The Test of an Improved Jumbo Windmill.

V. Maelzer.

Contents:

The use of wind as a prime mover is a very ancient method of obtaining power. The large four vaned wind mill of Holland has been embodied in literature just as the high magestic over shot water-wheel. Both are quite old. But age is not always a sign of developement. Windmill construction has received quite an impetus in the last few years because of the increased demand for the utilization of windpower in the growing field of irrigation. Hence we see constant efforts being made to improve in order to get the greatest amount of power for the wind velocity and the size of the wheel.

Here in Kansas the windmill is of special importance because, in the first place, we have the wind, and in the second place we have much need of just such a power for pumping water for stock and for irrigation purposes, for running feed grinders, etc. To meet this demand for improvement the resulting forms of wind motors have been numerous and the variety extends over a wide range. Even so much so that the uninitiated traveler in the sun flower state would not recognize many of the contrivances as belonging to the genus wind-mill. Probably the principal reason for the apparent success of all the types of wind engines is the difficulty of making a practical test of their relative merits. The difficulties are perhaps more numerous than those attending the testing of milk cows before the advent of the Babcock test. These obstacles are, however, quite easily overcome by suitable apparatus and the proper method. But accurate windmill testing in natures wind can never become practical in the sense that every farmer can test his mill and determine just how much better it is than his neighbors. In testing ordinary windmills of different manufacture, the the difference in gearing alone will make considerable changes in the result of an experiment in the same wind velocity. This is because each mill has, with a given load, in which the largest percent of the force or power in the wind can be obtained. This part of the problem has not been wrestled with in the following experiment. It is not of first importance, however it has its influence. The load being constant and the wind velocity for each trial of the different phases of the machine was practically the same makes this of less importance. Although we may say the wind velocity is practically the same, but to observe any fine distinction is well nigh impossible. To get an idea of the great and constant change of wind velocity in nature we only need to reflect a little. The air is a very mobile gas. Every obstacle it encounters deflects it from its course to a greater or less extent. The interfering objects are very numerous, such as trees, buildings, hills, etc. Then in a twentyfive mile an hour wind we are not to think of it as a steady stream with an even speed like a train of cars, but like a swirling gushing stream of water in flood time. This has been partly over come by taking the average of a large number of wind velocities from an anemometer. The maker of the model, whose name I do not know, intended to obtain and increased amount of work by condensing the air. Below is given a cross section through the mill showing the relation of the different parts.

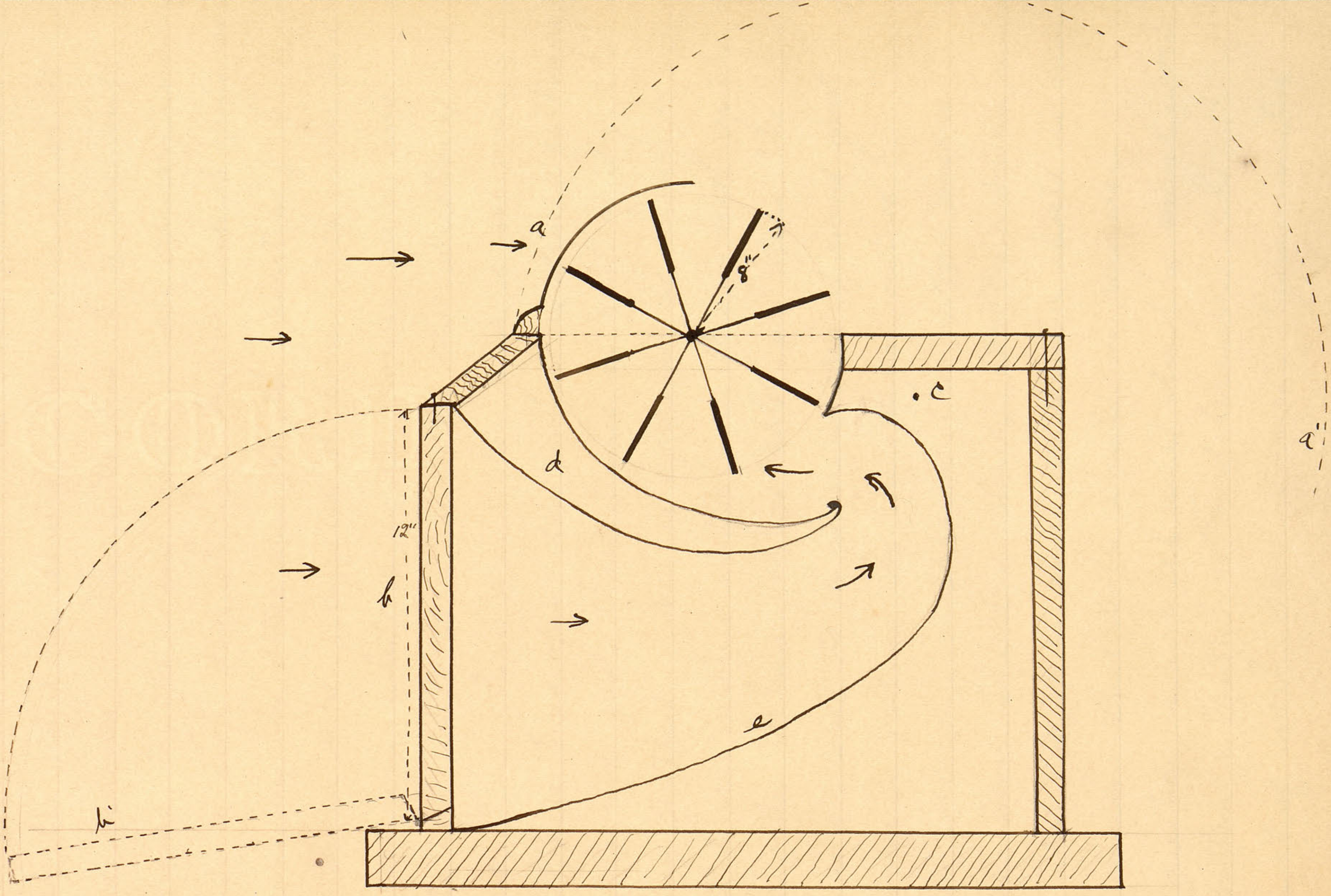

Fig 1.

Scale 1:4.

In Fig. 1 a is a shield which shuts off the wind from the upper front quadrant of the wheel. When this is closed the wind is shut off entirely, and if it is open as indicated by the dotted line to a' the mill is exposed to the wind just as an ordinary jumbo. At b is a drop door hinged below which opens as indicated by the dotted line to the position of b'. The horn like projection d forms the upper part of the condenser while e is the lower guide and directs the wind as shown by the direction of the arrows. The horn d and the guide e are made of tin. When b is open the wheel is has a gathering area of wind just three times as great as by the ordinary method. This is condensed as shown, to about three inches and strikes the wheel on the lower side. When both shield are open the wheel is exposed to a gathering area of wind just four times as great as by the ordinary method.

In the following discussion 'the top open' means that the lower shield is closed, Botton or botton open means that the top is closed while lower shield is open. Both means that both shields are removed.

The question is which will do the most work Top, botton or Both? To determine the amount of work done a small dynamometer or friction brake was attached. The load was some what changed as the velocity of the wind was high or low. a small groove pulley was attached to the end of the main shaft as shown by the dotted ~~line~~ circle in Fig 1. Over this pulley a cord was ~~passed~~, on one end of which a small scale pan ~~was~~ exactly attached. On the other end was a scale pan of exactly the the same weight as the former, and a graduated spring, i.e. one whose rate of strech per gram had been determined. To balance this apparatus it is neccessary to attach weights on the lighter side which will just equal the weight of the spring. This done, the end with the spring is secured to a support so that when the pulley revolves it will tend to lift the the spring by the friction between pulley and cord. From the difference in length of the spring while the pulley is at rest and when in motion the amount of pull can be calculated. If we find the circumference of the pulley in feet, multiply it by the number of revolutions per minute, and this by the number of grams lifted as indicated by the spring will give the number of foot grams per minute. To reduce this to foot pounds it is neccessary to divide by 28 X 16. All experiments were made on the top of a building within twenty feet of an anemometer so the velocity of the wind could be determined for any time of the experiment. The number of revolutions were counted by means of a speed indicator and recorded for each half minute.

The following tables are the figures of the velocities taken in the field and show the averages. The load is also given.

Table I 796

Number of revolutions per each half minute taken consecutively. May 13 2 P.M. Load from 29.7 grams at lowest speed to 37.4 grams at higest speed.

Bottom 1.	Both 2.	Top 3.	Bottom 4.	Both 5.	Top 6.	Bottom	Both	Top.
145	125	140	200	150	140	145	155	250
100	180	145	300	155	170	100	230	200
65	130	165	300	100	150	155	155	205
135	95	145	295	220	120	205	220	120
120	140	150	190	210	170	155	260	170
55	150	230	150	155	100	185	220	50
55	200	240	140	185	125	6/945	1240	995
50	125	200	190	175	110	157.	206.	166.
95	225	250	220	85	80			
25	190	195	205	85	15			
125	235	205	140	55	150			
125	130	195	210	110	230			
100	125	220	135	105	100			
80	75	165	13/2775	1870	1660			
140	80	175	213	144.	127	averages		
150	95	165						
125	135	270						
17/1690	2435	3255	averages.					
99.5	143.	191.5						

Table I con.

May 19 4.22 P.M. Load 37.4 to 42.6 grams by extremes of speed. 797

7. Bottom	8. Bath	9. Top	10 Bath	11. Bottom	12 Top	5.25 13. Top	14 Bath	15. Bottom
180	215	135	150	165	70	245	105	120
120	185	150	185	190	220	115	115	210
150	115	115	105	155	120	130	175	200
215	100	80	110	170	130	70	175	200
100	130	85	140	160	165	170	240	190
170	120	160	180	120	215	200	240	180
245	120	200	120	110	150	240	230	120
225	100	195	100	190	120	220	220	130
160	115	170	175	180	140	160	200	50
105	125	205	185	70	130	175	265	80
90	90	200	220	105	100	210	225	170
135	100	175	250	115	60	150	185	100
115	100	245	205	205	75	125	250	120
125	150	215	180	180	65	105	265	115
120	230	200	200	185	110	150	250	80
100	260	200	165	100	100	130	250	130
100	150	180	100	100	185	55	135	100
155	230	170	160	135	100	85	240	160
160	170	150	200	130	65	65	230	130
210	110	130	160	130	110	50	135	130
20/2980	2915	3360	3290	2895	2380	2850	4130	2715
149.	145.7	168	164.5	144.7	119	142.5	206.5	135.7

table I con.

May 20, 8:5 A.M. Load 38.8 to 42.6 at extremes of speed.			May 21, 4:40 P.M. Load Empty			May 24, 8:10 A.M. Load:- 36.1 to 42.6 by extreme of speed			798
16. Both	17 Bottom	18. Top	19 Both	20 Bottom	21 Top	22 Both	23 Bottom	24. Top	
180	225	110	210	140	125	100	130	50	
240	235	150	175	185	80	100	155	115	
230	270	150	150	185	45	140	110	120	
270	380	210	115	160	80	135	50	185	
240	200	180	135	170	90	140	135	60	
190	215	150	165	155	110	150	160	100	
110	210	190	180	120	190	125	50	70	
110	270	160	200	100	135	125	15	65	
240	220	190	150	45	120	160	100	85	
220	240	190	170	50	125	135	185	35	
250	225	250	100	100	100	130	105	70	
270	265	220	150	80	70	135	130	50	
180	265	270	150	90	90	130	100	100	
250	200	250	150	100	100	150	150	100	
180	220	190	120	70	80	120	190	70	
270	260	250	80	15	65	110	180	60	
330	290	190	100	60	65	75	170	110	
300	260	100	190	150	130	50	80	60	
285	290	150	225	185	180	75	30	90	
265	150	150	145	180	130	60	30	75	
20/4610	4840	3700	3210	2340	2060	2345	2355	1620	
230.5	242.	185	160.5	117	103.	117.2	117.7	83.[illegible]	

Table II

11.

Date hours and minutes	Wind velocity in feet per min.	Port of mill open.	average number of Revolutions per ½ min.	Foot grams per min.	Grams lifted per foot of wind movement.	Load in grams.	
P.M. May 13, 2 to 2:8½	1211	Bottom	100	3100	2.56	31	1
" " 2:8½ to 2:17	1117	Both	145	4495	4.02	31	2
" " 2:17 to 2:25½	1553	Top	185	5735	3.69	31	3
" " 2:25½ to 2:32	1615	Bottom	206	6386	3.95	31	4
" " 2:32 to 2:38½	1615	Both	156	4836	2.99	31	5
" " 2:38½ to 2:45	1220	Top	138	4278	3.5	31	6
May 19, 4:22 to 4:32	1848	Both	149	5850	3.2	39.26	7
" " 4:32 to 4:42	1848	Bottom	146	5600	3.3	38.3	8
" " 4:42 to 4:52	2112	Top	167	6680	3.16	40.	9
" " 4:52 to 5:2	2288	Both	164	6560	2.87	40.	10
" " 5:2 to 5:12	2112	Bottom	145	5382	2.65	38.3	11
" " 5:12 to 5:22	1848	Top	119	4440	2.35	37.3	12
" " 5:25 to 5:35	2112	Top	142	5396	2.55	38.	13
" " 5:35 to 5:45	2244	Both	206	8652	3.85	42.	14
" " 5:45 to 5:55	2112	Bottom	135	5140	2.43	38	15

tab

Table II con.

	Date hrs and minutes	Wind velocity in feet per minute	Part of mill open	Average speed per half minute	Foot grams per min.	Grams lifted per foot of wind movement	Load in grams	Nos.
16	A.M. May 20, 8:5 to 18:15	1980	Both	230.5	9450	4.77	41	16
17	" " 8:15 to 8:25	2376	Bottom	237.	9717	4.1	41	17
18	" " 8:25 to 8:35	2376	Top	185.	7585	3.2	41	18
19	P.M. " 21, 4:40 to 4:50	1293.6	Both	116.5	empty.	4.3 No. of feet	Empty.	19
20	" 21, 4:50 to 5:	1161.6	Bottom	117.		4.96 passing per		21
21	" 21, 5:00 to 5:10	1161.6	Top	103.		5.72 revolution of wheel		21
22	A.M. " 24, 8:10 to 8:20	880.	Both	118	4248	4.83	36	22
23	" 8:20 to 8:30	880.	Bottom	118	4248	4.83	36	23
24	" " 8.30 to 8.40	1056.	Top	120	4320	4.1	36	24

12.

The different columns in the table will easily be understood with a little explanation. The first four columns explain themselves. The fifth headed foot grams per minute means that the numbers ~~are the~~ show how many grams were raised one foot high in one minute. It was obtained by multiplying the number of revolutions per half minute of the pulley by the weight lifted. This is a short cut to a result; i.e as the circumference of the pulley is just 6 inches, then then two revolutions will raise the load one foot. Or the number of revolutions per half minute times load gives foot grams. The figures in the sixth column are obtained by dividing the total number of foot grams per minute by the wind velocity which gives the number of grams lifted for each foot of passing wind.

By taking the grand averages of the column headed grams lifted per foot of wind movement ~~after~~ arranging according to Tok Botton both the result of this analysis is shown.

The following is a table so arranged.

Table III

Top	Botton	Both
3.69	2.56	4.02
3.50	3.95	2.99
3.16	3.30	3.20
2.35	2.65	2.87
2.55	2.43	3.85
3.2	4.1	4.77
4.1	4.83	4.83
7/22.55	23.82	26.53
3.22	3.40	3.79

This result shows that the amount of work done by the bottom open is 5.6% better than the ordinary exposure. Both open gives 17.7% better than top alone and 11% better than the bottom alone.

There are, however, serious objections to such an analysis of the data. First, the load for the varying velocity was not, because the proper load was unknown, changed so as to get the highest possible efficiency for each velocity. Secondly there was no fine adjustment on the apparatus to keep it square in the wind at all times. The slight variation in the direction of the wind might easily, in such a limited number of experiments, give one methods an undue advantage. Third. The wind velocity was taken from an anemometer record sheet that records miles on a card with five minute graduations upon it. And the result is that the velocity in feet per minute is largely an estimate, not in the total but in the seperate ten minute calculations.

Fourth. It is not fair to base a decision on the number of grams lifted per foot of wind movement at different velocities. The amount of ~~work done or~~ power in a moving fluid varies as the square of the velocity. Hence much more is expected of a foot of wind moving at the rate of ten miles an hour than at five. To obviate this difficulty it is necessary to square the velocities and determine the proper ratio of the power. To do this accurately each of the twenty four velocities given should be squared. But even this would ~~not~~ be far from correct, because each velocity given is an average of from 6 to ten minutes If the wind traveled three fourths of its distance during one half of the time and one fourth during the remaining half the amount of power would be greater than if the velocity was uniform and of the average of same. But if we could observe the velocity for each minute we would be little nearer the truth, a glance at Table I will show that the variation for consecutive half minutes is as high as several hundred percent. Therefore only the average velocity of each method is here given to get a rough estimate of the relative amounts of power presented to the different methods.

Table IV

Both	Bottom	Top
1848	1211	2276
2288	1615	1056
2244	1848	1848
1980	2112	2112
1645	2112	2112
880	2376	1220
1117	*880	1553
7) 11972	12154	12277
1710	1750.5	1768

$\overline{1710}^2 = 2,924,100$

$\overline{1750}^2 = 3,062,500$

$1768^2 = 3125848.$

These stand in the ratio of 1 (Both) : 1.047 (Bottom) : 1.069

This apparently shows that the method of both open is still more efficient than the others as the wind velocity of that method is less than the others. But as intimated above it must not be given too much weight.

In all the foregoing averages another difficulty presents itself. If the variation in result of the same method is as great as between different methods very little faith can be placed in the result of one average. We might arrange the different methods according to the number of revolutions, as a result, in an ascending scale as follows:- Only such are given that have a wind velocity varying less than 2 or 3 hundred feet per minute. Table V.

Both	Top	Bottom	Top	Both	Bottom
5) 156	3) 185	4) 206	18) 185	16) 230.5	17) 237
			6) 138	5) 156	4) 206

Table II. con.

Both	Bottom	Top
22) 118	23.) 118	24) 120

Bottom	Top	Both
15.) 135	13. 142	14.) 206
11.) 145	9.) 167	14) 206
15) 135	13) 142	(7) 144
13.) 146	9.) 167	14). 206
15.) 135	13.) 142	10) 164

Top	Bottom	Both.
12) 119	8.) 146	7.) 149
13) 119	15.) 135	10) 164
13) 142	11.) 145	10) 164
13.) 142	8) 146	7.) 144
13) 119	10.) 145	7.) 149
13) 119	11.) 145	10) 164
12) 119	15.) 135	7. 149
12.) 119	15.) 135	14) 206
21) 103	20.) 117	19) 160.5

Bottom	Both	Top
11) 100	2) 145	8.) 185
8.) 146	10.) 164	9.) 167
11) 145	10) 164	9.) 167
15.) 135	19) 164	9.) 167
15.) 135	7.) 144	9.) 167
11) 145	7.) 144	9.) 167
8.) 146	7.) 149	9.) 167.

The figures to the left and above of each refers to the number of the experiment in table II. The above arrangement seems to show again the order of efficiency to be top bottom both in the ascending scale. However to make an accurate test in a natural wind is simply impossible. It is possible by a large number of experiments to detect any great variation, but the margin of error will be so great that little can be based upon it.

If this Jumbo will give the amount of power indicated by the crude test, as it probably will, the practicability will now depend on whether the increased efficiency will pay for the increased cost in building sucha windmill. However an increase of 17.7% would doubtless much more than pay for the added expense of making the improvement.

Although the above device has shown merit it can be much improved at less cost.

It is a well known fact or law in physics that any moving substance whether solid or liquid or gas loses velocity, and consequently power, whenever it changes direction. This loss increases as the abruptness of the change increases. Further in the pumbo wind-mills the wind has the greatest effect when it strikes the vane at right angles to the diameter of the wheel. In the model experimented with it will be seen that the wind is forced to make an angle of nearly 180° in a short turn. This certainly decreases the effect considerably. The improvement consists in applying the the condensed wind, as we might term it, in the most efficient manner and at the same time with as little change in direction as possible. This could be done in the following manner. As the wind near the center of the wheel has little effect the wheel could be less than half exposed. Instead of admitting the air at the bottom it would be much better to admit it at right angles to the vanes just as they emerge to the straight wind. This will necessitate a change of direction of less than 90° and still keep the most of the effect. of the straight wind. This method has several advantages over the former. First as explained above increased efficiency. Second, ease of construction being much simpler than the other. Third it can be put on both sides of the mill so it can be run the same as an ordinary jumbo.

It seems as if this latter would be of some practical benefit to the farmer. The guides could be made to support the wheel.

Finis V. Maelzer.