THE WINDMILL AS A FARM POWER

SENIOR THESIS WORK
MICHIGAN STATE UNIVERSITY

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THESIS

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AS A

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Senior Thesis Work

on

The Windmill as a Farm Power

by

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THESIS

The Windmill as a Farm Power.

As the farmers, dairymen, and stockmen come more in the possession of small machinery, such as grinders, feed cutters, corn shellers, wood saws, etc., it becomes necessary for them to have some power or motor for running their machinery. It is the object of this "Thesis Work" to investigate the power windmill as to the adaption, durability, convenience, and economy for running light machinery.

The motors used for running small machinery are steam engines, gas and gasoline engines, electrical motors, water motors, tread or railway powers, sweep powers and power windmills. It is a well known fact that windmills have been used for motive power for years #, and have done their work well, but until comparatively recent time they were so rudely constructed that so much time was lost in the attempt to adjust them to the varying winds that they did not come into extensive use.

If the power of a wind that passed over a farm could be harnessed and utilised it is very reasonable to assume that it would do all of the work on the farm and leave a nice margin for extras. If this power could be controlled and made to do service to man in driving machinery it would make a cheap motor, for the wind is free to all.

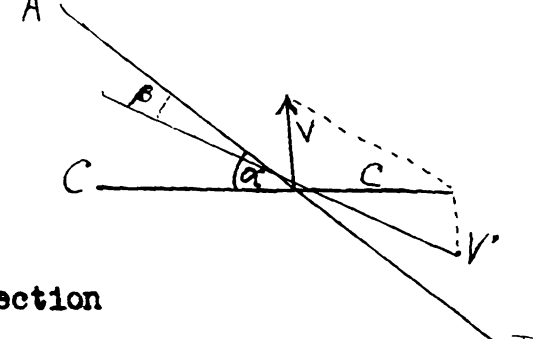
The power windmill as a motor differs from other motors in its working conditions. Its source of power is not stored or controlled like that of other motors, but is subject to "the freaks of the wind." By having some knowledge of the action of the wind, the windmill as a motor could be better understood, for it is the pressure of the wind against the sails that rotates the driving wheel.

The Windmill as a Prime Mover, by Alfred R. Wolff, contains an account of the early history of windmills.

The pressure of the wind against a plane surface varies with the temperature, the barometric pressure, and the square of the mean velocity. The following table is known as Smeaton's Results, and is nearly accurate for a temperature of about 45°F at the sea level:-

Description	Miles per Hour	Feet per Minute	Feet per Second	Force in Pounds per Square Foot
Scarce Perceptible-	1	88	1.47	.005
Just Perceptible - 2 to	(2	176	2.93	.020
	(3	264	4.04	.044
Gentle Breeze- - - 4 to	(4	352	5.87	.079
	(5	440	7.33	.123
Pleasant Breeze- - 10 to	(10	880	14.67	.491
	(15	1320	22.	1.107
Brisk Gale - - - - 20 to	(20	1760	29.03	1.968
	(25	2200	36.06	3.075
High Wind- - - - - 30 to	(30	2640	44.	4.428
	(35	3080	51.03	6.027
Very High Wind Storm- 40 to	(40	3520	58.06	7.872
	(45	3960	66.	9.963
Great Storm- - - - 50 to	(50	4400	73.03	12.300
	(60	5280	88.	17.712
	(70	6160	102.07	24.108
Hurricane- - - - - 70 to	(80	7040	117.03	31.488
	(100	8800	146.06	49.200

From the above table, it is to be seen that the pressure of the wind is four times as great when the velocity of the wind is only doubled. Theoretically, the windmill will develope four times as much power with a 20 mile wind as with a 10 mile wind. From the above table, it is also to be seen that the power or energy of a brisk gale or high wind is very great. But the windmill has not yet reached such a stage of perfection that it can utilize much of the power or energy of the wind which comes in contact with the surface of its sails. The reason why the windmill utilizes so small an amount of the energy of the wind may be seen from the following: Let A B, in the diagram, be a strip taken from the outer end of one sail of a windmill. It may be curved, but for this purpose it may be considered a plain. This strip makes an angle α with the absolutedirection of the wind.



C represents the amount and direction of the wind; V represents the amount and direction of the velocity of the surface A B. Then the relative velocity of the wind- that is, its velocity with respect to the moving surface A B- is V'; the diagonal of the parallelogram constructed on V and C as sides V' makes an angle β with the sloping surface A B. If $V = 0$- that is, if the wheel is held so that it cannot revolve- the angle $\beta = \alpha$. As V increases β grows less and less, and finally becomes zero, in which case V' is parallel to surface A.B. In this case the surface receives no pressure from the wind- this portion of the sail is not utilizing any of the energy of the wind. If V be still further increased, β becomes negative and the wind pressure is on the opposite side of A B. This portion of the sail is then doing work on the wind instead of the wind doing work on the sail. The effective wind area of a sail being the projection of the sail on a plain at right angles to the relative velocity of wind over it- that is, to V- it is seen that as V increases the effective wind area decreases. The energy which the sail takes from the wind is proportional to the effective wind area.

The tables on this page and the following one are the records of the velocity of the wind during 1897 at M.A.C., which is as nearly complete as could be obtained from the record sheets. The number of hours the wind moved at a certain velocity are tabulated for the day time from 6 o'clock A.M. to 6 o'clock P.M. and for the night time from 6 o'clock P.M. to 6 o'clock A.M; for each month of the year.

From 6 o'clock A.M. to 6 o'clock P.M.

months / miles per hour	hours not recorded	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Jan.	4	9	14	39	25	24	39	29	27	26	31	23	18	19	13	9	7	7	4		1	1				1	1	1						
Feb.	12	25	26	37	40	33	27	23	11	3	7	15	11	7	8	7	8	3	5	7	4	4	1	1	1									
Mar.	96	12	12	11	15	18	21	37	41	15	21	12	18	5	7	8	5	7	4	3	2	2												
Apr.	25	8	30	26	17	31	31	35	30	28	21	16	13	11	14	6	5			2	2	1			2	1		1	2	1			1	
May	22	42	20	37	39	28	25	25	21	18	22	19	17	18	9	4	6																	
June	26	3	20	41	54	39	29	37	35	30	10	14	12	5	3	1	1																	
July	40	13	40	63	60	45	26	27	19	12	8	7	2	6	4																			
Aug.	0	38	40	65	55	36	40	31	17	15	12	6	7	4	3	1																		
Sept.	8	63	53	48	62	57	30	17	12	3	6	1	2	1	3																			
Oct.	30	34	38	43	45	34	19	25	26	19	15	26	10	8																				
Nov.	6	14	13	20	34	31	18	47	46	39	14	14	13	18	20	8	2	2	1															
Dec.	0	11	30	40	37	50	42	31	25	16	12	19	10	12	12	6	5	1	7	3	2	1												
The number of hours for the year.	269	282	336	470	485	420	347	364	310	224	179	172	133	114	96	50	39	20	21	15	11	9	1	1	3	2	1	2	2	1			1	

From 6 o'clock P.M. to 6 o'clock A.M.

The number of hours for the year.	Dec.	Nov.	Oct.	Sept.	Aug.	July	June	May	Apr.	Mar.	Feb.	Jan.	Miles per hour	Months
243	0	0	30	0	20	26	28	38	13	78	0	10		Hours not recorded
829	32	40	64	106	121	174	57	45	67	31	57	35	0	
822	50	30	81	119	109	103	78	92	57	30	37	42	1	
483	40	36	38	34	42	39	71	60	22	28	33	39	2	
380	52	36	46	19	33	28	34	25	28	22	32	25	3	
273	29	30	22	12	14	19	28	31	23	23	23	19	4	
300	29	35	28	8	16	27	20	34	30	23	25	25	5	
229	38	25	23	7	5	6	18	15	31	22	19	20	6	
195	26	29	13	3	7		11	8	20	32	13	33	7	
140	22	25	8	2	2	2	8	4	17	23	18	19	8	
139	7	24	11		3		2	5	16	20	18	33	9	
81	12	10	3			1	1	2	12	19	10	16	10	
61	11	6	4				2	5	3	9	11	10	11	
58	5	10						6	5	4	16	12	12	
34	7	8	1		1			1	2	4	7	3	13	
33	5	5						1	1	4	8	9	14	
27	5	6							2	1	3	10	15	
23	6	5							3	2	4	3	16	
13	4								4	1		4	17	
6	2								1	1		2	18	
2									1			1	19	
2									1			1	20	
1									1				21	
1									1				22	
													23	
1												1	24	
													25	
1									1				26	
1									1				27	
													28	
2									2				29	
													30	
													31	
													32	

The average velocity of the wind for the day time during 1897 at M. A. C., was 58 miles per hour; for the night time 3.59 miles per hour. The number of hours the velocity of the wind was above 9 miles per hour was 522 hours for the day time, and 348 hours for the night time. In the U. S. Weather Bureau Report for 1896-'97, we find the average velocity of the wind ending Dec. 31,1896, as follows:

	Detroit	Alpena	Grand Haven	Marquette	Port Huron	Sault Ste. Marie
Jan.	10.4	9.5	11.1	10.8	10.8	8.4
Feb.	13.2	11.1	12.5	10.6	13.8	9.0
Mar.	11.9	11.3	11.2	12.8	13.5	9.4
Apr.	11.2	10.5	13.0	10.7	12.0	9.4
May.	11.1	10.5	10.5	9.8	11.7	10.4
June.	7.8	7.7	7.6	7.7	8.3	7.4
July.	8.8	7.5	7.7	8.3	9.8	6.7
Aug.	7.9	8.0	8.3	9.3	9.5	7.3
Sept.	8.9	9.5	9.1	11.8	10.7	8.7
Oct.	9.9	9.0	9.6	9.9	10.6	8.2
Nov.	12.8	11.6	13.8	11.4	13.7	11.2
Dec.	9.9	8.8	9.8	9.9	10.6	8.0
Year	10.2	9.6	10.4	18.2	11.2	8.6

The windmill as a power is adapted to run all sorts of small machinery where constant and steady power is not required, the work being in proportion to the size of the mill. It is made to run a pump, and the pump may be at any reasonable distance; it is most largely used for grinding, cutting feed, and shelling corn, but may also be attached to wood saws, lathes, churns, elevators, or other light machinery. The cream separator cannot be run by this kind of power, because the wind is not steady; nor can it be used for filling silos with ensilage, because the wind cannot be depended upon.

The durability of the power windmill depends largely upon the material and the workmanship in its construction, but the care of the mill is also an important factor. Being

exposed to the weather three hundred sixty-five days of the year, the gearing of the windmill needs to be kept well oiled, and its wood work needs to be kept well painted. Like other machinery, the power windmill will last longer if it is simply constructed. If a steel power windmill is properly erected on a good foundation there is no reason to doubt but that it will last as long as any other. power.

The convenience of the power windmill depends upon the use to which it is put. It is as convenient as any stationary motor, except it can be used only when the wind blows. With bins and elevators the power windmill for grinding has the same advantage over other motors as the windmill for pumping has over other motors. The power windmill needs but very little attention, and it generally runs on stormy days when work cannot be done out of doors.

The motor that furnishes the desired amount of power for the least current expense is the most economical. The current expense depends upon the first cost, interest on the capital invested, deterioration, repairs, attendance, oil, and fuel (when used). The last is zero in the case of the windmill, for the wind is a free gift of nature. The attendance for the leading American type of windmill requires only the filling of oil cups once a week, (which can be done in a few minutes), twenty-five cents a month would be extravagant wages for such service. The expense for repairs and depreciation items could be covered by five per cent per annum on the investment, and the expense for lubricants for one year would not exceed one dollar.

A certain 14-ft power windmill and grinder, costing

$150.00 during the year 1897, finely ground 60 tons of hay, besides cutting all the stalks from 6 acres of good corn, and doing other work. At eight cents per cwt., it would cost $25.60 for grinding 16 tons. The expense for grinding this amount with the windmill was as follows:

Interest at 7% on $150.00- - -	$10.50
Repairs, etc at 5% on $150.00-	7.50
Attendance at 25¢ per month- -	3.00
Oil - - - - - - - - - - - - -	1.00
Total-- --	$22.00

The difference in the cost of grinding the grain would be $3.60, while the power for the rest of the work would be clear gain. In this case the handling of the grain was not considered, for it would have been necessary to handle the grain if it had been ground by any other power. I should also say that this mill did not do one fourth of what it could have done.

The mechanical horse power developed by the power windmill varies with the size of the wheel and the velocity of the wind. With varying velocity of wind, several tests of different mills were made by means of the Proney brake. The brake consisted of a piece of six inch belt laid over the top of the driving wheel A spring balance reading to quarters of a pound was made fast at one end, the other end being fastened to the tight end of the belt. By weighting the loose end of the belt, the spring balance could be made to read any desired number of pounds, and thus the load on the mill could be regulated. By holding the speed counter on the end of the shaft, the number of revolutions of the driving-wheel per minute was found. If V equals the number of revolutions of the driving-wheel per minute, L the load as shown by the spring balance minus the weights

on the belt, and D the diameter of the driving-wheel in feet, we have the number of foot- pounds per minute: Feet-pounds equal $L\,V\,\pi\,D$. The horse-power equals $\frac{L V D \pi}{33000}$

During the time each mill was tested, the velocity of the wind was measured by an anemometer near the sails. The results are as follows:

Size of mill.	Temperature.	Velocity of wind	Horse power	Remarks.
12 ft steel windmill	20°F	22½	.227	
#13 " "	28°	13½	.208	
" " "	"	12.74	.203	
" " "	26°	13½	.2173	)
" " "	"	12.73	.2	) mill stopped for a
" " "	"	14.	.248	) few seconds during
" " "	"	13½	.3212	the test.
" " "	30°	30	1.31	
14 ft wood windmill	20	14	.2185	
" " "	24	18	.538	
" " "	20	27	1.219	
14 ft steel windmill	22	27	1.06[illegible]	#the seven following are from the same mill.
13 ft steel mill	20	13½	.305	
" " "	20	17	.5305	

In order to obtain more practical information regarding motors for farm purpose, a few letters were sent to different parties containing the following questions:

1-How long have you had your power?
2-What condition is it in now?
3-What did it cost you?
4-Do you use it much?
5-What machinery do you run by it?
6-Does the power pay for itself?
7-Have you paid out much for repairs?
8-What is the expense of running it one day?
9-What can you accomplish in one day with it?
10-If you have objections to your present power, please state them briefly.
11-If you did not have your present power, what kind of a power would you purchase?
12-What kind of power would you recommend for a common farmer to buy?

The following are answers corresponding to the questions:-

A 14 ft. steel mill.

1-Nearly three years.
2-Nearly as good as new.
3-$214.00, with grinder.
4-Yes.
5-Wood saw, emery wheel, feed grinder and feed cutter.
6-It would pay for itself in six years.
7-No.
8-Nothing.
9-Grind from 5 to 10 bushels per hour.
10-It does not always run when I want to use it.
11-Steam engine.
12-Power windmill. (This person has a 14 ft steel mill).

A 14 ft wood wheel.

1-Eighteen years.
2-Fair condition.
3-$225.00 for mill and grinder.
4-Yes.
5-Grinder, wood saw, feed cutter, and corn sheller.
6-Yes, many times.
7-Nothing only for oil.
8-Nothing.
9-Grind 15 bushel per hour.
10-I have no objections.
11-Windmill.
12-Windmill.

A 14 ft wood wheel.

1-Four years.
2-Nearly as good as new.
3-$100.00.
4-Yes.
5-Grinder, saws, emery wheel, grindstone, corn sheller, and feed cutter.
6-Yes.
7-None.
8-No expense.
9-Grind from 5 to 10 bushel per hour.
10-None.
11-Windmill.
12-Windmill.

Three Horse tread power.
1-Five years.
2-Good.
3-$120.00, and freight.
4-About one month.
5-Thresher and separator, 34 inch cylinder.
6-Yes.
7-Very little.
8-The use of three horses.
9-Thresh 75 bushels.
10-
11-Tread mill

Tread Power.

1-Sixteen years.
2-Good.
3-$180.00.
4-Yes.
5-Threshing machine, wood saw, and ensilage cutter.
6-Many times over.
7-Repairs too little to consider.
8-Very little.
9-
10-No objections.
11-A new one like it.
12-A two horse tread power.

Gasoline Engine.

1-Nearly three years.
2-Good as new.
3-$800.00.
4-Fall and winter, mostly.
5-Corn husker, buzz saw, feed grinder, and corn sheller.
6-It will in time.
7-75¢ per dozen tubes, and one tube will last three days.
8-40¢ to 80¢ per day.
9-Husk 5 acres of corn, cut 15 to 20 cords of wood, and grind a bag of grain in 90 seconds.
10-Fire goes out on windy days.
11-Gasoline engine.
12-For the amount of money, a gasoline engine.

The amount of feed ground by a 14 ft wood wheel windmill for three years was fifty tons. (This was done beside doing other work). The same mill ground 466 pounds of corn and 200 pounds of oats in 11 hours with a ten mile wind. With a 24 4/7 mile wind it ground 330 pounds of corn and 270 pounds of oats in three hours. In both cases the grain was ground fine. At another time it ground six bushels of grain in one hour, and it furnished the power to cut 20 cords of wood in five hours, velocity of the wind not known.

It may be of interest to note that Mr. McQuesten, of Marblehead Neck, Mass., has a 20 foot power windmill which furnishes power for a small electric light plant, consisting of a 3 Kw. dynamo and a set of 48 cells of storage

battery, having 140 lamp-hours capacity. This plant furnishes lights for his buildings, containing in all 137 lamps. From 40 to 90 lamp hours per day are used.

From a letter written to Mr. McQuesten inquiring about the electric light plant, the following letter was received from his brother:

"Dear Sir: Replying to your favor of January 7th, the electric light plant you refer to belongs to my brother, who is abroad and will not return for several months.

While I am not well enough acquainted with the plant to give you all the information you ask for, I know the plant is, and always has been, a success. It is practical, gives a steady light, and is economical to run."

For further information on this subject, the following articles found in the Library at M. A. C., may be of service:

The Windmill as a Prime Mover, by A. R. Wolff,(T.B.W.83)
The Power of a 16 ft Windmill,Bulletin No.68 of the Wis. Ag. Exp. Sta.

Wind and Tread Powers,	Breeders' Gazette,	yr.	1896,	page	147.
Wind Power,	" "	"	"	"	106.
" "	Mich. Farmer	"	1897	"	158. Feb. 27
" "	" "	"	"	"	37. Jan. 16
" "	" "	"	1898	"	117. Feb. 13
" "	" "	"	1897	"	177. Mar. 6
" "	" "	"	"	"	278. Apr. 10
" "	" "	"	"	"	297. " 17
" "	" "	"	"	"	337. May 1
" "	" "	"	"	"	398. " 22
" "	" "	"	"	"	438. June 8
" "	" "	"	"	"	458. " 12
" "	" "	"	"	"	497. " 26
" "	" "	"	"	"	81. Aug. 7
A Well Arranged Farm Mill	" "	"			Dec. 4
Wind Power	" "	"	1898	"	282. Apr. 9
Steam Power	" "	"	1897	"	91. Aug. 7
Gasoline Engine	" "	"	"	"	374. Nov. 20
Home-made Horse Power	" "	"	"		Dec. 11
Tread Power	Breeders' Gazette	"	1896	"	50
Tread Power vs. Sweep Power	" "	"	"	"	206.
Gas Engine	" "	"	"	"	107

The following is a list of addresses of the leading windmill manufacturing companies in the United States:

United States Wind, Engine and Pump Co.,Batavia, Ill.
Appleton Mfg., Co., Batavia, Ill.
The Challange Windmill Co., Batavia, Ill.
Fairbanks, Morse & Co., Chicago, Ill.
Aermotor Co., Chicago, Ill.
E. B. Wineger, Chicago, Ill.
American Wheel Works, Aurora, Ill.
Perkins Windmill Co., Mishawaka, Ind.
Flint & Walling, Kendallville, Ind.
Mast, Foos & Co., Springfiled, O.
Althouse Wheel Co., Waupun, Wis.
S. Freeman & Sons Mfg., Co., Racine, Wis.
Maud-S Windmill Co., Lansing, Mich.
Phelps & Bigelow Windmill Co., Kalamazoo, Mich.
Eureka Windmill Co., Kalamazoo, Mich.