XLVII. TEST OF WIND-ELECTRIC PLANT AND RELATION OF WIND-MOVEMENT TO GENERATED ELECTRICITY

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I. Introduction.

Wind power is an old subject. Everyone knows that wind possesses power to do work. Centuries ago wind was used to propel the ships of the sea. Today wind pumps the water for cattle on many farms, and in some of our drier sister states wind is extensively used to pump water for irrigation. Although wind power has been and is today widely used for the purposes above mentioned, no attempt to harness the wind for general utility purposes has been made until recently.

That wind possesses large quantities of power has long been known. To make this clear one only needs to mention a few facts. For example, the theoretical wind power passing through a circle 14 feet in diameter, which is the diameter of many ordinary farm windmills, is 6.1 horse-power at a twenty mile per hour wind, and 20.4 horse-power at a wind velocity of thirty miles per hour. No one realized this better than the farmer himself and naturally the first attempts to harness the wind electrically were made by farmers.

The first wind electric plant that we have record of in the literature is one built by Mr. Forrest in Wisconsin. This plant has been in almost continual operation for more than fifteen years. Wallace Manikowski a farmer in North Dakota designed and built such a plant as early as 1911. It was apparent to all farmers, experimenting with the general utilization of wind power, that the best way to harness the wind was to have the windmill drive a dynamo. The electricity generated in turn was used to charge a storage battery. Power could then be taken directly from the generator while it was running or from the battery during periods of calm.

Although these pioneer plants were built years ago, not much progress was made until recently when one of the leading windmill manufacturers took interest in the general utilization of wind power for farm purposes, and developed and placed on the market such a wind-electric plant. The subject of wind was suddenly given a new interest, and with plenty of capital behind the venture the prospects for a satisfactory and reliable wind electric plant looked very promising.

When the marketing of this commercial wind-electric plant was announced the Iowa State College immediately requested to have one of these plants placed on its campus for observation and test so that actual operating data and experience in Iowa wind could be given out to any Iowa farmers interested in its possibilities. The electrical and agricultural engineering departments were asked to conduct such tests as would show its performance and to observe its operation. These tests, with which the writer was associated, were begun in the summer of 1922. In the remainder of this article the writer will give a brief description of the plant, present some of the important data obtained, and from this data predict what may be expected from such a plant in Oklahoma wind.

II. Description of Plant.

The plant consisted of a windmill, a generator with gearing, a switchboard and a storage battery.

Windmill. The windmill had an ordinary type wheel 14 feet in diameter and was mounted on a fifty foot tower. The wheel had a maximum speed of sixty revolutions per minute. It was held in the wind by means of a self-regulating rudder, which also turned the wheel out of the wind when the wheel was running sixty R. P .M. This corresponds to a wind velocity of about thirty miles per hour.

Generator. The generator was a direct current machine of the differentially compound type. Its rating was forty volts and twenty-five amperes, over a speed range from 750 to 2500 R. P. M. The electrical characteristics of this generator are such that the voltage does not vary more than from 32 to 40 volts over its entire speed range. A machine which will generate a constant voltage at variable speed is not a new thing nor is it very uncommon. Almost every automobile has a generator which accomplishes the very same thing. It charges the storage battery of six volts over the speed range from 12 or 15 miles per hour upward. The feature which accomplishes this is the differentially compound winding. Such a generator has two windings, a series and a shunt, which are so connected as to oppose each other. When the generator circuit is open only the shunt field is excited and a large voltage may be generated. But when the charging circuit is closed the charging current must flow through the series field, thereby opposing the excitation produced by the shunt field. As the speed of the generator increases more voltage is generated, and more charging current flows. The increased series field current develops more opposition to the shunt field, thereby reducing the excitation and consequently the voltage. In this way the voltage is brought back to normal at the increased speed. If the speed should drop off, less voltage would be generated and less charging current would flow. The reduced current through the series field would thus result in less opposition to the shunt field. Less opposition to the shunt field would allow the voltage to rise again to its former value.

Step Up Gear. The generator was geared direct to the wind wheel through a two stage step up gearing which gives forty revolutions of the generator for every one of the wind wheel. The reason for the use of a gear was to make possible the use of a smaller machine for the same output. It is a rule in electrical design that the higher the speed of an electrical motor or generator the smaller its size for the same output.

Switchboard. From the generator the current is carried to a collector brush which allows the mill to revolve about a vertical axis. From the collector the wires are carried down the tower to the building where the switchboard and storage battery are installed. On the switchboard are mounted fuses, switches, voltmeter, ammeter, but most important of all an automatic contactor which automatically connects the battery to the generator when the mill is revolving fast enough to begin charging. This normally occurs when the wind is blowing about 8 miles per hour.

Storage Battery. The storage battery consists of 16 cells of two volts each connected in series to give 32 volts as the terminal voltage. The battery has an intermittent rating of 240 ampere-hours, which is supposed to be sufficient capacity to store enough energy to furnish power for light for a period of eleven successive days.

III. Results of Tests.

Space will not be taken to describe the methods employed in making the various tests nor in telling of any weaknesses discovered in the original plant for which suggestions were made and which now are part of the present plant. Space will only be taken to present the data of greatest importance in determining the practical value of the plant.

Charging Current. The current is quite variable, in fact as variable as the wind velocity itself. This is due to the gustiness of the wind. The wind velocity is continually varying. Fig. 1

shows the wind velocity and charging currents on the same graph and clearly shows the close relation between charging current and wind velocity. Fig. 2 is a curve showing the actual relation between average charging current and average velocity. Furthermore it shows that charging does not begin until the wind blows about 8 miles per hour. At twenty miles per hour the charging current is 18 amperes and at thirty miles per hour it is twenty-eight amperes. This is greater than the current rating of the generator, but it is here that the self-regulating rudder commences to pull the wheel out of the wind.

Monthly Kilowatt-Hour Production. The monthly generation of energy for one year is given in Fig. 3. The year shown is from June 1922 to June 1923. The results are much as might be expected, namely, that the winter and spring months are the windy months and the summer months the calm months. March shows the largest amount of energy generated, nearly 200 K. W. hours and in this respect runs true to form. The months of July and August, show about 30 K. W. hours each. These are the low months, which also conforms to common experience.

Energy Available for Farm Use. Not all the current generated and delivered to the battery is available for use. Batteries are not 100% efficient. On this plant the plant efficiency was found to vary considerably. During the windy months when the batteries were kept well charged, a large part of the current passed directly from generator to load. Under these conditions the plants was around 70% efficient. But during the calm weather where the major portion of the energy used had to be stored for a time the plant efficiency dropped down to 60% and lower.

Figure 3 also shows the current available for farm use, figured upon the basis of a 60% plant efficiency. This figure is about the average for a new battery but would probably become lower as the battery grew older.

Relation of Monthly Wind Movement to K. W. Hours Generated

In Figure 4, the K. W. hours generated per month are plotted against the total wind movement in miles per month. This shows the interesting relation that there seems to be a nearly uniform increase in energy output as the total wind movement increases. The curve shows a tendency to bend upward which seems in line with what might be expected. As the total monthly wind movement increases a larger percentage of the wind is above 8 miles per hour than at lower values. Therefore, instead fo the curve being a straight line it has a characteristic upward curvature.

IV. Predicted Oklahoma Wind-Electric Power

The curve of Fig. 4 suggests the basis for the easy interpretation of monthly wind movement into electrical output. The United States Weather Bureau reports on wind movement are available in almost all sections of the country. All that needs to be done is to obtain the miles of wind movement per month, find the point on the curve, and then read the corresponding kilowatt-hours generated.

In Table 1 are given the miles of monthly wind movement for Oklahoma City for the ten year period from 1915 to 1924. These are the recorded values for Oklahoma City, which is located quite centrally in the state and are therefore somewhat typical of the entire state.

Using the curve of Figure 4 values of generated Kilowatt Hours can be read from it corresponding to the monthly wind movements of Table 1. An examination of this table shows a maximum monthly production of 485 and a minimum of 104 K. W. hours, with an average production throughout the ten year period of about 280 Kilowatt-Hours per month. It will be noted that in order to use the curve of Figure 4 showing the relation between kilowatt-hours generated and monthly wind movement it was necessary to extend the curve way beyond the limits reached in Iowa. Although Iowa is known as the Cyclone state it does not have nearly as much wind movement as Oklahoma. The maximum reached in any month in Iowa was in the neighborhood of 8000 miles per month where as in Oklahoma the weather bureau records show several months running as high as 14,600 miles per month. In extending the curve into this region it was extended conservatively as a straight line and not with its characteristic upward bent.

It will furthermore be noted that the wind is well distributed and no month can be said to be especially low. This is an important point, for a plant of this kind is no better than its weakest month. In this respect it is much like the proverbial chain which is no stronger than its weakest link.

V. Conclusions.

From the data presented it is evident that such a wind-electric plant shows great possibilities in Oklahoma, with its abundance of wind. Moreover, Oklahoma wind is well distributed throughout the year which is also greatly in the plant's favor.

With an estimated minimum production of over 100 kilowatt-hours per month such a plant should be adequate to meet the needs of most farmers in the state. One-hundred kilowatt-hours will more than provide light for the home, yards, and barns and power for washing, ironing, and other household devices. Many farmers using electricity today do not consume as much as 50 kilowatt-hours per month. Therefore this plant should in addition be able to provide power for small fractional horse-power motors for pumping, separating, churning, etc. Although the plant may not be entirely adequate in Iowa on account of lesser wind movement, in Oklahoma it should be of sufficient capacity in almost every instance.

VI. A New Development.

Hardly were the tests described above completed when an entirely new idea was brought forth, namely, the use of an aeroplane propeller in place of the ordinary windmill wheel. Today the plant tested is already obsolete. A new plant with a ten foot propeller weighing only 18 pounds is replacing the old 14 foot wheel which weighed over a 1000 pounds. The entire head on the new plant only weighs 300 compared to 1500 on the old plant. Instead of exposing 150 square feet to the wind the new wheel exposes only 5 square feet. This is also an important factor because it decreases the likelihood of being blown down. The much reduced weight and decreased wind exposure make possible the use of a much lighter tower which eventually may take the form of a mast with guys. The claims made for the new plant are that it will generate more electricity in the same wind than the old.

What the future of the aeroplane plant may be no one knows. How widely it will ever come into use is a matter of speculation. This much is sure, the more plants placed on Oklahoma farms the sooner will the day come when all the farmers will enjoy the benefits and advantages of electric service. It is likely that this wind plant and the gasoline plant will be the forerunners of a general rural electrification. Certainly they will hasten the day.

PLATE VIII.

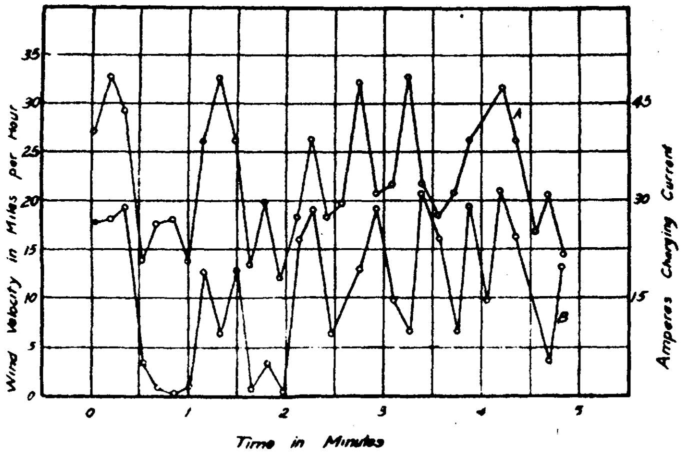


Figure 1. Graph of Wind Velocity (A) and Charging Current (B) showing similarity between the two curves.

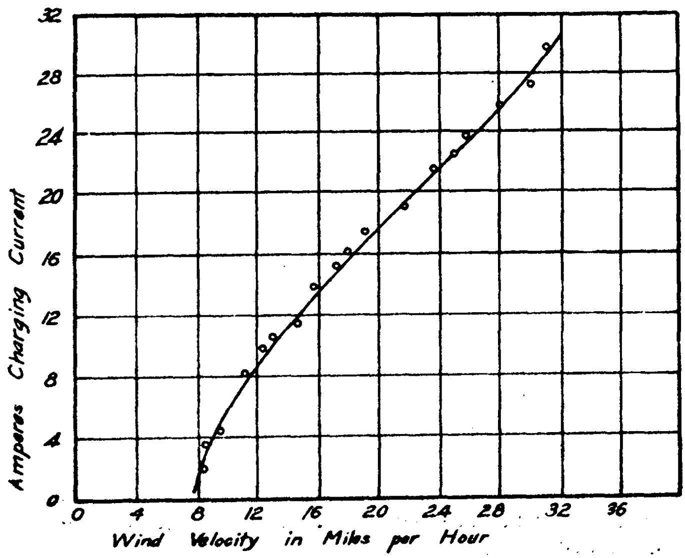
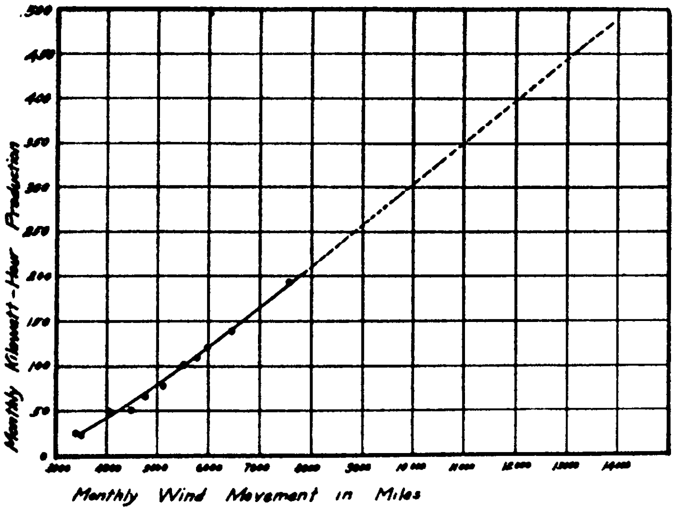


Figure 2. Relation between average Charging Current and Average Wind Velocity.

PLATE IX.



Fifure 3. Monthly Kilowatt-Hour Production.

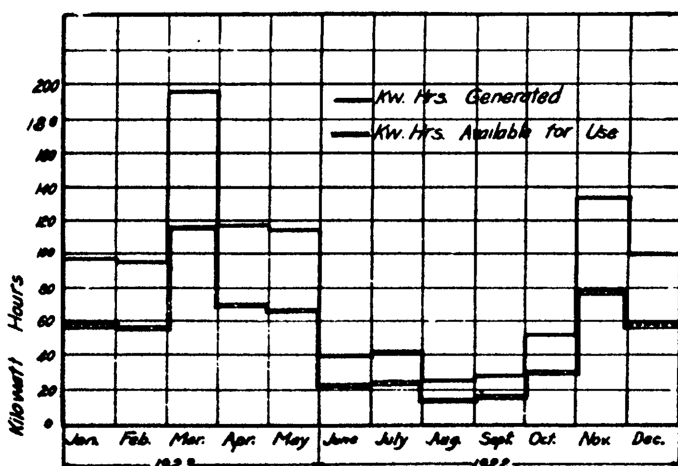


Figure 4. Relation of Monthly Wind Movement to Kilowatt-Hours Generated.

TABLE I.

U. S. Department of Agriculture, Weather Bureau.

Station, Oklahoma City State, Oklahoma.

Total Wind Movement—Miles

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1915	10622	11659	10063	10577	9436	9527	9908	7294	9591	8542	11651	10550	119420
1916	12549	9577	13606	12239	12466	9912	5883	8844	9250	9842	11871	11469	127508
1917	10271	10061	14005	13740	10954	10756	9425	7350	7543	11225	8677	10255	124262
1918	10956	11258	11302	10075	12469	7404	8230	8743	8288	7535	9902	9781	115942
1919	8518	11364	11210	11062	8517	6846	7987	8099	8475	9287	9377	10569	111311
1920	9487	9320	14006	12345	8820	9002	6985	6777	7696	10636	9562	11531	116170
1921	9820	7482	12145	11734	8979	7209	7543	7729	7589	7590	9411	10124	107355
1922	8765	7955	12598	9239	7380	6180	7823	6750	6457	7367	7733	9048	97295
1923	8755	7769	11200	9061	8661	7996	5654	6342	6549	5958	6049	8316	92311
1924	7820	7174	8501	8094	7379	8366	6602	7234	6954	7143	7801	7519	91487