.

The "build up" of the rotating table is described by the text and illustrations of plates no. 22 and 23.

PLATE No. 66

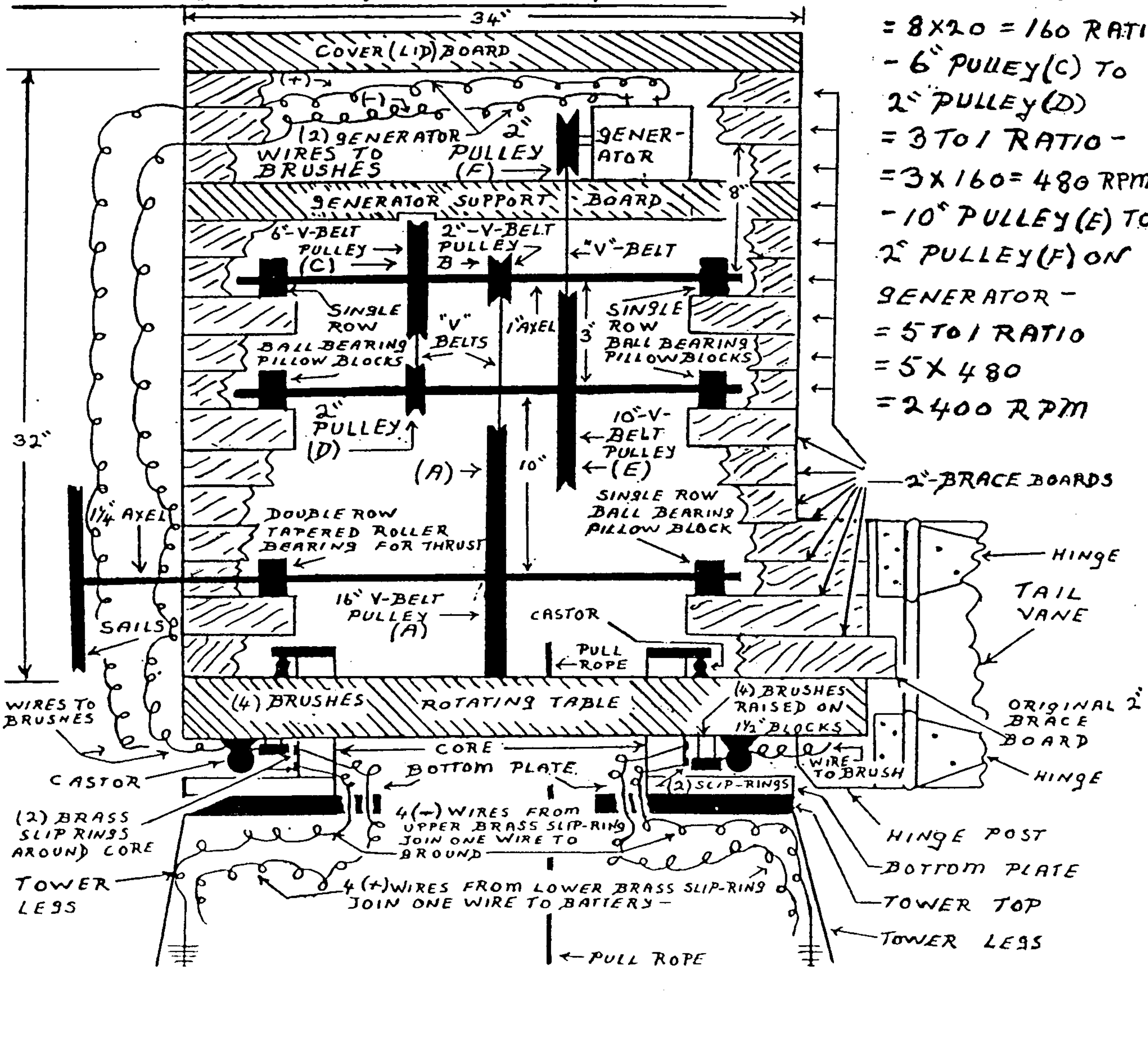
- ELECTRICAL CONNECTIONS - I.
- GEAR UP - 13 FOOT DIAMETER MULTIBLADE
- SLIP RINGS - WOODEN ROTATING TABLE -

NOTE - GEAR UP INCREASES THE NUMBER OF REVOLUTIONS PER MINUTE - (R.P.M.) DELIVERED BY THE SAIL AXEL OR WINDSHAFT TO A SPEED CAPABLE OF DRIVING A GENERATOR - OR ALTERNATOR - MOST GENERATORS AND ALTERNATORS COMMENCE MAKING ELECTRICITY AT ABOUT 1500 R.P.M. - A THIRTEEN FOOT DIAMETER MULTIBLADE TURNS AT ABOUT 20 R.P.M. IN A 10 MILE AN HOUR WIND - GEAR UP OF 100 TO 1 = GENERATOR R.P.M. OF 2000 R.P.M. - ALLOWS FOR 30% MECHANICAL LOSS -

7-FOOT DIAMETER - 2-BLADE AIR FOIL - AT-4-TIMES WIND-SPEED - ROTATES AT-88-RPM - GEAR UP RATIO = 23 TO 1 = 23 x 88 = 2034 RPM - ALLOWS (2034 - 1500 = 534-RPM) 30% FOR MECHANICAL LOSS -

NOTE - SLIP-RINGS ALLOW ELECTRICAL CURRENT TO PASS FROM THE GENERATOR (ALTERNATOR) - ON THE ROTATING TABLE - TO THE TOWER AND THENCE TO THE BATTERY BANK AND THE GROUND - OTHERWISE THE WIRES WOULD TWIST AS TABLE ROTATES -

GEAR UP AND SLIP-RINGS - 13' DIAMETER - MULTIBLADE - WOODEN ROTATING TABLE (1)



13'-DIA. MULTIBLADE GEAR-UP

- 16" PULLEY (A) ON WINDSHAFT - TO 2" PULLEY (B) = 8 TO 1 RATIO = 8 x 20 = 160 RATIO
- 6" PULLEY (C) TO 2" PULLEY (D) = 3 TO 1 RATIO - = 3 x 160 = 480 RPM
- 10" PULLEY (E) TO 2" PULLEY (F) ON GENERATOR - = 5 TO 1 RATIO = 5 x 480 = 2400 RPM

PLATE NO. 67

Note “gear up V belt principles” in fig. 1. This applies to all gear ups or gear downs, using “V” belts. Gear up increases R.P.M. by increasing power input.

The principle of the slip ring is that a carbon starter motor brush is held, by means of a spring, against a brass, aluminum or copper ring. As the rotating table moves around, the brush maintains contact with the ring. Both the brush and the ring are insulated from their mounts, (see fig. 3 and 4).

The brushes on the rotating table are connected by wire to the generator or alternator.

The rings, on the core, are connected by wire to the battery system and load, (fig. 2).

The spring loaded brush holders (fig. 4), can be purchased with the brushes from any auto supply store.

Slip rings are examined with more detail under the heading, “Electrical Connections V”.

PLATE No. 67

- ELECTRICAL CONNECTIONS - II
- GEAR UP - MULTIBLADE - CONT'D
SLIP-RINGS-ASSEMBLY - SLIP RINGS - WOOD ROT. TABLE - CONT'D

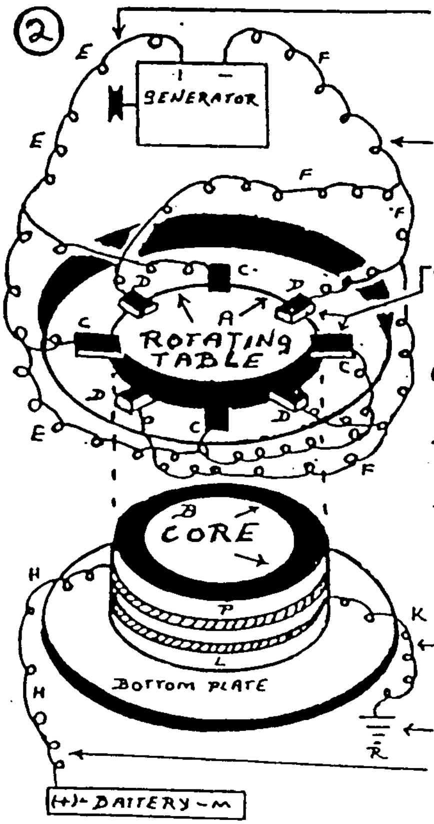
NOTE - ROTATING TABLE (A) FITS OVER AND ROTATES AROUND CORE (B) - ROT. TABLE (A) ROTATES ONLY TO ACCOMODATE SAILS TO WIND DIRECTION CHANGES AS TRANSLATED BY THE TAIL VANE MOUNTED ON THE ROT. TABLE ITSELF - AS SAILS MUST ALWAYS FACE INTO THE WIND - SO ROT. TABLE DOES NOT ROTATE FAST OR OFTEN - BUT IF WIRES WERE CONNECTED DIRECTLY FROM THE GENERATOR TO THE GROUND AND BATTERY - THEY WOULD TWIST AND BREAK AS TABLE (A) ROTATES WITH CHANGING WIND DIRECTIONS - SO SLIP-RINGS ARE NECESSARY -

- (8) ALTERNATOR - OR AUTOMOBILE STARTER BRUSHES (C=+) AND (D=-) MOUNTED ON THE ROTATING TABLE (A) ARE CONNECTED TO THE PLUS AND MINUS POLES OF THE GENERATOR BY WIRES (E) AND (F) -

- AS THE ROTATING TABLE (A) ROTATES AROUND CORE (B) THE BRUSHES (C) AND (D) CONTACT THE POSITIVE AND NEGATIVE SLIP RINGS (P) AND (L) -
- THE SLIP-RINGS - (P) AND (L) ARE CONNECTED TO THE BATTERY (+) AND GROUND (-) BY THE WIRES (H) AND (K) -

- SLIP RINGS CAN ALSO BE MADE OF ALUMINUM OR COPPER - COPPER DOOR INSULATION MAY BE CHEAPEST -

(2)



POSITIVE WIRES (E) FROM GENERATOR TO (4) BRUSHES (C) ON ROTATING TABLE (A)

NEGATIVE WIRES (F) FROM GENERATOR TO (4) BRUSHES (D) ON ROTATING TABLE (A)

(8) BRUSHES (C) AND (D) ON ROTATING TABLE (A)
- NOTE - (4) (-) BRUSHES (D) ARE MOUNTED ON 1½" BLOCKS TO CONTACT LOWER BRASS SLIP-RING (L)
- THE (4) (+) BRUSHES (C) ARE MOUNTED DIRECTLY ON THE ROTATING TABLE (A) TO CONTACT THE UPPER BRASS SLIP-RING (P)

(-) WIRE (K) CONNECTS SLIP-RING (L) TO (R) TO GROUND

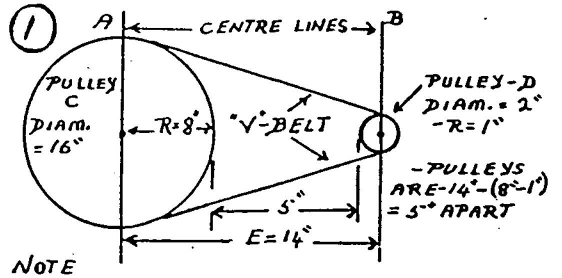
GROUND (R)

(+) WIRE (H) CONNECTS SLIP-RING (P) TO BATTERY -

- NOTE - (+) - POSITIVE GENERATOR POLE CONNECTS THROUGH WIRE (E) - BRUSH (C) - SLIP-RING (P) -
- WIRE (H) TO BATTERY (M) -
- (-) NEGATIVE GENERATOR POLE CONNECTS THROUGH WIRE (F) - BRUSH (D) - SLIP-RING (L) - WIRE (K) TO GROUND (R)

GEAR-UP-V-BELT PRINCIPLES

(1)



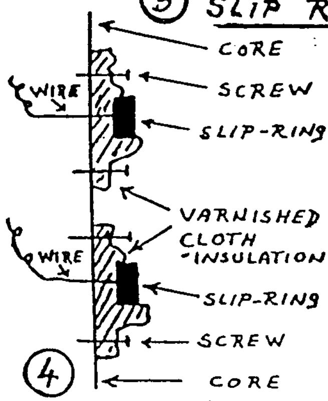
NOTE
- V-BELTS TRANSMIT POWER THROUGH THEIR SIDE WALLS - BY WEDGING ACTION -
- PULLEYS MUST BE FAR ENOUGH APART TO ALLOW BELTS TO COVER HALF OF EACH PULLEY -

RULE - DISTANCE (E) - BETWEEN THE PULLEY CENTRES (A-AND-B) - MUST EQUAL THE DIFFERENCE BETWEEN THE TWO PULLEY DIAMETERS -
∴ DISTANCE (E) = 16" (C) LESS 2" (D) = 14"

BELT LENGTH = 2 × (E) + ½ OF CIRCUMFERENCE (C) + ½ OF CIRCUMFERENCE (D) -

NOTE - PLAIN LEATHER BELTS OR CHAINS CAN REPLACE "V"-BELTS -

(3) SLIP RINGS (ON CORE)



SLIP-RINGS ARE HELD IN PLACE AND ARE INSULATED BY VARNISHED CLOTH (OR PLASTIC BLOCKS) SCREWED TO THE WOODEN CORE -
- THE WHOLE SYSTEM MUST BE KEPT DRY -
- WIRES SOLDERED TO UNDER SIDE OF SLIP RINGS

(4) BRUSHES (ON ROTATING TABLE)

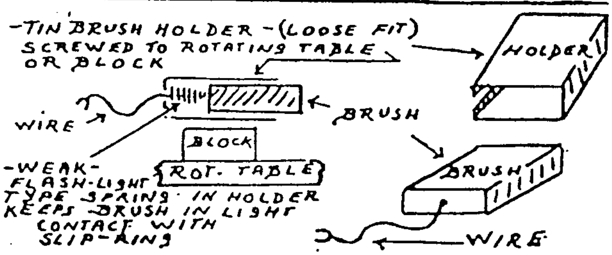


PLATE NO. 68

The primary difference between the metal rotating table for electrical production in this illustration, and the metal rotating table using the right angle drive, (plate no. 31 and 32, is that in this type, the pull rope passes down through the swivel pipe to the ground, (fig. 1, 2 and 3), instead of passing down the outside.

The rest of the shut off system is the same, so both types of metal rotating table should be studied.

The second, and perhaps most significant difference, is the adaptation of the "Pilot Vane", (fig. 1), which is essential to all rotor type applications.

The blade, of course, is vertical and not horizontal, (as in the illustration).

Its purpose is to prevent over run by steering the sails out of the wind when the wind speed gets too high.

The pilot vane should be the same shape as the main tail vane but of half the size.

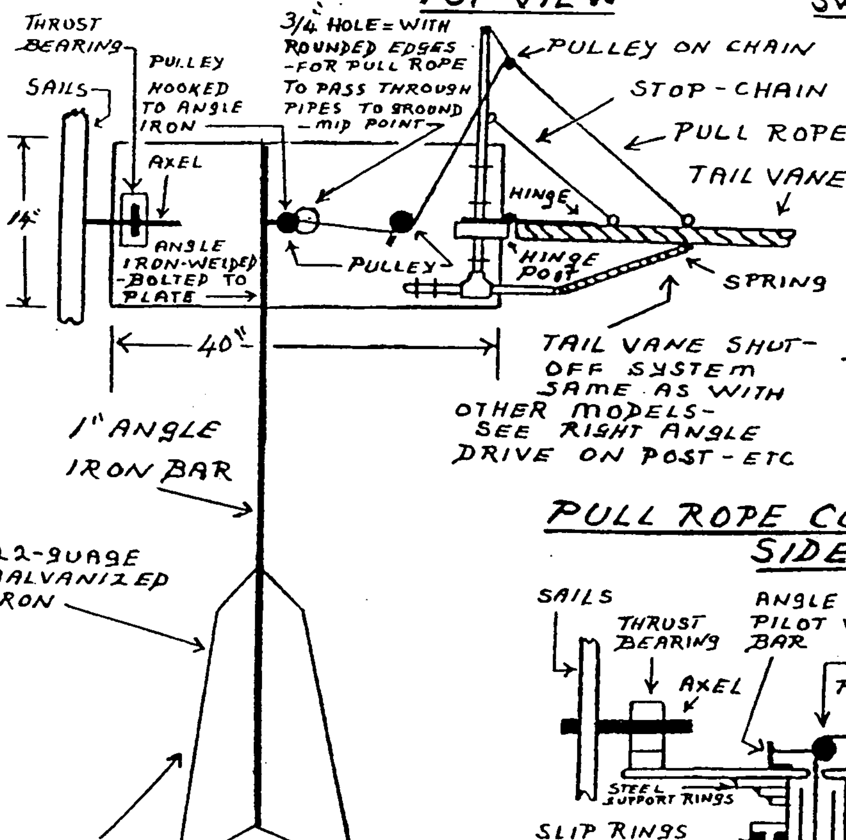
It should project at right angles to the wind shaft axle. Its bar, measured from the centre of the bed plate to the near, or pointed, end of the vane, should be equal to half the diameter of the sails.

It will be noted that the pilot vane bar is welded or bolted fast to the bed plate. It does not swing or move in any way.

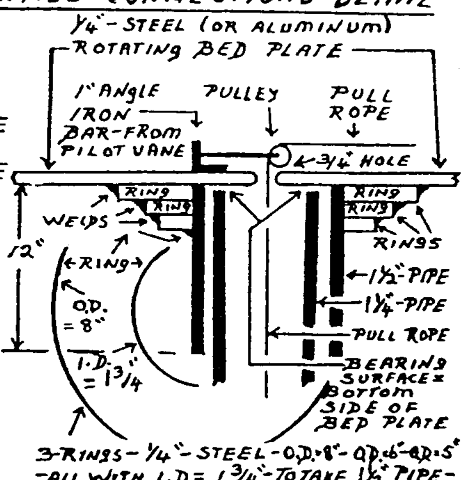
PLATE No. 68

-ELECTRICAL CONNECTIONS-III
-METAL ROTATING TABLE I
-PULL ROPE CONNECTIONS

PULL ROPE CONNECTIONS
TOP VIEW

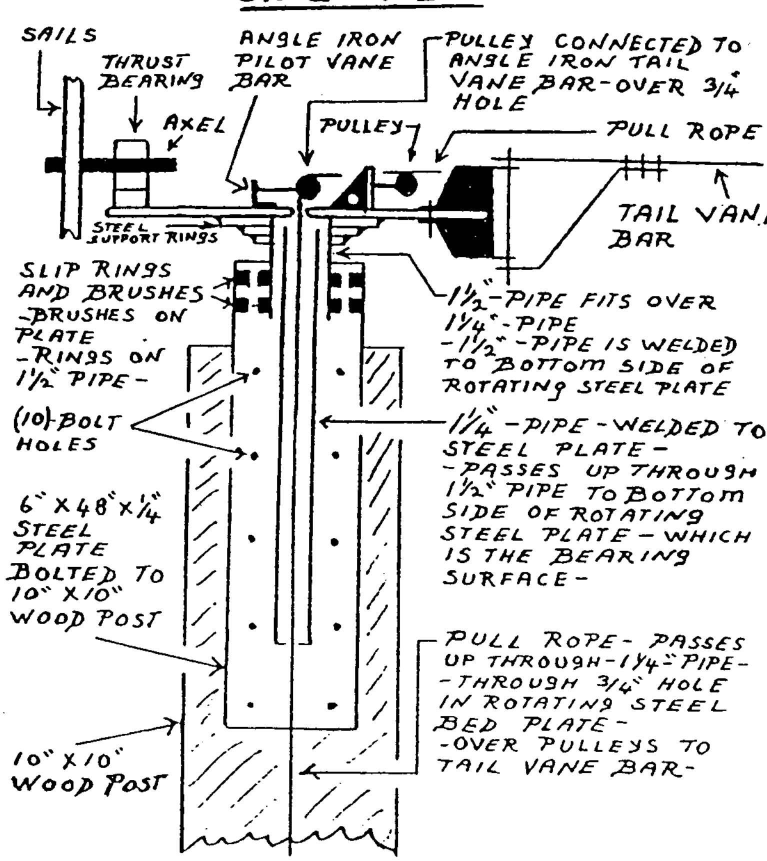


ROTATING BED PLATE
SWIVEL CONNECTIONS-DETAIL



PILOT VANE
- 1/2-SIZE OF MAIN TAIL VANE.
- FROM JUST AHEAD OF MID OR PIVOTAL POINT-
- NOT HINGED - BUT WELDED OR BOLTED TO STEEL BED PLATE-
- FUNCTION IS TO STEEL SAILS OUT OF WIND DIRECTION TO PREVENT OVER RUNNING OF SAILS IN HIGH WINDS-

PULL ROPE CONNECTIONS
SIDE VIEW



NOTE- SWIVEL- 1 1/2" PIPE-12" LONG- IS WELDED TO BOTTOM SIDE OF 1/4" STEEL BED PLATE-

-3-1/4"- STEEL RINGS FIT AROUND 1 1/2"-PIPE-AND ARE WELDED TO BOTH 1 1/2" PIPE AND STEEL BED PLATE TO GIVE STRENGTH TO JOINT OF BED PLATE AND-1 1/2" PIPE-WHICH HAS AN OUTSIDE DIAMETER OF 1 3/4"-

- 1 1/4" PIPE-WELDED TO TOWER POST FITS UP INSIDE OF 1 1/2" PIPE AND SWIVELS ON UNDER SIDE OF BED PLATE-

PLATE NO. 69

The metal rotating table slip rings work on the same principles as slip rings on the wooden rotating table, (plate no. 67), see also text under "electrical Connections V".

PLATE No. 69

- ELECTRICAL CONNECTIONS IV
- METAL ROTATING TABLE II
- SLIP RINGS

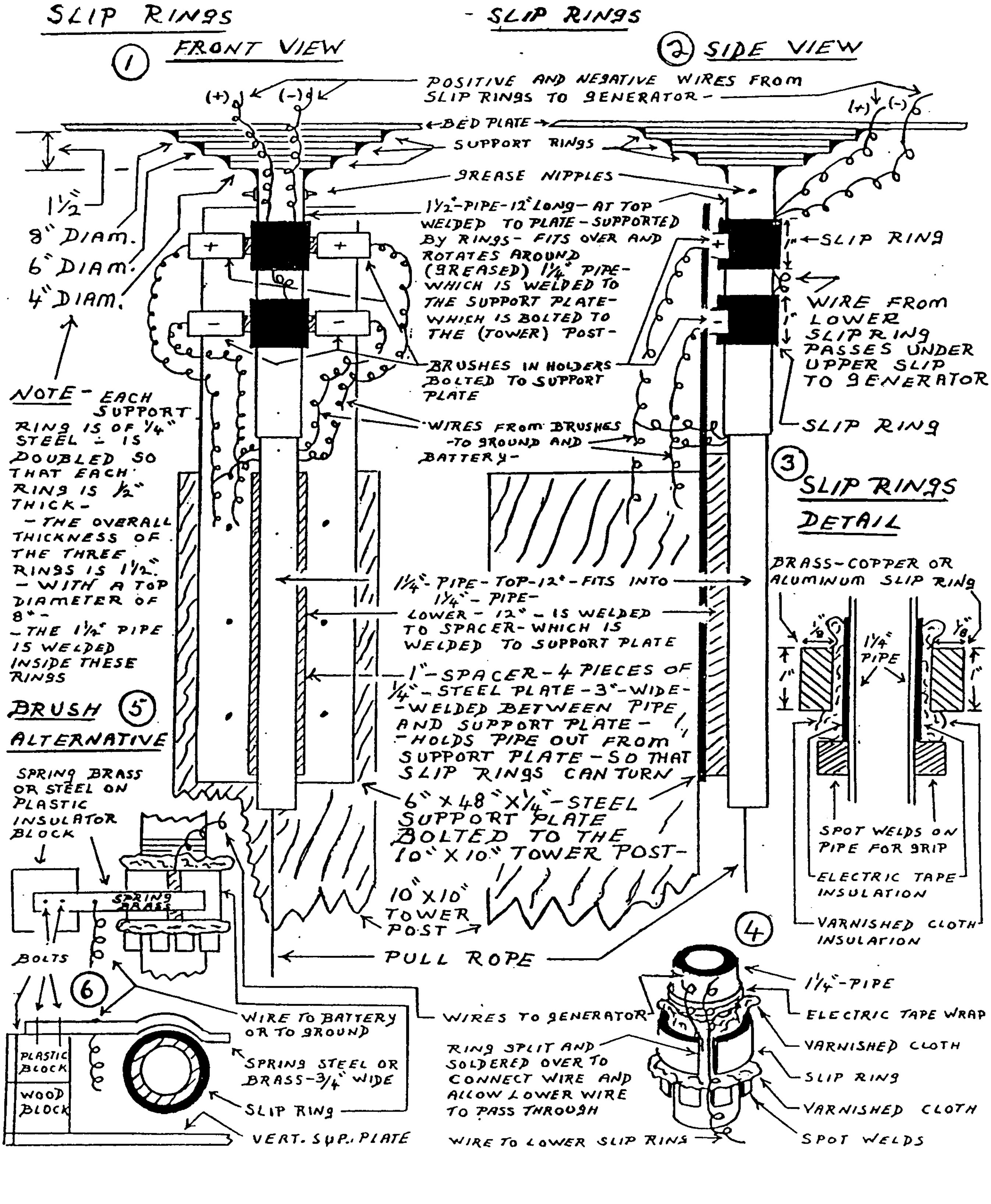


PLATE NO. 70

This is the set up for the "gear up" machinery which follows subsequent illustrations.

The gear up machinery has to be raised on bed bars, in order to allow free movement of the shut off system for the tail vane and pull rope.

The size of the bed plate has to be decided on according to the principles laid out in the text, (this section), for plate no. 31.

Gear up ratio formulas are discussed in the section entitled "Introductory Principles".

PLATE No. 70

- ELECTRICAL CONNECTIONS V
- METAL ROTATING TABLE - III
- POWER TRANSMISSION TO GENERATOR - I
- TRANSMISSION EQUIPMENT

BED BARS AND SUPPORT BLOCKS

NOTE - POWER TRANSMISSION EQUIPMENT MUST BE RAISED, - BY MEANS OF BLOCKS AND ANGLE IRON BARS - HIGH ENOUGH ABOVE THE 1/4" STEEL (OR ALUMINUM) BED PLATE - TO ALLOW THE PULL ROPE EQUIPMENT ON THE BED PLATE TO OPERATE WITHOUT INTERFERENCE -

THE BED BARS AND BLOCKS IN CONTEXT ①

(SUPPORT) BED BARS AND BLOCKS - DETAIL SIDE VIEW ②

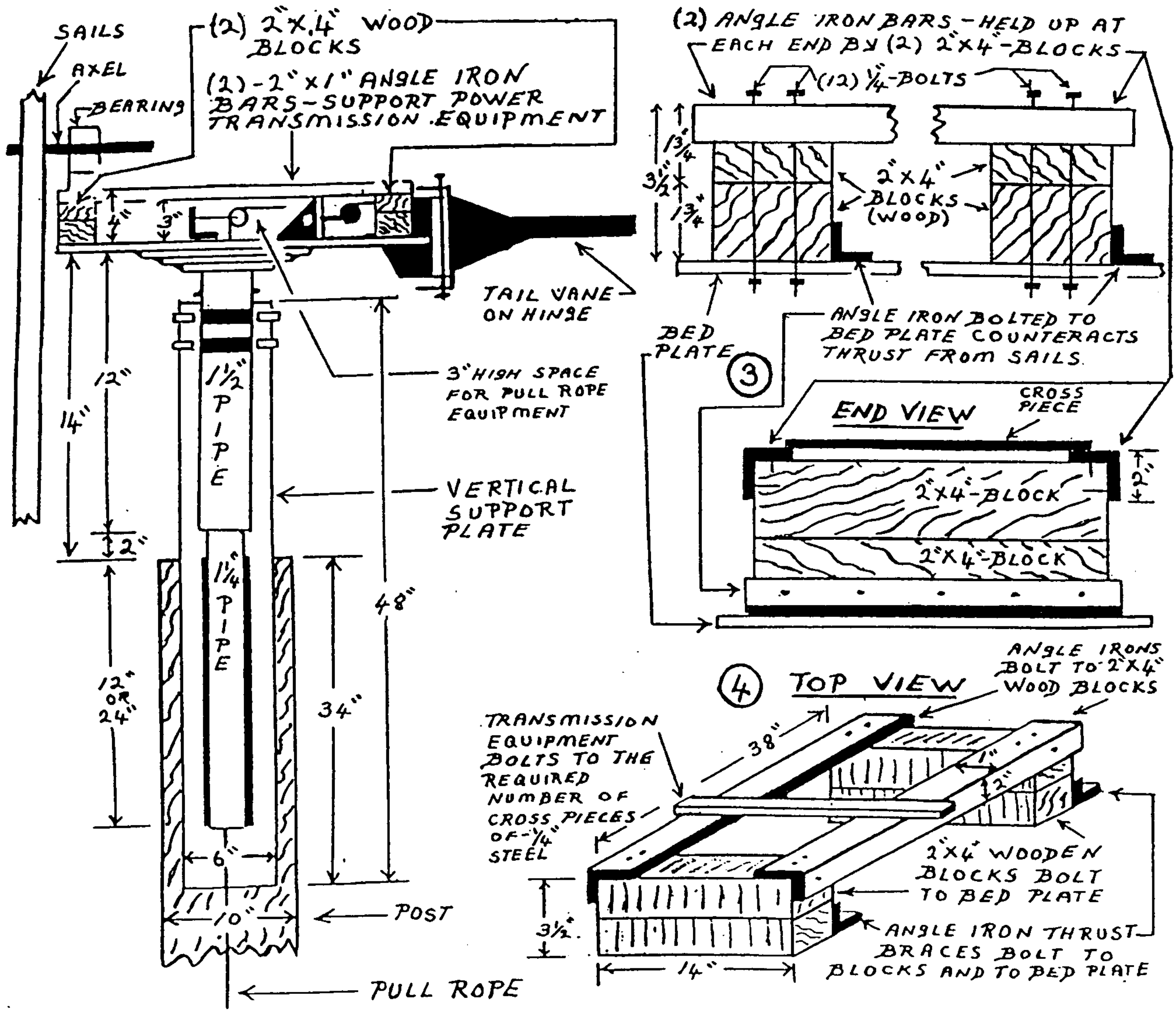


PLATE NO. 71

The principle here is to reverse a normal garden variety speed reducer to make a speed increaser for wind shaft axle gear up.

Speed reducers are available through most bearing dealers, as well as from farm and auto supply houses.

Some specialized oil field supply houses sell actual speed increasers.

Talk to the dealer before you buy.

Note the belt tightener bar in fig. 3. This is every bit as essential on a wind machine as it is on a motor vehicle.

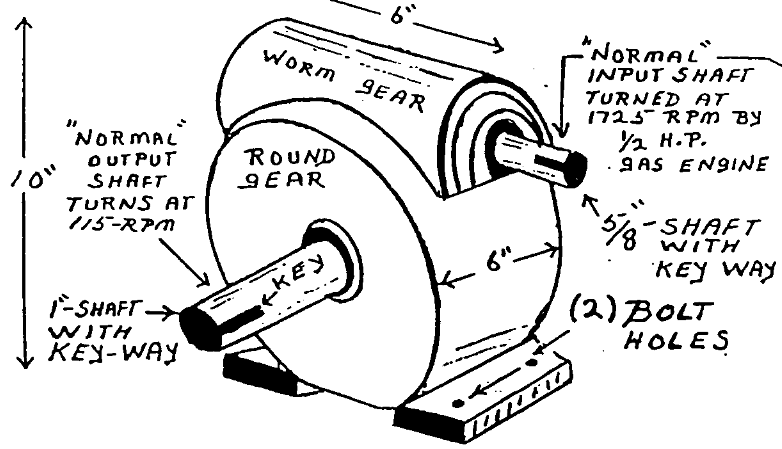
If you use motorcycle chains and sprockets, instead of "V" belts and pulleys, you should still have a belt (chain), tightener, as you do on a motor cycle.

PLATE No. 71

- ELECTRICAL CONNECTIONS - VI
- METAL ROTATING TABLE - IV
- POWER TRANSMISSION TO GENERATOR - II
- GEAR UP - SPEED INCREASERS - I

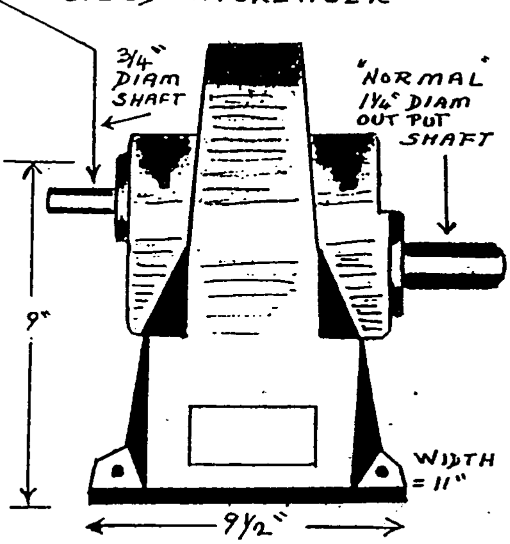
(1) 25-TO-1- ANGLE DRIVE SPEED REDUCER

-REVERSES TO BECOME- 1-TO 25 - SPEED INCREASER

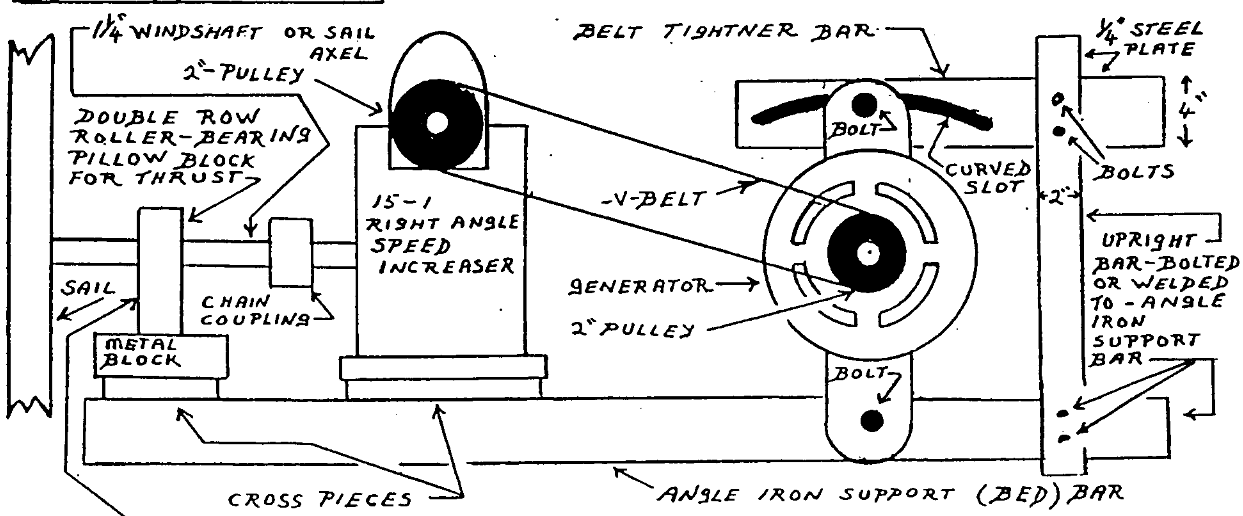


(2) "STRAIGHT LINE" ANGLE DRIVE - 8.5-TO-1-REDUCER

-REVERSES TO BECOME SPEED INCREASER -



(3) RIGHT ANGLE DRIVE (SPEED REDUCER → INCREASER) CONNECTED TO GENERATOR ON SUPPORT BARS



NOTE - THRUST BEARING SHOULD BE AS CLOSE AS POSSIBLE TO SAIL HUB TO REDUCE UPWARD LEVERAGE ON SPEED INCREASER

PLATE NO. 72

Fig. 1 shows a one to one ratio right angle drive used to change the power direction to a large pulley that can pass below the edge of the bed plate. In this case, only one drive pulley will be needed for the gear up; mechanical and slippage losses will be reduced.

Fig. 2 shows how the bed plate can be redesigned so that "bed bars", (plate no. 70), are not required. The tail vane shut off mechanism is placed on the added section of the bed plate at the back.

The large pulley for the gear up is on the wind shaft axle itself. As this pulley, (as in fig. 1), passes below the level of the bed plate, only one drive pulley is required.

This design obviates the need for right angle drives, speed increasers, (reducers), as well as bed bars.

Note the presence of belt tighteners in both fig. 1 and fig. 2.

Fig. 4 shows a straight line design that operates on a direct drive system without drive pulleys or belts. This will afford the least possible mechanical and slippage losses. Again, the speed increaser is a speed reducer simply turned around.

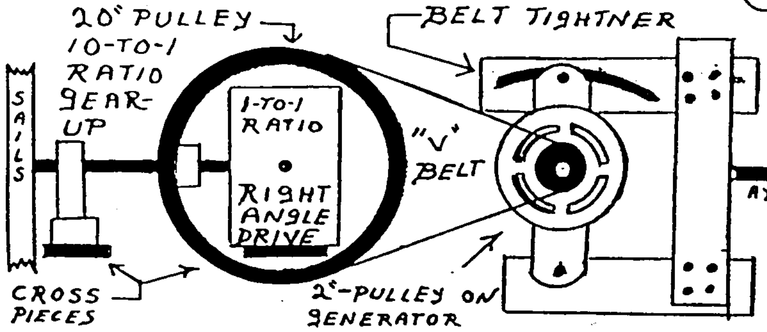
Note the presence of bed bars. Read carefully note on plate no. 31, Re: bed plate.

PLATE No. 72

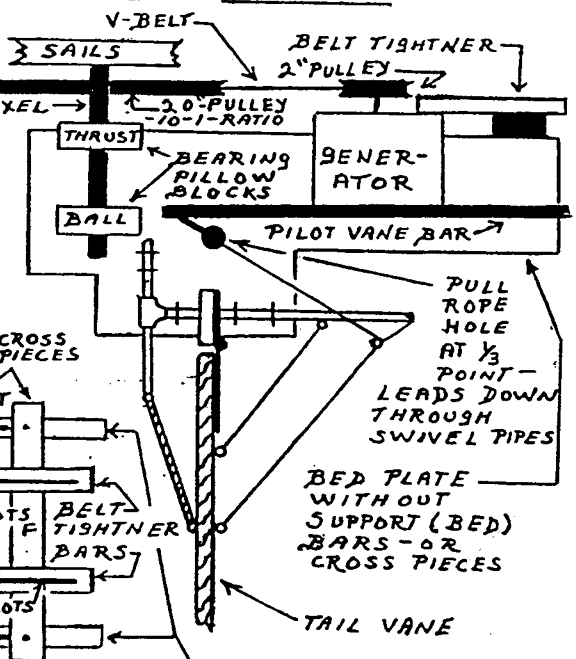
-ELECTRICAL CONNECTIONS - VII
-METAL ROTATING TABLE - V
-POWER TRANSMISSION TO GENERATOR - III
-GEAR UP - SPEED INCREASERS - II

(1) 1-1-RATIO ANGLE DRIVE AND "V"-BELT

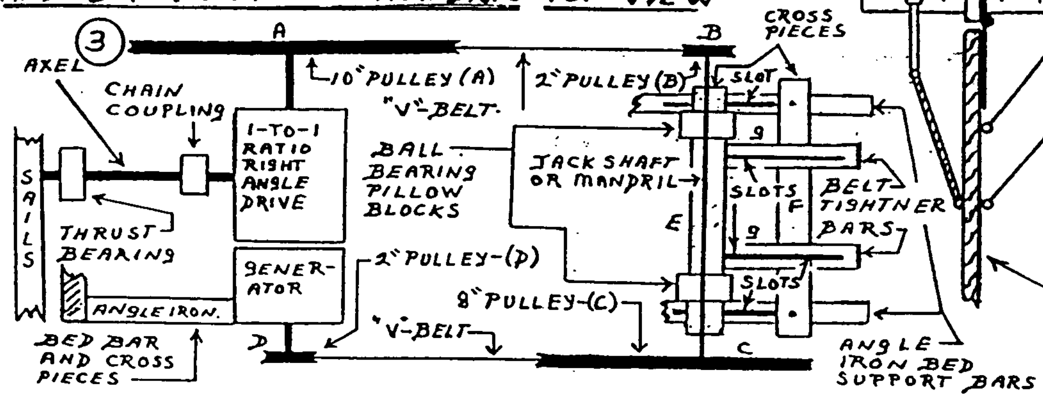
SIDE VIEW



(2) "V"-BELT PULLEY ON WINDSHAFT (SAIL AXEL)-NO RIGHT ANGLE DRIVE- TOP VIEW-



RIGHT ANGLE DRIVE-"V"-BELT PULLEYS AND JACK SHAFT-OR MANDRIL-TOP VIEW-

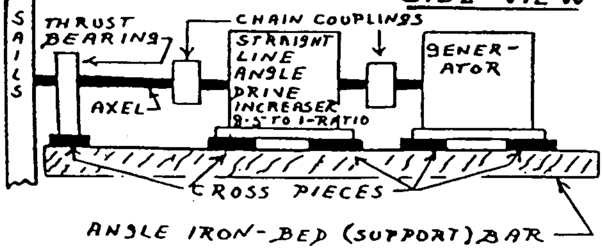


NOTE - THE RIGHT ANGLE DRIVE -(A)- BEING - 1 TO - 1 - RATIO TURNS AT THE SAME SPEED AS THE SAILS AND WIND SHAFT -
-(10") PULLEY (A) TURNS (2") PULLEY (B) IN A - 5-TO-1 RATIO - SO PULLEY (B) TURNS 5 TIMES AS FAST AS PULLEY (A) - AND FIVE TIMES AS FAST AS THE SAILS AND WIND SHAFT
- PULLEY (C) BEING ON THE SAME SHAFT AS PULLEY (B) TURNS AT THE SAME SPEED-
-(8") PULLEY (C) TURNS (2") PULLEY (D) IN A RATIO OF - 4-TO-1 - SO PULLEY (D) TURNS 4 TIMES AS FAST AS PULLEY (C)

∴ GEAR UP = (A-TO-B) 5 x (C-TO-D) 4 = 20-TO-1 - SO GENERATOR TURNS AT 20 TIMES THE R.P.M. OF THE WIND SHAFT AND SAILS -
- IF THE WIND SHAFT TURNS AT 80 R.P.M. THE GENERATOR WILL TURN AT 20 x 80 = 1600 R.P.M.

(4) STRAIGHT LINE ANGLE DRIVE

SIDE VIEW



NOTE - ABOVE - BELT TIGHTNER - CROSS PIECE (E) SLIDES TOWARD CROSS PIECE (F) BY MEANS OF BOLTS IN THE ANGLE IRON BED BAR SLOTS - AND IS HELD BY BARS (g) AND (g) - BOLTS IN SLOTS OF BARS (g) AND (g) - HOLD FAST BY BOLTING INTO CROSS PIECE (F) -

NOTE - LEFT - STRAIGHT LINE DRIVE AFFORDS THE LEAST POSSIBLE POWER LOSS -

PLATE NO. 73

The purpose of the "wind switch" is to turn the field wire "on" when the wind speed reaches 8 m.p.h. and to turn it "off" again when the wind drops below that speed.

It performs the same function as the ignition switch on a car. This is to say, it stops the ALTERNATOR from draining the battery when the wind machine is operating below "cut in speed".

A wind switch is not necessary in a D-C GENERATOR System.

See Electrical Connections, Section V.

PLATE No. 73

-ELECTRICAL CONNECTIONS VIII
-THE WINDSWITCH - OR - WIND SENSOR
-FOR BOTH WOODEN AND METAL ROTATING TABLES-

NOTE - A GENERATOR DOES NOT REQUIRE A WINDSWITCH - -BECAUSE- IT HAS PERMANENT MAGNETS THAT DO NOT HAVE TO BE INITIALY ENERGISED BY A BATTERY-

BUT - FOR AN AUTOMOBILE ALTERNATOR TO COMMENCE CHARGING - ITS FIELD MUST FIRST BE ENERGISED BY THE BATTERY - THIS IS DONE WHEN THE DRIVER TURNS ON THE KEY - WHEN THE MOTOR STOPS - THE KEY MUST BE TURNED OFF OR THE ALTERNATOR WILL SLOWLY DRAIN THE BATTERY BY CONTINUING ITS ELECTRO-MAGNET'S DEMAND TO BE ENERGISED-

-THE WIND (SENSOR) SWITCH TURNS THE ALTERNATOR "ON" WHEN THE WIND IS BLOWING HARD ENOUGH (8 MPH) TO GENERATE POWER - AND TURNS IT OFF WHEN THE WIND SPEED IS BELOW 8 M.P.H. - AND CAN NOT GENERATE POWER - - AN 8 M.P.H. WIND SPEED - WITH THE PROPER GEAR UP - WILL TURN MOST ALTERNATORS AT 750 - 950 R.P.M. - AT WHICH POINT THE ALTERNATOR VOLTAGE WILL BE GREATER THAN THE BATTERY VOLTAGE -

- THE WIND SWITCH - OR SENSOR - IS ACTIVATED BY A - 8" x 8" - PADDLE OR VANE MOUNTED ON THE TAIL VANE BAR - AT LESS THAN ARMS LENGTH FROM THE HINGE - SO IT CAN BE SERVICED - THE PADDLE BLOWS OVER TO MAKE CONTACT - "ON" - AND FALLS BACK TO BREAK CONTACT - "OFF" - WHEN THE WIND FALLS BELOW 8 M.P.H. -

- SET THE WIND SWITCH BY ADDING OR SUBTRACTING LEAD COUNTERWEIGHTS ON THE LOWER END - WHILE THE WINDSWITCH IS HELD ALOFT ON THE BACK OF A TRUCK - WHILE THE TRUCK IS TRAVELING - 8 M.P.H. DOWN A FLAT ROAD ON A WINDLESS DAY - HOLD THE WIND SWITCH WELL ABOVE THE AIR STREAM PASSING OVER THE TRUCKS CAB -

-THERE MUST ALSO BE A MANUAL SWITCH AT THE TOWER BOTTOM - TO SWITCH OF THE FIELD WIRE WHEN THE WIND MACHINE IS TURNED OFF BY THE PULL ROPE -

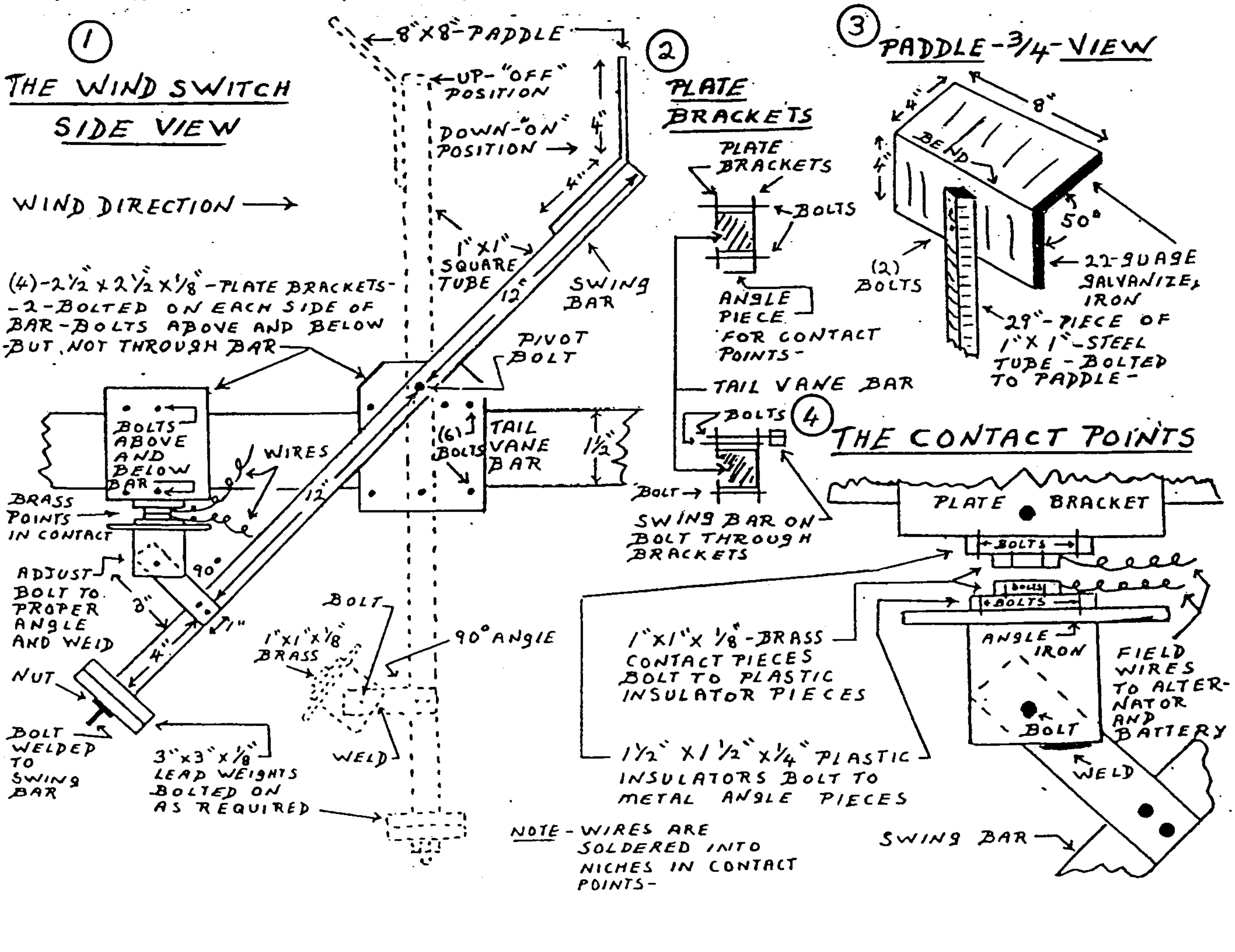


PLATE NO. 74

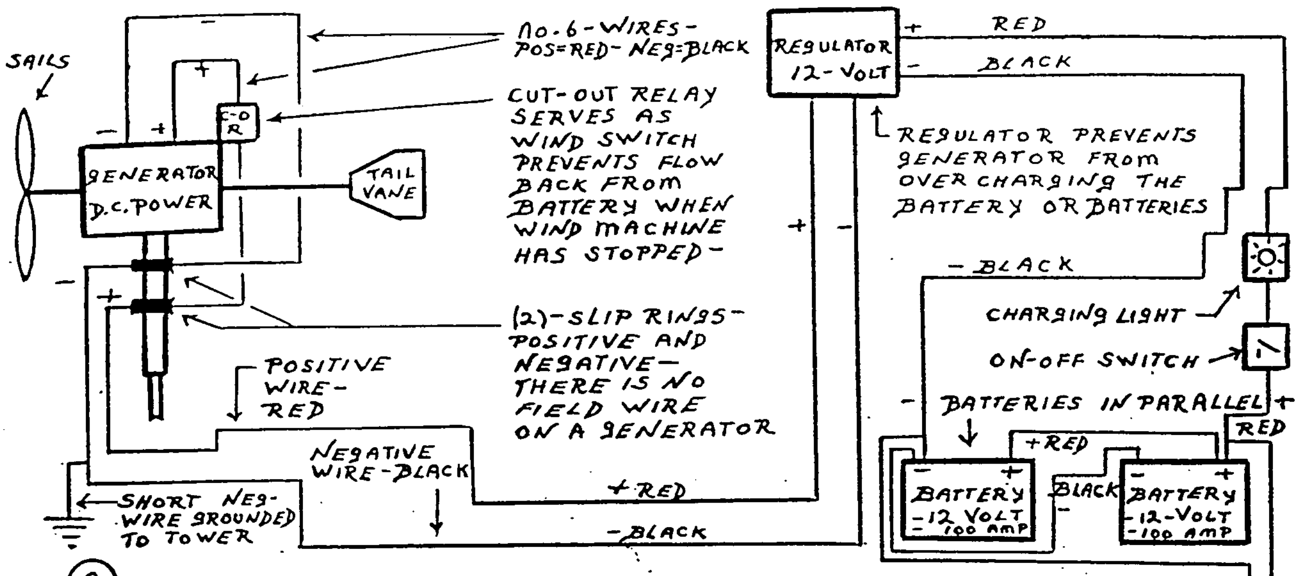
These wiring diagrams should be in front of you when you read the section on "Electrical Connections".

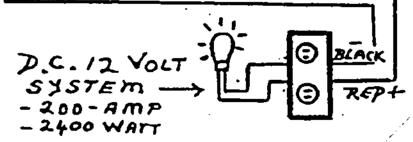
PLATE No. 74

-ELECTRICAL CONNECTIONS - IX
-WIRING DIAGRAMS - GENERATOR-ALTERNATOR

(1)

GENERATOR WIRING DIAGRAM - 12-VOLT D.C. SYSTEM GENERATOR COMMENCES MAKING ELECTRICITY AT ABOUT 1500 R.P.M. - SO NEEDS MORE GEAR UP - BUT NO WIND SWITCH





(2)

ALTERNATOR WIRING DIAGRAM - 12-VOLT D.C. SYSTEM - WITH A.C. CONNECTIONS - ALTERNATOR COMMENCES MAKING ELECTRICITY AT ABOUT 750-950-RPM - SO REQUIRES LESS GEAR UP - BUT DOES REQUIRE A WIND SWITCH -

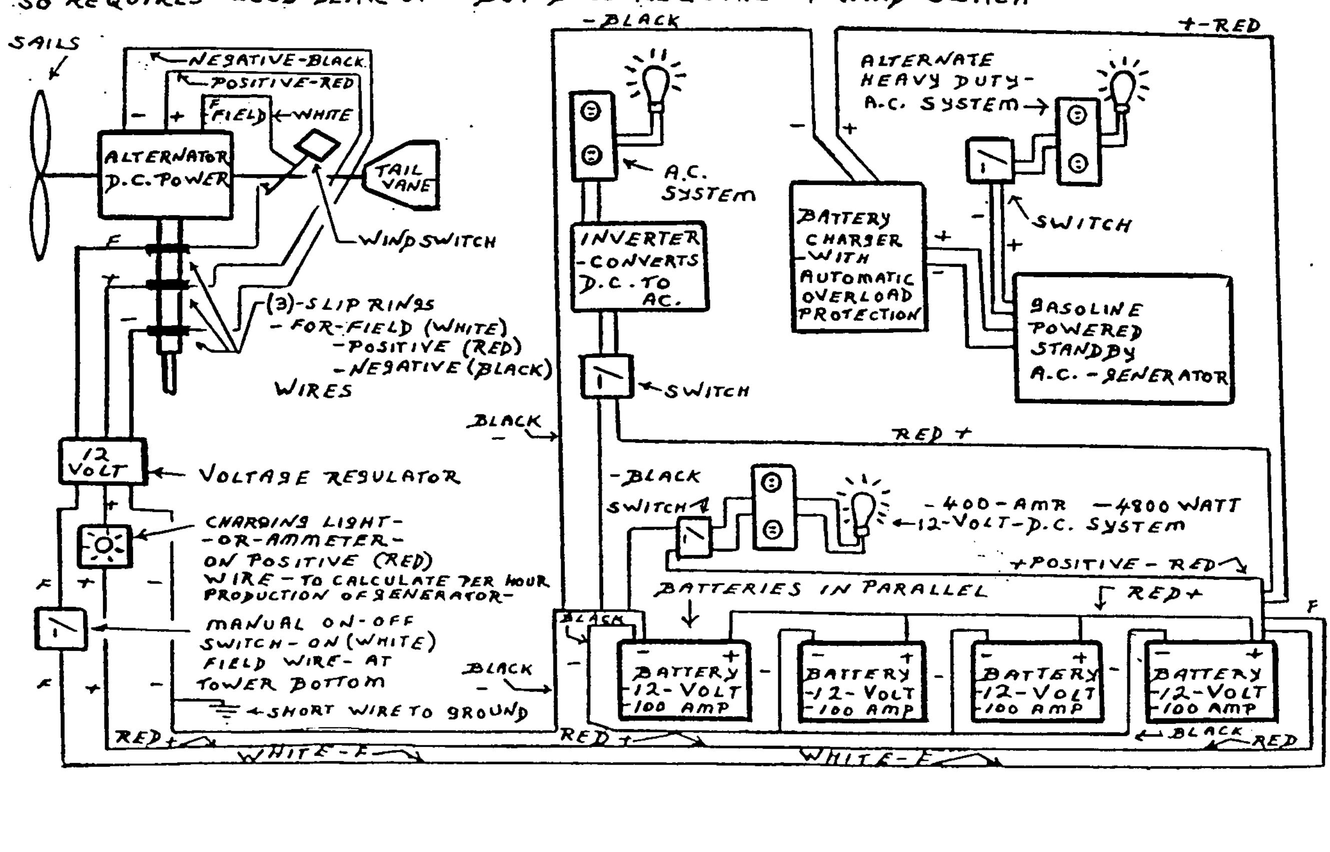


PLATE NO. 75

Fig. 1 and 2 show batteries connected in parallel which means that the voltage remains the same as it is in each single battery but the storage capacity increases.

Fig. 2 is the most practical, as it allows batteries to be easily added or taken out by simply connecting to or disconnecting from the busses.

Fig. 3 shows batteries connected in series which means that the voltage increases, but the storage capacity remains the same. Groups of batteries in series can be connected to each other in parallel.

See “Electrical Connections”, Section IV, The Battery System.

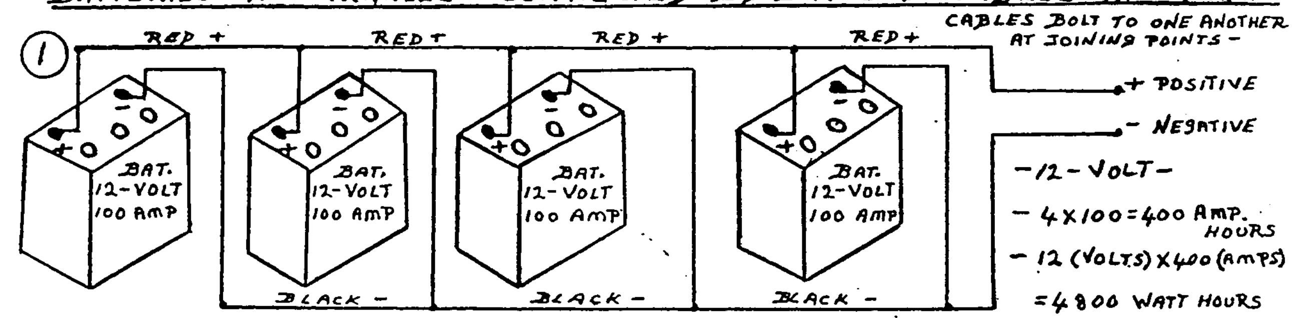
PLATE No. 75

- ELECTRICAL CONNECTIONS X
- BATTERY HOOK-UPS - PARALLEL AND SERIES -

BATTERIES IN PARALLEL

- BATTERIES ARE CONNECTED - POSITIVE TO POSITIVE AND NEGATIVE TO NEGATIVE -
- EVERY BATTERY IN THE BANK MUST BE OF THE SAME VOLTAGE - THE AMP-HOUR RATING PER BATTERY MAY VARY -
- THE VOLTAGE RATING OF THE WHOLE BANK WILL REMAIN THE SAME AS EACH INDIVIDUAL BATTERY IN THE BANK - IF FOUR 12-VOLT BATTERIES ARE USED - THE VOLTAGE RATING OF THE WHOLE BANK WILL BE 12-VOLTS -
- THE AMPERAGE - OR AMP. HOURS (STORAGE CAPACITY) HOWEVER WILL BE CUMULATIVE A BATTERY BANK OF 4 - 12-VOLT - 100 AMP. HOUR BATTERIES - WILL HAVE AN AMP. HOUR RATING OF 4 x 100 = 400 AMP HOURS -
- EXTRA BATTERIES MAY BE ADDED TO THE BANK AT WILL - SO THAT STORAGE CAPACITY WILL SUPPLY THE ELECTRICAL OUTLETS WHEN THE WIND HAS STOPPED AND THE GENERATOR IS NOT TURNING.
- IN PARALLEL - ANY NUMBER OF BATTERIES CAN BE ADDED OR TAKEN AWAY ACCORDING TO NEED -
- WATTAGE IS CALCULATED BY MULTIPLYING VOLTS TIMES AMPS - EG. 400 (AMP HOURS) x 12 (VOLTS) = 4800 WATTS - = 1 - 60-WATT LIGHT BULB FOR (4800 ÷ 60 = 80) HOURS -
- ADD UP THE WATTAGE REQUIRED (ALL APPLIANCES) DIVIDE THAT BY THE WATTAGE PER BATTERY (12 VOLTS x 100 AMPS = 1200 WATTS) THEN ADD SURPLUS BATTERIES FOR ESTIMATED NUMBER OF WINDLESS DAYS -

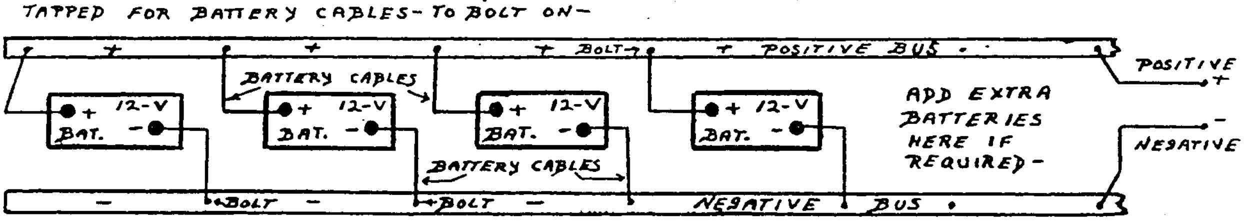
BATTERIES IN PARALLEL - CONNECTED BY BATTERY CABLES - 12-V-SYSTEM



(2)

BATTERIES IN PARALLEL - CONNECTED BY BUSSES - 12-VOLT SYSTEM

- BUSSES CAN BE MADE OF BRASS, COPPER, ALUMINUM, STEEL OR IRON BARS WITH HOLES TAPPED FOR BATTERY CABLES - TO BOLT ON -



(3)

BATTERIES IN SERIES - CAN BE CONNECTED BY BUSSES AND CABLES OR BY BATTERY CABLES ONLY - BATTERIES ARE CONNECTED POSITIVE TO NEGATIVE -

- ALL BATTERIES IN THE BANK MUST HAVE THE SAME AMP HOUR RATING - THE VOLTAGE RATING PER BATTERY MAY VARY -
- THE AMP HOUR RATING OF THE WHOLE BATTERY BANK WILL REMAIN THE SAME - BUT THE VOLTAGE RATINGS WILL BE CUMULATIVE - E.G. - CONNECT TWO - 6-VOLT - 100 AMP. GOLF CART BATTERIES IN SERIES AND THE BANK WILL PRODUCE - (2x6 = 12) VOLTS AND 100 AMPS.
- SUCH 12-VOLT SERIES BANKS - CAN BE CONNECTED TO SIMILIAR 12-VOLT SERIES BANKS IN PARALLEL TO CREATE A 12-VOLT SYSTEM WITH CUMULATIVE AMPERAGE -
- SERIES BANKS MAY ALSO BE USED TO CREATE 24 VOLT AND OTHER SUCH SYSTEMS -

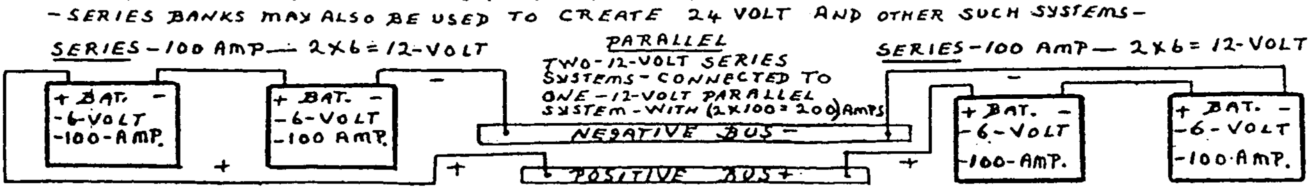


PLATE NO. 76

Before building a wind machine, you should always make a scale drawing of the machine and the tower so that you can tell how long to make the wind shaft axle. The sails must be far enough out so that the tips do not bang on the tower legs. If this is a problem, you can select the "post tower" in plate no. 81, fig. 3.

Read carefully, the information here and on plate no. 76, as there is no such thing as a wind machine that will not benefit from tower height.

The usual base to height ratio is one to three, that is to say, that the tower should be three times as high as it is wide at the base.

A tower 30 feet high and 10 feet wide at the base is conservative and safe. The maximum height should be 60 feet, with a 20 foot width at the base.

The foundations here shown, are all important methods of rooting the tower down to the ground so that it won't blow over. Remember, the wind forces against it can amount to several tons.

Fig. 1, (left), can be round instead of square, but, it is important that the foundation posts go down at least four feet into the ground. In areas where the frost goes deep, they should be deeper.

The steel cross bars should really be welded to the upright threaded bars, which should go all of the way down. The cross bars, however, can also be wired on if welding is not feasible. Make the mould, then put in the steel frames, then pour in the concrete. Be sure that all of the foundation post tops come to exactly the same level.

Fig. 3, (right), is for areas where it is not possible to sink foundation posts. This idea will work even in areas of heavy and deep ground frost, (see plate no. 1).

PLATE No. 76

THE TOWER - I

THEORY AND PRINCIPLES

TOWER FOUNDATIONS I

NOTE - TOWER HEIGHT SHOULD BE AT LEAST 30 FT TO AVOID FRICTION ON THE EARTHS SURFACE WHICH SLOWS DOWN THE WIND - AND REDUCES THE AMOUNT OF POWER DELIVERED TO THE WIND MACHINE -

- THE AMOUNT THAT THE WIND IS SLOWED DOWN BY GROUND FRICTION DEPENDS ON THE ROUGHNESS OF THE TERRAIN AND THE SPEED OF THE WIND - MOST WIND MACHINES REQUIRE CONSTANT WIND SPEEDS OF ABOUT 12 M.P.H. TO GENERATE SUFFICIENT POWER - YET AVERAGE WIND SPEEDS AT A GOOD SITE RARELY EXCEED 15-TO-18-M.P.H. - SO THE BEST MUST BE MADE OF WHAT IS THERE - WIND VELOCITY WILL FALL AS EARTH'S SURFACE (THE BOUNDRY LAYER) IS APPROACHED - ON THE SAME DAY THE MACHINE ON THE HIGHER TOWER MAY BE OPPERATING EFFECIENTLY WHILE THE MACHINE ON THE LOWER TOWER IS BECALMED - YET THE EXPENCE OF THE HIGHER TOWER MUST BE JUSTIFIED -

- WIND SPEAD AT 33 FT. CAN BE EXPECTED TO BE 26% GREATER THAN AT 13 FT. - BY THE SAME LAW USING CUBE ROOT - A 57 FT. TOWER WOULD HAVE 3 TIMES THE POWER OF A 13 FOOT TOWER AND 4.25 TIMES THE POWER OF A 5 FT TOWER - AN 80 FT TOWER WILL HAVE 5.3 TIMES THE POWER OF A 5 FT TOWER - IS IT CHEAPER TO BUILD ONE 60 FT TOWER OR TWO 30 FT. TOWERS?

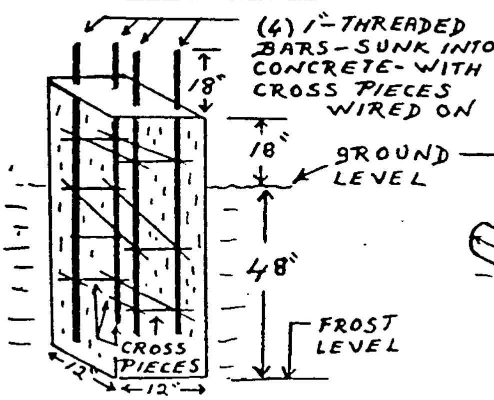
- THE TOWER SHOULD BE 20 FT. ABOVE ANY TREES OR OTHER OBSTRUCTIONS WITHIN 400 FT - - EDDY CURRENTS OR TURBULENCE CAUSED BY THE WIND PASSING OVER OBSTRUCTIONS WILL BUFFET THE WIND MACHINE AND CAUSE PREMATURE MECHANICAL FAILURE OF THE GENERATOR - A 50 FOOT TOWER ON A FLAT PLATFORM IN THE CENTRE OF A LARGE LAKE WILL CAPTURE 78% OF THE WIND SPEED AVAILABLE AT 200 FT. - THE SAME TOWER CLOSE TO FARM BUILDINGS AND TREES WOULD CAPTURE 55% - IN AN URBAN AREA IT WOULD CAPTURE 35% - AS THE HEIGHT OF GROUND OBSTACLES INCREASES SO DOES THE HEIGHT OF THE GRADIENT OR CONSISTANT AND USEFUL WIND - SO SELECT THE SITE AND PLAN THE HEIGHT OF THE TOWER WITH CARE -

- AS THE WIND MACHINE DOES NOT STOP THE WIND - IT CAN.NOT EXTRACT 100% OF THE WIND'S POWER - THE THEORETICAL MAXIMUM IT CAN EXTRACT IS 59.3% - THE MOST EFFECIENT WIND MACHINE MAY EXTRACT 70% OF THIS 59.3% - A GOOD WIND MACHINE MAY EXTRACT 30-TO-50% OF THE WINDS TOTAL POWER - SO A LESS EFFECIENT MACHINE MUST BE LARGER OR HIGHER

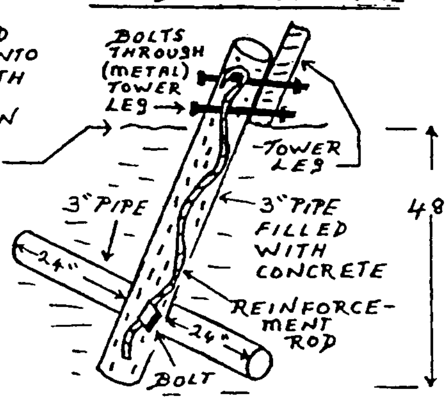
- YET - POWER = FORCE X VELOCITY - AND - POWER MULTIPLIED BY TIME = ENERGY - AND - ENERGY IS THE CAPACITY TO DO WORK -
- BUT - IF THE WIND SPEED DOUBLES - THE WIND POWER GOES UP BY A FACTOR OF EIGHT - IE IT IS EIGHT TIMES AS MUCH - WHEN THE WIND SPEED TRIPLES THE POWER THAT CAN BE EXTRACTED IS 27 TIMES AS GREAT - THIS IS AN EXTREMELY IMPORTANT CONCEPT THAT WILL FURTHER EFFECT YOUR SELECTION OF TOWER HEIGHT AND LOCATION -

TOWER FOUNDATIONS - I

(4) 12" X 12" CONCRETE CORNER POSTS



3" IRON PIPE FILLED WITH CONCRETE



LOG CRIB FILLED WITH ROCKS

FOR BARE ROCK OR FROST FREE AREAS

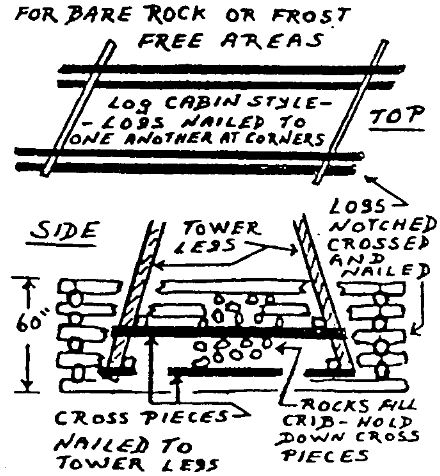


PLATE NO. 77

The purpose of the wood beam base frame in fig. 1 is to hold the concrete foundation posts together. Note how the four 1" threaded bars come up through the corners. You can drive nails down through the laminating boards every foot or so. Use 1" X 12" rough Douglas Fir or Pine planks laminating or overlapping at the corners.

Pole towers, (fig. 2, 3 and 4), will do a good job, but they can not be as strong as towers made from laminated lumber, (plates 79, 80, 81 and 82). See also the "Horizontal Tension Cable" in "U" of plate no. 1.

Be sure to use several coats of wood preservative on all wooden towers.

PLATE No 77

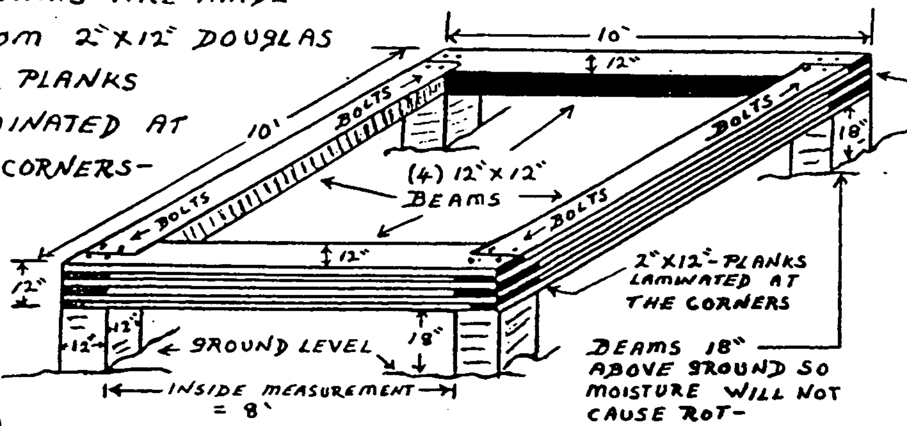
- THE TOWER II
- TOWER FOUNDATIONS II
- THE TOWER BASE
- POLE TOWER CONSTRUCTION

(1)

10'x10' - WOOD BEAM BASE FOR 30 FOOT TOWER

BOLTS ONTO 12"x12" CONCRETE POSTS - 18" ABOVE THE GROUND -

- BEAMS ARE MADE FROM 2"x12" DOUGLAS FIR PLANKS LAMINATED AT THE CORNERS -



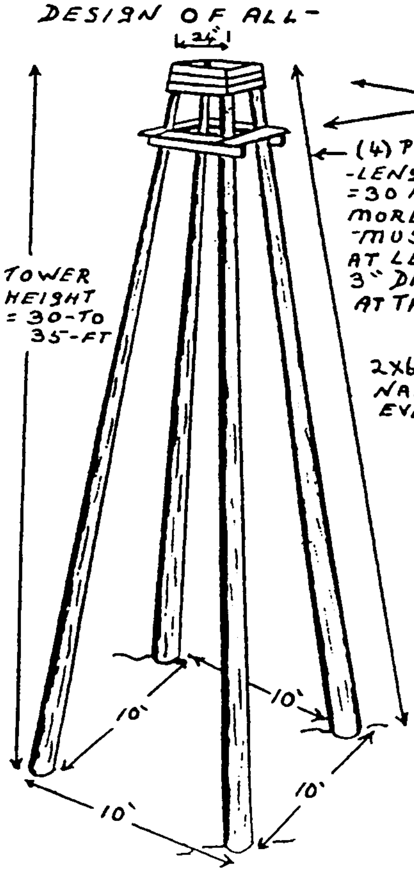
(6) 2"x12" - PLANKS PER SIDE - TOTAL = 4 x 6 = 24 PLANKS - CREATES - 4 - BEAMS - EACH - 12" x 12" x 120"

- BEAMS BOLT DOWN BY 1" THREADED BARS COMING UP THROUGH CONCRETE CORNER POSTS -

(2)

POLE TOWER

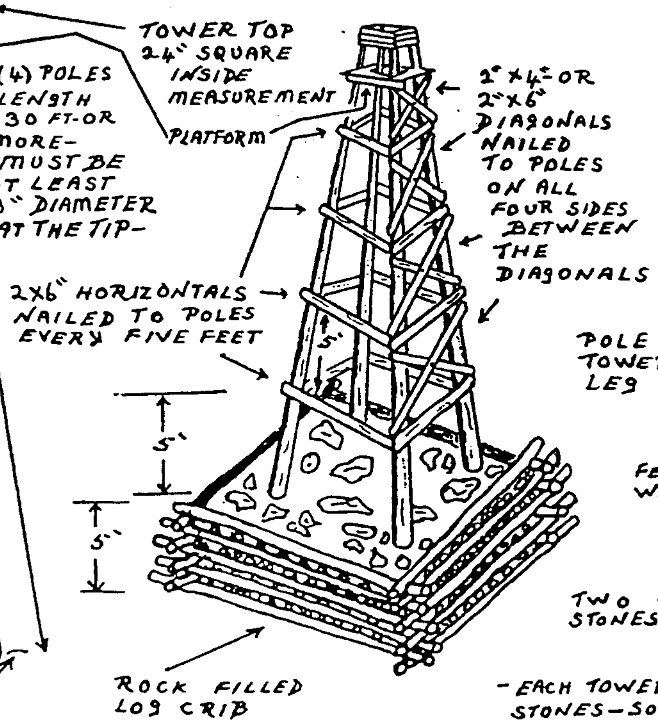
- THE SIMPLEST TOWER DESIGN OF ALL -



(3)

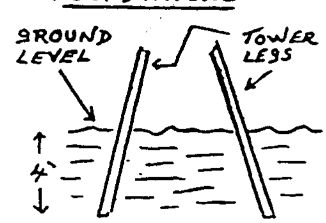
POLE TOWER

- DIAGONAL AND HORIZONTAL SUPPORTS -

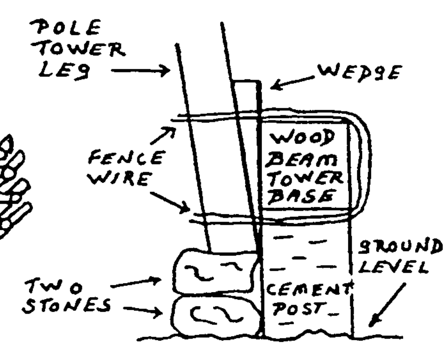


(4)

POLE TOWER ALTERNATE FOUNDATIONS



TOWER LEGS SIMPLY SUNK INTO THE GROUND



- EACH TOWER LEG SITS ON TWO STONES - SO MOISTURE CAN NOT RISE - TO CAUSE ROT -

- EACH TOWER LEG IS LASHED TO THE INSIDE OF THE BASE BEAM WITH FENCE WIRE -

PLATE NO. 78

Five feet between horizontal makes a very strong tower. They can, however, be as much as seven feet apart.

Note that the legs are of 2" X 6", the diagonals are of 2" X 6" and the horizontal are of 2" X 8" dressed lumber.

This 30 foot tower should sit on 10 foot wood beam base, illustrated in plate no. 77, fig. 1.

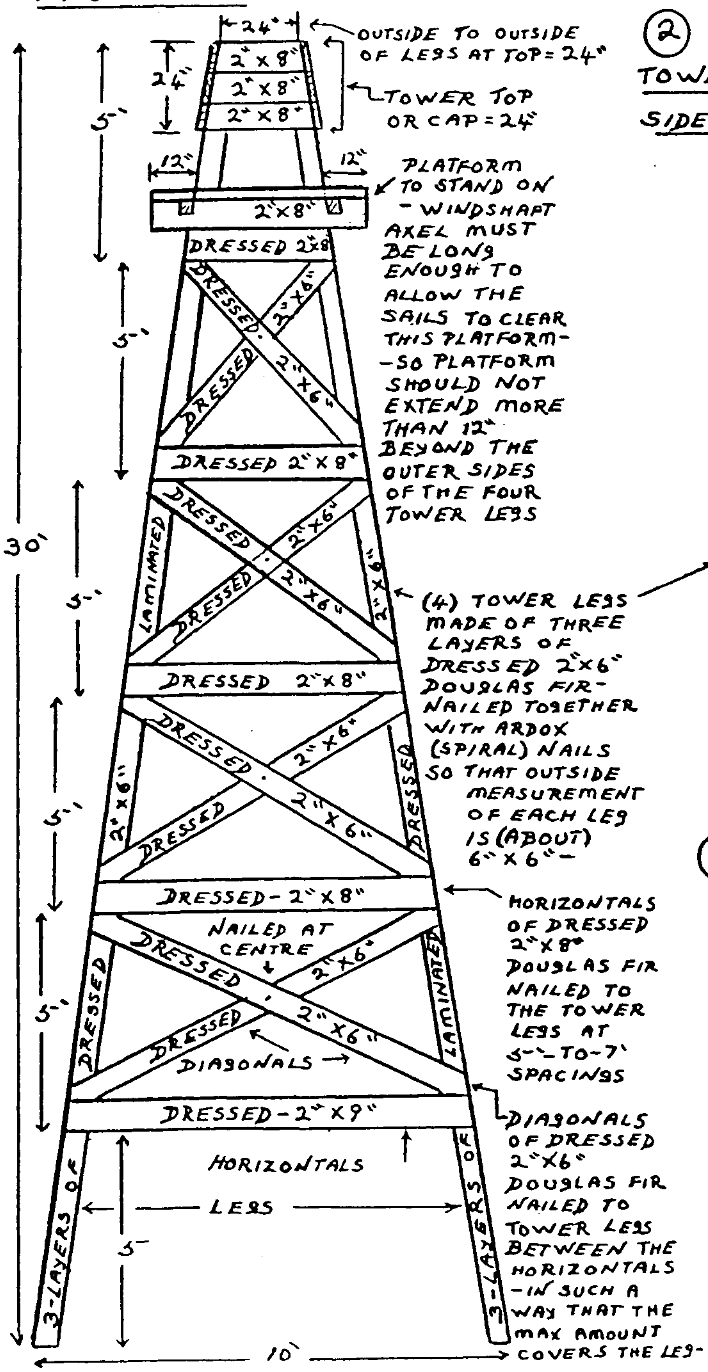
PLATE No. 78

– THE TOWER – III
– WOODEN TOWER I

NOTE – THE USUAL HEIGHT TO BASE RATIO OF A WIND MILL TOWER IS 3-TO-1 – AS IS THE CASE OF THE ONE ILLUSTRATED BELOW – BASE = 10' AND HEIGHT = (3 X 10' = 30') – THOUGH SOME WOODEN OIL RIG TOWERS HAD RATIOS OF FIVE AND EVEN FIVE AND A HALF TO ONE – WOOD TOWERS MAY BE AS HIGH AS 60 FEET WITH A 20 FOOT BASE – BUT THEY MUST BE CONSTRUCTED OF HEAVIER LUMBER – 2" X 10" INSTEAD OF 2" X 6" – FOR THE LEGS ETC. –

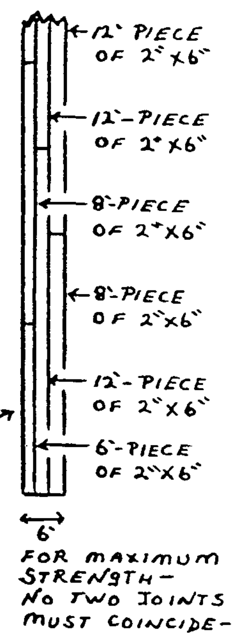
(1) 30 FOOT WOODEN TOWER – 1/4" = 1'

FRONT VIEW – ONE OF FOUR SIMILIAR SIDES



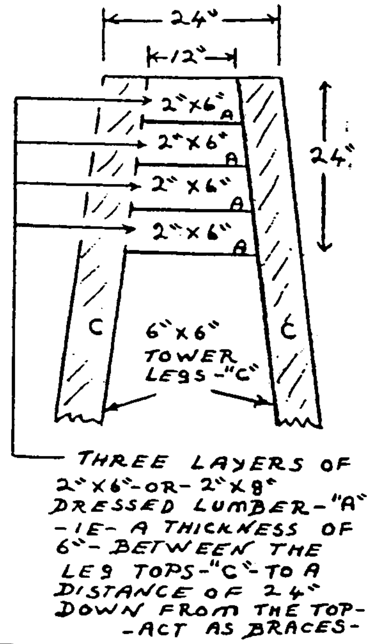
(2) TOWER LEG – DETAIL

SIDE VIEW – LAMINATION



(3) TOWER CAP DETAIL – SIDE VIEW – I

ONE OF FOUR SIDES – INTERIOR



(4) TOWER CAP DETAIL – SIDE VIEW II – EXTERIOR

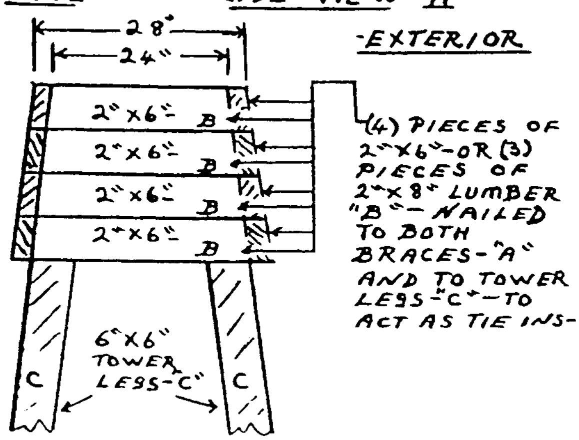


PLATE NO. 79

The tower cap, (fig. 1), top view, is the same as seen in plate no. 78, fig. 3 and 4, "side view". (See also plate no. 4, fig. 4, 5 and 6).

It is designed for the wooden rotating table, (plate no. 3, plate no. 4 and plate no. 5, etc.). The centre hole, "P", is for the eccentric rod and pull rope to pass through.

Note the bottom plate, "M", which is the base of the "core" around which the rotating table moves. The axle bearings, tail vane post etc., are mounted on the rotating table.

The "bottom plate", (core), is simply nailed to the tower top, though through bolts will be stronger. Use "spiral" type ardox nails. The object is to separate, and at the same time, bind in, the tower legs, "C" in such a way as to give absolute maximum strength. The trick is always to brace something against itself. That is how the big ships were rigged in the days of the sailing navies.

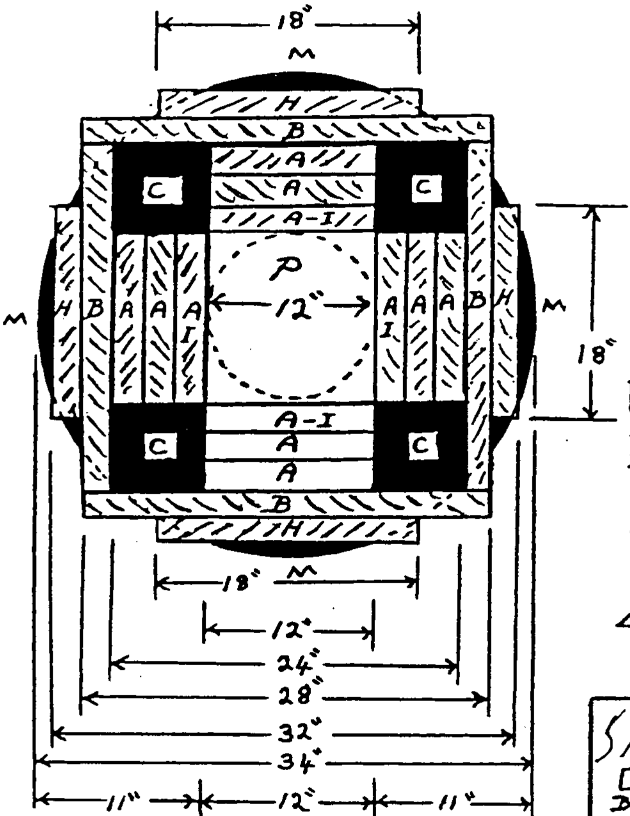
The standing platform, (fig. 2, 3 and 4), is constructed on the same principle. It must be strong enough to hold a lot of weight, as you could be resting the rotating table and sails on it during construction or repair. It must also be at a convenient height for the operator to easily work.

PLATE No. 79

- THE TOWER - IV
- THE 30 FOOT WOODEN TOWER - II
- TOWER CAP - CONTINUED -
- THE STANDING PLATFORM -

(1) 30-FOOT TOWER

TOWER CAP III - TOP VIEW



NOTE (5)

- FROM ILLUSTRATIONS - I AND II (SIDE VIEW) - FROM PREVIOUS PAGE -
- (4) - TOWER LEGS "C" (6" X 6")
- (4) - BRACE - "A-I"
- (6) - BRACES - "A"
- (4) - TIE INS - "B"

- 12" HOLE "P" - FOR ECCENTRIC ETC. MAY BE INCREASED IN SIZE TO DIAMETER = 16" - BY REMOVING BRACES - "A-I" - OR TO - 14" - BY REDUCING THE THICKNESS OF "A-I" FROM - 2" - TO - 1" -

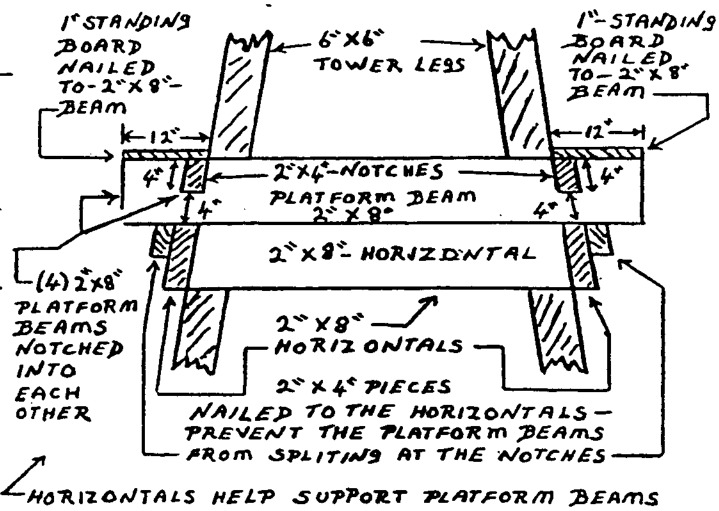
- NOTE - ALSO (6)

- 15" PIECES OF 2" X 6" LUMBER "H" WHICH ARE NAILED ONTO THE TOP TIE IN PIECES "B" - TO SUPPORT THE BOTTOM PLATE "M" - ONTO WHICH THE CORE IS BOLTED - SEE PLATE NO. I -

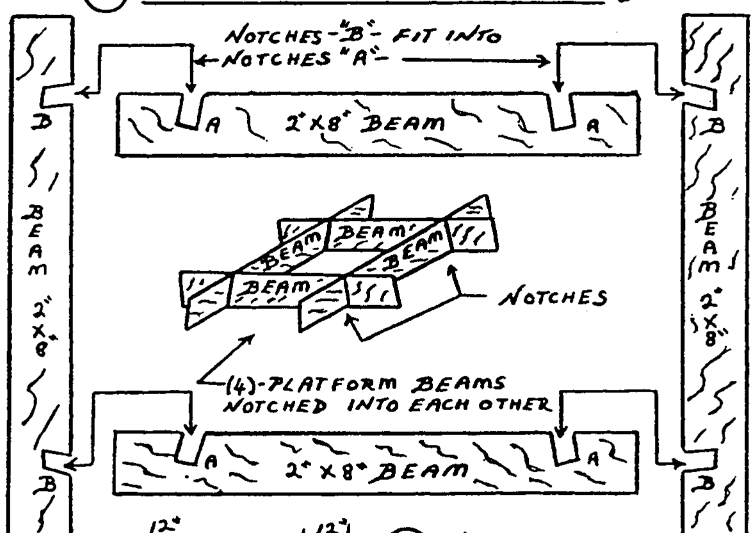
- BOTTOM PLATE "M" IS NAILED TO THE TOP EDGES OF - "A" - "A-I" - "B" - "C" - AND "H" - WITH 4 INCH "ARDOX" OR SPIRAL NAILS -

(2) 30-FOOT TOWER

PLATFORM TO STAND ON - SIDE VIEW



(3) PLATFORM - BEAM ASSEMBLY



(4) PLATFORM

TOP VIEW

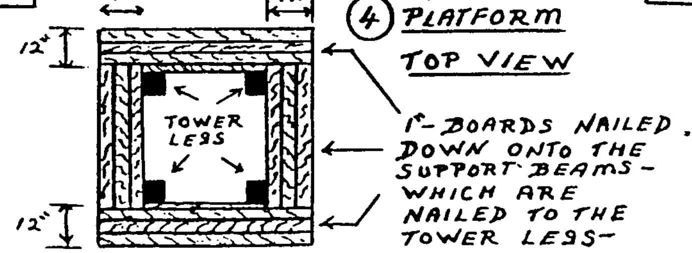


PLATE NO. 80

Fig. 1 shows how the steel straps hold the four tower legs, (plate no. 78, fig. 1), down onto the base beam, (see plate no. 77, fig. 1). There should be two straps at each corner because the tower legs angle in from four sides. Note how the straps (hook") under the beams.

Fig. 2 shows the tower base house which strengthens the foundation by binding the tower legs to the base beams and by adding weight. It also makes good use of space and provides a location for pump machinery, battery banks, food freezers etc.

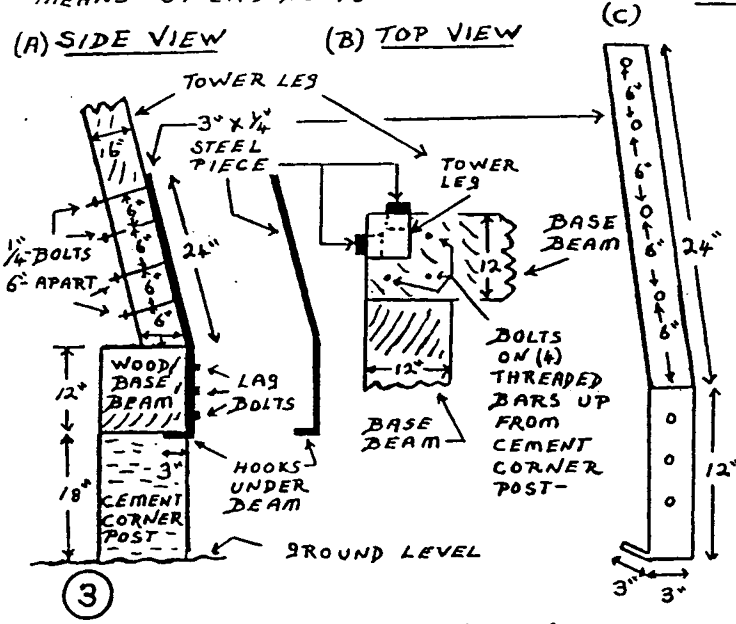
Fig. 3, 4 and 5, show heavier construction methods for higher towers. These are the methods used for the construction of the old wooden oil rig towers which were sixty or so feet high and almost indestructible. Remember the height to base ratio should remain the same. A sixty foot tower should have a twenty foot base, that is to say, 3:1 ratio.

PLATE No. 80

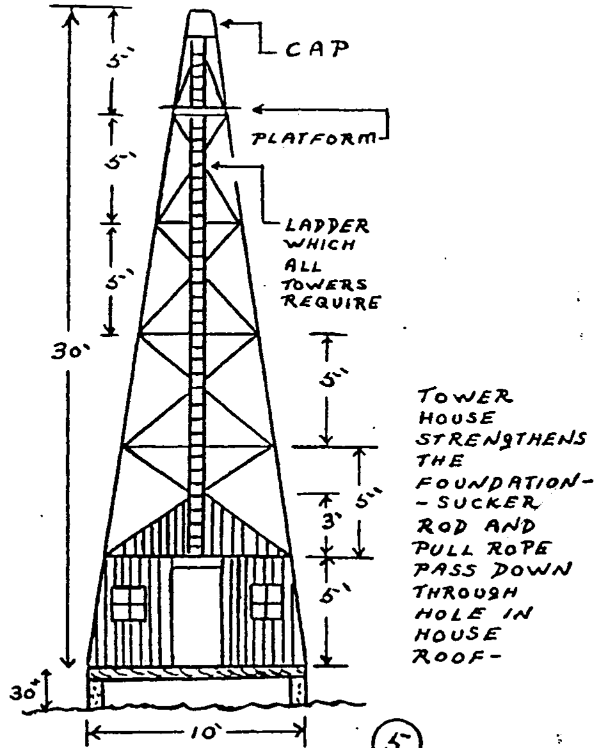
-THE TOWER-V
-THE 30 FOOT WOODEN TOWER III
-FOUNDATIONS - STEEL BAND
-TOWER BASE HOUSE
-HEAVIER CONSTRUCTION METHODS FOR HIGHER TOWERS

(1) 30 FOOT WOODEN TOWER FOUNDATION

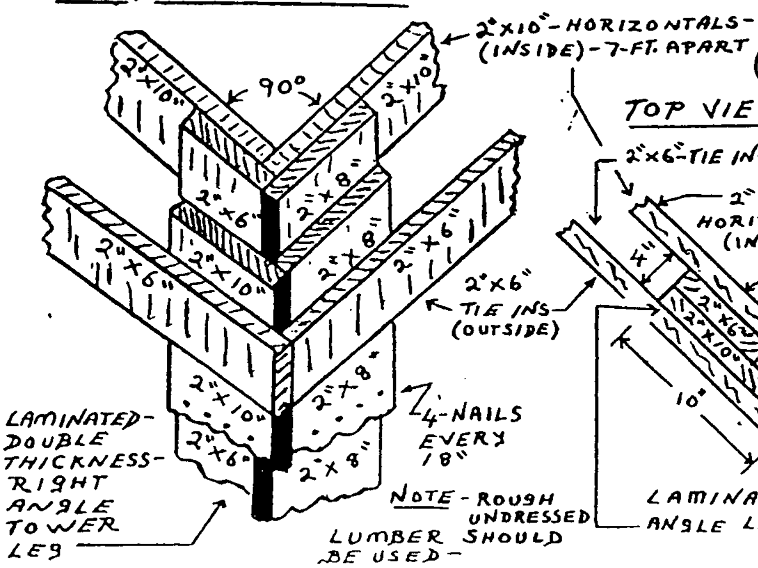
-THE FOUR TOWER LEGS ARE HELD DOWN ONTO THE 12" x 12" BASE BEAMS BY MEANS OF EIGHT - 3"-BANDS OF 1/4"-STEEL PLATE - TWO STEEL BANDS PER LEG - THE STEEL BANDS BOLT ONTO THE TOWER LEGS AND HOOK UNDER THE BASE BEAMS - THEY ALSO BOLT ONTO THE SIDES OF THE BASE BEAMS BY MEANS OF LAG BOLTS -

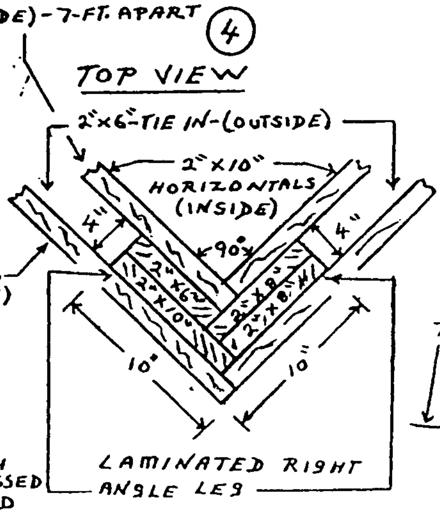


(2) 30 FOOT WOODEN TOWER - TOWER HOUSE



(3) HEAVIER CONSTRUCTION ALTERNATIVES FOR HIGHER WOODEN TOWERS - UP TO 70' HIGH -





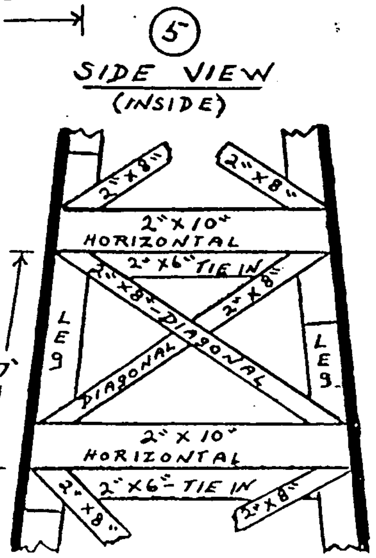


PLATE NO. 81

The post tower is designed for the metal rotating tables, illustrated in plate No. 31 and 32, as well as plates no. 68 and 69.

An advantage of the post tower is that the wind axle can be shorter because there is no worry of the sail tips hitting the tower legs.

Note that the 10" X 10" post is laminated from 10" X 1" planks. It passes up through the hole, "P", (plate no. 79, fig. 1). After the post is raised to height, it is braced in the hole with 1" boards to hold it tight.

It is best to build the post inside the tower and raise it up as it is constructed.

It is also best to build on the wind machine and sails as the post emerges from the tower top.

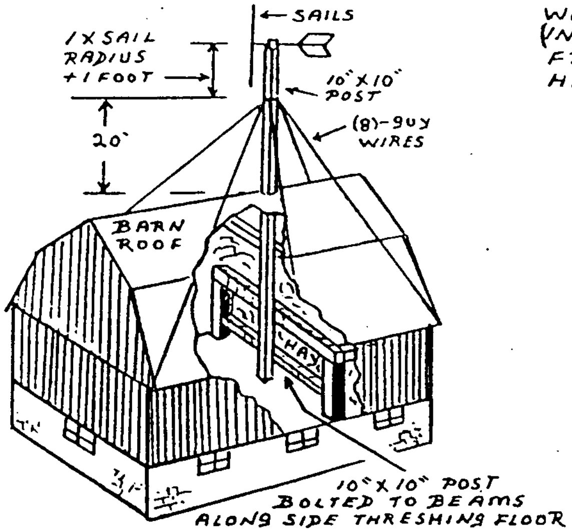
The base measurement should be calculated on the tower height plus the post height.
In other words, if fig. 3 is a 7 foot post on a 30 foot tower, the base measurement should be 30' + 7' divided by 3 = 13 feet.
The tower itself should be erected as illustrated in plate no. 82.
Note the post brace, (fig. 5), and the post base, (fig. 6).

The post on barn roof, (fig. 1), should place the wind machine 20' above the roof. In actual fact, however, the distance was usually about 10' & above the roof. It is believed easier to put up with vibrations than with the difficulties of bracing, etc.

PLATE No. 81

-THE TOWER- VI
-THE POST TOWER

THE POST TOWER I
ABOVE BARN ROOF



METHOD OF ERECTING POST

-LAMINATE THE POST BY NAILING DIFFERING LENGTHS OF ROUGH LUMBER 2" X 10" PIECES TOGETHER-
- BUILD THE FIRST 10-16-FT OF THE POST ON THE BARN LOFT FLOOR-
- ERECT THIS EASY TO LIFT LENGTH AND TIE IT LOOSELY TO THE HORIZONTAL BARN BEAMS-
- THEN BUILD ONTO THE POST FROM THE BOTTOM - LIFTING IT AS YOU DO SO WITH A BLOCK AND TACKLE-
- WHEN THE POST EMERGES FROM THE TOP OF THE ROOF - BUILD ON THE WIND MACHINE AND THEN THE GUY WIRES - ALSO ADD LENGTHS OF DRIVE SHAFT IF NECESSARY-
- CONTINUE TO BUILD AND LIFT FROM THE BOTTOM UNTILL THE DESIRED HEIGHT IS REACHED-
- BOLT FIRMLY TO THE HORIZONTAL BEAMS-

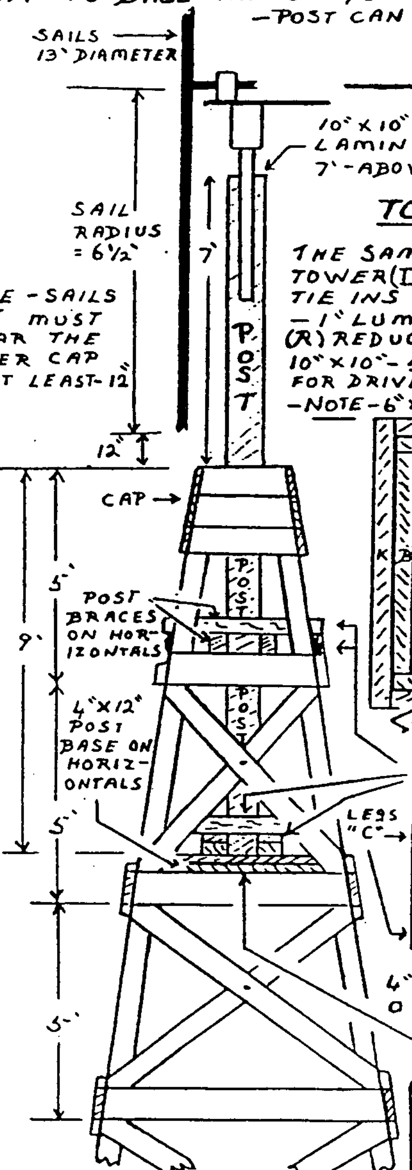
-THIS WAS DONE IN ONTARIO WITH 13 FT DIAMETER MULTIBLADES - USED TO GRIND GRAIN AND BUS-SAW FIRE WOOD - BUT THEY TENDED TO SHAKE LOOSE THE WOODEN PEGS IN THE BARN BEAMS - PERHAPS BECAUSE THE POSTS WERE LESS THAN 20-FT- ABOVE THE BARN ROOF-

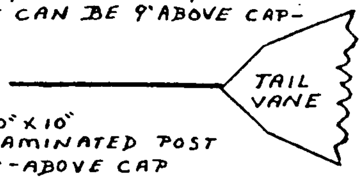
-IT IS NOT ADVISED TO INSTALL A TOWER ON THE ROOF OF A HOUSE IN WHICH PEOPLE LIVE - AS THE LOADS ON A 12'-14' DIAMETER AIR FOIL OR MULTIBLADE CAN BE SO GREAT AS TO CAUSE STRUCTURAL DAMAGE TO THE ROOF-

-EVEN 6'-8' DIAMETER SAILS - WHEN THE MACHINE IS IN PERFECT RUNNING ORDER - CAN SET UP VIBRATION FREQUENCIES THAT CAUSE MOANING SOUNDS - WHICH PREVENT SLEEP-

THE POST TOWER II
ON 30 FT TOWER

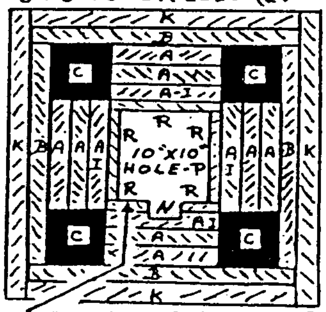
- 10" X 10" POST - 16 TO 20 FT - BASE TO TIP - IS MOUNTED ON A 30 FT WOODEN TOWER LIKE THE ONE ALREADY SHOWN (IN TOWER III) - THE BASE CAN BE INCREASED FROM 10' TO 14' - TO GIVE THE PROPER -3-TO-1- HEIGHT TO BASE RATIO - 40 FT TO 14 FT-
-POST CAN BE 9' ABOVE CAP-





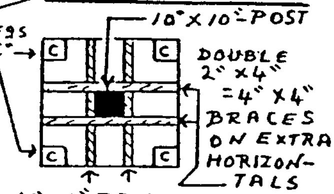
TOWER CAP

THE SAME AS ON 30 FT TOWER (III) - EXCEPT FOR EXTRA TIE INS (K) TO ADD STRENGTH - 1" LUMBER INNER LINING (R) REDUCES HOLE (P) SIZE TO 10" X 10" - NOTE ALSO SPACE IN) FOR DRIVE SHAFT IF NECESSARY - NOTE - 6" X 6" TOWER LEGS (C)



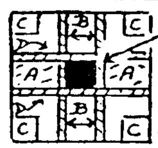
POST PASSES THRU HOLE-P

POST BRACES



4" X 4" BRACES ON HORIZONTALS

POST BASE



POST SITS ON DOUBLE 2" X 12" PIECES (A) BETWEEN THE HORIZONTALS - AND IS HELD BY 4" X 4" - BRACES (B-B) AND (D-D) ON ADDITIONAL HORIZONTALS-

NOTE

ASSEMBLE (LAMINATE) POST INSIDE TOWER - AND PULL UP WITH BLOCK AND TACKLE - SAME AS POST ON BARN ROOF - (LEFT)

PLATE NO. 82

It is best to erect the 30' tower with at least the rotating table in place. It is not hard to build on the sails when the tower is in place because the sails can be carried up in relatively small and light pieces. Also, the sails are the most likely components to become injured during the process of erection.

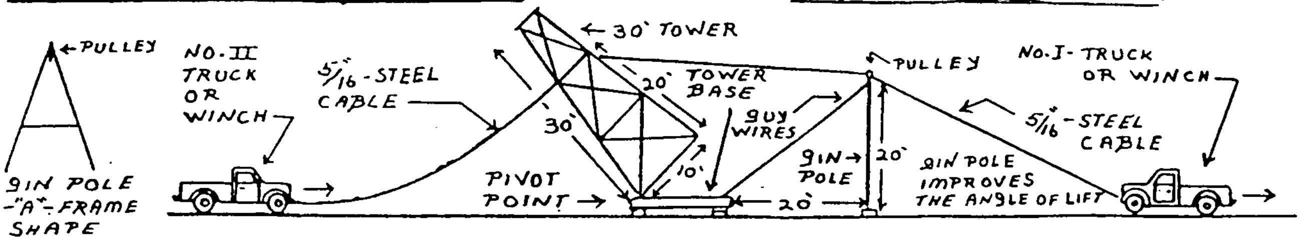
Oil rig wooden towers were always "built like a house", as in fig. 2. They were not erected as in fig. 1 because they were just too big and too heavy.

The key word in tower erection is DANGER.

PLATE No 82

–THE TOWER VII
– TOWER ERECTION
–BY PULLING IT UP
–BY BUILDING IT UP

TO PULL UP TOWER WITH WINCH OR MOTOR VEHICLE– USING A GIN POLE–30 FT TOWER



NOTE – PURPOSE OF GIN POLE IS TO GIVE LIFTING POWER TO A PULLING FORCE–

– GIN POLE HAS "A" FRAME SHAPE TO PREVENT IT FALLING TO THE SIDE– LEGS OF GIN POLE SHOULD BE SUNK 6"–9"–INTO THE GROUND TO PREVENT SLIPPING– 20'–FROM TOWER BASE – MUST NOT BREAK– SO SHOULD BE OF 4"X4" LUMBER OR 3" PIPE– SHOULD BE NO LESS THAN 15' OR NO MORE THAN 20' HIGH NO MATTER WHAT THE HEIGHT OF THE TOWER– GUY WIRES TO THE BASE BEAMS HOLD THE GIN POLE ERECT–

– TRUCK NO. I – PULLS TOWER UP – DRIVER FACES TOWER TO PREVENT ACCIDENTS–

– TRUCK NO. II – (NOTE SLACK CABLE) PREVENTS TOWER FALLING OVER TOO FAST–

– TRUCKS NO. III – AND NO. IV – NOT SHOWN – WITH SIMILIAR CABLES – PERMANTLY STATIONED ON EACH SIDE – PREVENT THE TOWER FALLING TO THE SIDE – SO THERE IS NO NEED FOR PEOPLE TO STAND IN THE DANGER ZONE CLOSE TO THE TOWER–

– 5/16"–STEEL CABLE SHOULD BE ENOUGH TO RAISE A 54' TOWER–

– 20'–GIN POLE WILL LIFT A 130' FOOT TOWER–

– TOWERS 20'–TO–40'–HIGH CAN BE LIFTED WITH THE WIND MACHINE ATTACHED–

RECAP – IF SPACE ALLOWS – FOR TRUCKS ETC. – TOWERS UP TO 60' HIGH CAN BE PULLED UP–

– TOWERS UP TO 40' FT HIGH CAN BE PULLED UP WITH WIND MACHINE AND SAILS ATTACHED – BUT LOAD ON CABLE WILL INCREASE – SO INCREASE CABLE THICKNESS TO AT LEAST 1/2" –

TO BUILD THE TOWER UP FROM THE GROUND – LIKE A HOUSE – 60 FT. TOWER–

STEP ONE

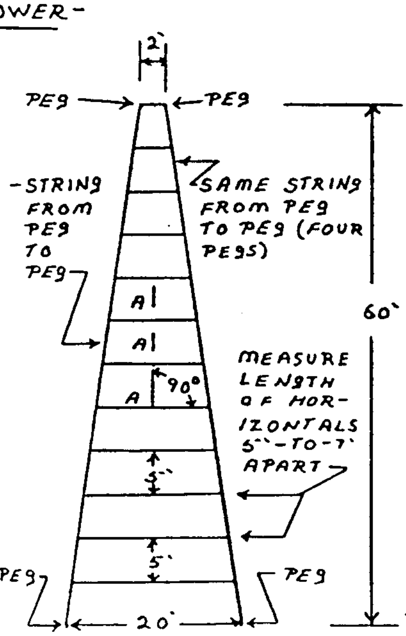
– STRING LINE THE PLAN ON THE GROUND BY DRIVING IN PEGS AT THE FOUR CORNER POINTS –

– THEN RUN A TIGHT STRING BETWEEN THE FOUR PEGS –

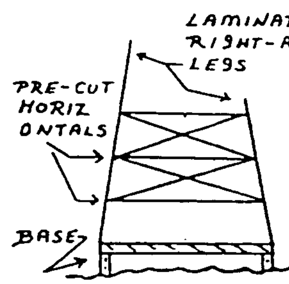
– MAKE SURE THE CENTRE LINE "A" IS 90° – TO THE BASE – AND TO THE HORIZONTALS

– MEASURE, MARK, AND RECORD THE LENGTH OF THE HORIZONTALS – STRING TO STRING–

– PRE-CUT THE HORIZONTALS–

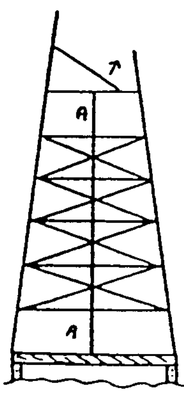


STEP TWO



– ASSEMBLE THE LOWER TWO OR THREE BAYS ON THE GROUND– THEN ERECT–

– NAIL ON THE THE PRE-CUT HORIZONTALS–



STEP THREE

– BUILD ON THE (PRE-CUT) HORIZONTALS BY STANDING ON TEMPORARY PLATFORMS ACROSS THE HORIZONTALS ALREADY IN PLACE–

– CHECK CENTRE POINTS CONSTANTLY – WITH PLUMB LINE DOWN CENTRE LINE "A" –

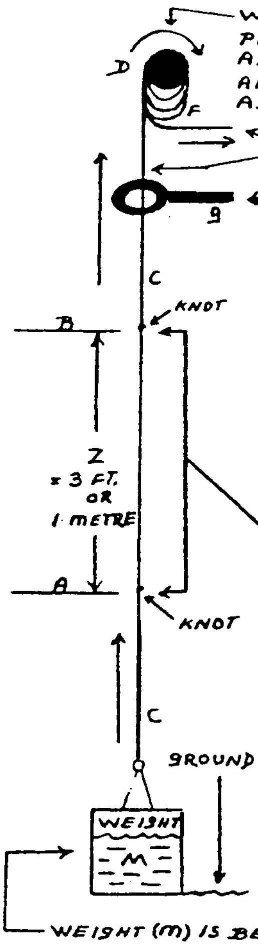
– LAMINATE ON LEGS AS YOU GO UP – DIAGONALS DO NOT HAVE TO BE PRE-CUT–

PLATE NO. 83

Read, carefully, the sections on theory and on airfoil, and study the formulas. Consider also the use of a tachometer to measure the R.P.M. and the simple application of formulas.

PLATE No. 83

DYNAMOMETER



WIND MACHINE AXEL (D) OR PULLEY ON WIND MACHINE AXEL - WINDS UP ROPE (C) AND SO LIFTS WEIGHT (m) AS IT TURNS -

(FIBRE) ROPE (C) WRAPPED LOOSELY IN FESTOONS - CAN BE PULLED SHARPLY TO THE RIGHT AND HELD WITH TENSION - CAUSES ROPE (C) TO GRIP ONTO AXEL OR PULLEY (D) AND SO RAISE WEIGHT (m) WHEN DESIRED -

BRAKE-BOARD (g) WITH HOLE LARGE ENOUGH TO ALLOW ONLY THE ROPE TO PASS THROUGH - PREVENTS WEIGHT (m) FROM REACHING AND SPINNING AROUND THE AXEL (D) - WHICH WOULD BE HIGHLY DANGEROUS -

MARKS (A) AND (B) ON TOWER - USED TO MEASURE SPEED AT WHICH AXEL (D) LIFTS WEIGHT (m) AT A WIND SPEED OF 10 M.P.H. - STOP WATCH TIME TAKEN AT (A) AND THEN AGAIN AT (B) - DISTANCE (B) TO (D) MUST BE ENOUGH TO ALLOW UPWARD MOVEMENT OF WEIGHT (m) TO ATTAIN SUFFECIENT SPEED - -SUGGESTED DISTANCE BETWEEN (A) AND (B) = 3' OR 1m. -MEASURE TIME IN SECONDS -

WEIGHT (m) IS BEST MADE FROM A PLASTIC JUG FILLED WITH WATER - ADD WATER UNTILL WEIGHT IS SUFFICIENT TO CAUSE JUG TO MOVE UP SLOWLY ENOUGH TO BE TIMED THROUGH (Z) - -AFTER EXPERIMENT - WEIGH AND RECORD WEIGHT OF JUG + WATER WHICH WILL EQUAL "m" IN THE FORMULA - REPEAT EXPERIMENT SEVERAL TIMES DURING HALF HOUR OF 10 M.P.H. EQUAL WIND SPEEDS - THEN AVERAGE THE RESULTS - -WEIGHT CAN BE AS MUCH AS 20 POUNDS -

FORMULA

$$\text{POWER} = \frac{mgz}{T} = (m \times g \times z) \div T$$

WHERE - m = THE LIFTED WEIGHT IN POUNDS OR KILOGRAMS -

g = GRAVITY = 32.2 POUNDS PER SECOND^2 = 9.81 METERS PER SECOND^2 (USE ONLY THE 32.2 OR THE 9.81 - FORGET ABOUT THE SEC^2 OR THE SECOND PER SECOND) -

Z = THE DISTANCE - (A) TO (B)

T = THE TIME IN SECONDS - (THRU-Z)

- USE - FEET AND POUNDS TO GET THE RESULT IN HORSE POWER (MECHANICAL USE) -
- USE - METERS AND KILOGRAMS TO GET THE RESULT IN WATTS (ELECTRICAL USE) -

THE DYNAMOMETER

MEASURES TWISTING FORCE (TORQUE) OF WINDMILL AXEL - TO DETERMINE MECHANICAL POWER OUTPUT IN HORSE POWER - OR ELECTRICAL POWER OUTPUT IN WATTS - DEDUCT 30% FOR NORMAL MECHANICAL LOSS RESULTING FROM EXPECTED INEFFICIENCY OF THE WIND MACHINE -

NOTES ON FORMULAS

POWER = THE RATE OF DOING WORK -
= TORQUE × ANGULAR VELOCITY -
= FORCE × DISTANCE ÷ TIME
= FORCE × A DISTANCE PER UNIT TIME
= ENERGY AVAILABLE FOR DOING WORK

WORK = TRANSFER OF ENERGY FROM ONE BODY TO ANOTHER - CAUSING THE BODY ACTED UPON TO MOVE -
= POWER × TIME
= FORCE × DISTANCE

HORSE POWER = A UNIT MEASURING THE RATE OF WORK BEING DONE
= THE ABILITY TO LIFT (BY MEANS OF A ROPE AND PULLEY) 550 POUNDS THROUGH ONE LINEAR FOOT IN ONE SECOND = ONE HORSE POWER = 746 WATTS -

FOOT POUND = A UNIT OF ENERGY - THE AMOUNT NECESSARY TO RAISE A ONE POUND MASS THROUGH ONE LINEAR FOOT - -FOOT POUNDS ÷ 550 = HORSE POWER -

WATT = THE PRACTICAL UNIT OF ELECTRICAL POWER = THE POWER DEVELOPED WHEN ONE AMPERE FLOWS THROUGH A RESISTENCE OF ONE OHM.
= VOLTS TIMES AMPS -
= 1 HORSE POWER DIVIDED BY 746 -

TO CONVERT HORSEPOWER TO WATTS -
= MULTIPLY HORSE POWER BY 746 = WATTS
OR ÷ WATTS BY 746 = HORSE POWER -

NOTES ON WINDSPEEDS

WIND MACHINES WORK WELL AT WIND SPEEDS OF 8 M.P.H. (GENTLE) THROUGH MODERATE (16 M.P.H.) TO FRESH (24 M.P.H.) -
- TEST THE DYNAMOMETER (LEFT) AT 10 MPH. WIND SPEED - GENTLE -
- MEASURE WIND SPEED WITH A WIND SWITCH OR A WIND SOCK (A TYPE OF FLAG WITH AN OPEN MOUTH - LIKE A SOCK - 3'-4' LONG -

- OR BETTER - USE AN ANENOMETER PURCHASED FROM A MARINE SUPPLY STORE -

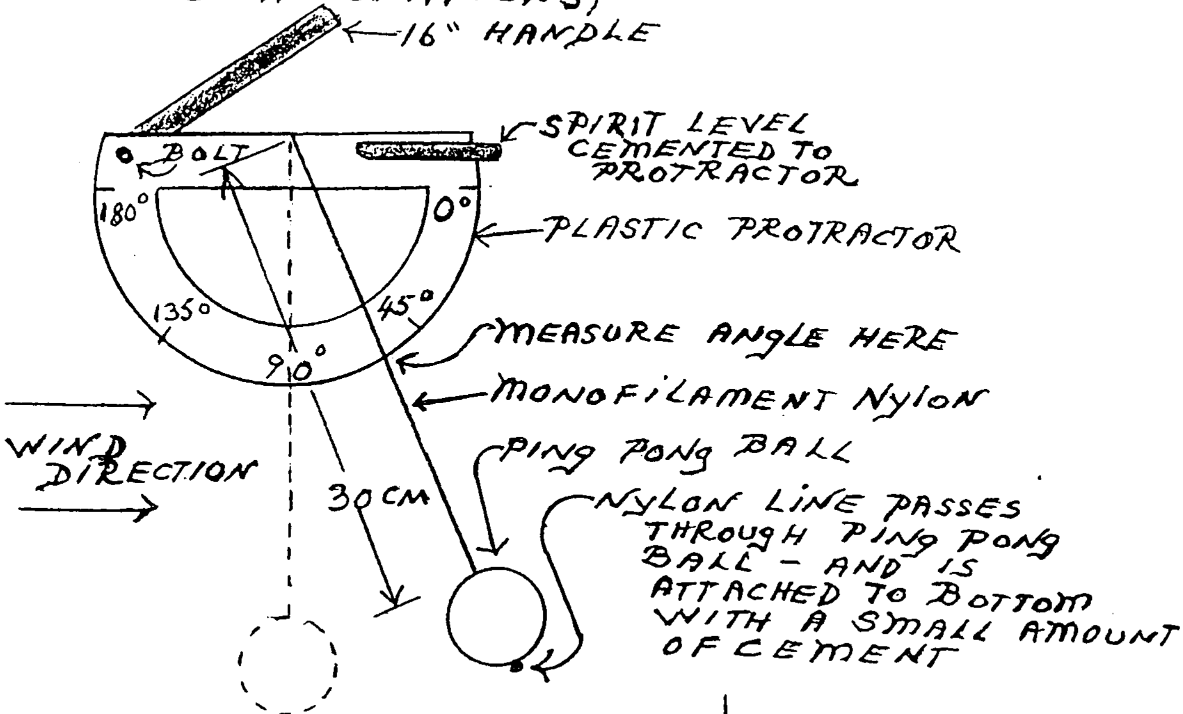
PLATE NO. 84

Anendometers: Here are two instruments for measuring wind speed that you can make yourself. Calibrations and all necessary detail will be found in Section VIII of Chapter Four. To understand the matter totally, however, you should study the whole chapter.

PLATE No. 84

HOME MADE ANENOMETERS
- FOR MEASURING WIND SPEEDS

① HAND HELD WIND GUAGE
(SEE CHAPTER FOUR, SECTION VIII, FOR CALIBRATIONS)



② REVOLVING CUP ANENOMETER