E. J. Blanchard.

DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 29

WELLS AND WINDMILLS IN NEBRASKA.—BARBOUR

WASHINGTON
GOVERNMENT PRINTING OFFICE
1899

IRRIGATION REPORTS.

The following list contains the titles and brief descriptions of the principal reports relating to water supply and irrigation, prepared by the United States Geological Survey since 1890:

1890.

First Annual Report of the United States Irrigation Survey, 1890; octavo, 123 pp.

Printed as Part II, Irrigation, of the Tenth Annual Report of the United States Geological Survey, 1888-89. Contains a statement of the origin of the Irrigation Survey, a preliminary report on the organization and prosecution of the survey of the arid lands for purposes of irrigation, and report of work done during 1890.

1891.

Second Annual Report of the United States Irrigation Survey, 1891; octavo, 395 pp.

Published as Part II, Irrigation, of the Eleventh Annual Report of the United States Geological Survey, 1889-90. Contains a description of the hydrography of the arid region and of the engineering operations carried on by the Irrigation Survey during 1890; also the statement of the Director of the Survey to the House Committee on Irrigation, and other papers, including a bibliography of irrigation literature. Illustrated by 29 plates and 4 figures.

Third Annual Report of the United States Irrigation Survey, 1891; octavo, 576 pp.

Printed as Part II of the Twelfth Annual Report of the United States Geological Survey, 1890-91. Contains "Report upon the location and survey of reservoir sites during the fiscal year ended June 30, 1891," by A. H. Thompson; "Hydrography of the arid regions," by F. H. Newell; and "Irrigation in India," by Herbert M. Wilson. Illustrated by 93 plates and 190 figures.

Bulletins of the Eleventh Census of the United States upon irrigation, prepared by F. H. Newell; quarto.

No. 35, Irrigation in Arizona; No. 60, Irrigation in New Mexico; No. 85, Irrigation in Utah; No. 107, Irrigation in Wyoming; No. 153, Irrigation in Montana; No. 157, Irrigation in Idaho; No. 163, Irrigation in Nevada; No. 178, Irrigation in Oregon; No. 193, Artesian wells for irrigation; No. 198, Irrigation in Washington.

1892.

Irrigation of western United States, by F. H. Newell; extra census bulletin No. 23, September 9, 1892; quarto, 22 pp.

Contains tabulations showing the total number, average size, etc., of irrigated holdings, the total area and average size of irrigated farms in the subhumid regions, the percentage of number of farms irrigated, character of crops, value of irrigated lands, the average cost of irrigation, the investment and profits, together with a résumé of the water supply and a description of irrigation by artesian wells. Illustrated by colored maps showing the location and relative extent of the irrigated areas.

1893.

Thirteenth Annual Report of the United States Geological Survey, 1891-92, Part III, Irrigation, 1893; octavo, 486 pp.

Consists of three papers: "Water supply for irrigation," by F. H. Newell; "American irrigation engineering" and "Engineering results of the Irrigation Survey," by Herbert M. Wilson; and "Construction of topographic maps and selection and survey of reservoir sites," by A. H. Thompson. Illustrated by 77 plates and 119 figures.

A geological reconnoissance in central Washington, by Israel Cook Russell, 1893; octavo, 108 pp., 15 plates. Bulletin No. 108 of the United States Geological Survey; price, 15 cents.

Contains a description of the examination of the geologic structure in and adjacent to the drainage basin of Yakima River and the great plains of the Columbia to the east of this area, with special reference to the occurrence of artesian waters.

1894.

Report on agriculture by irrigation in the western part of the United States at the Eleventh Census, 1890, by F. H. Newell, 1894; quarto, 283 pp.

Consists of a general description of the condition of irrigation in the United States, the area irrigated, cost of works, their value and profits; also describes the water supply, the value of water, of artesian wells, reservoirs, and other details; then takes up each State and Territory in order, giving a general description of the condition of agriculture by irrigation, and discusses the physical conditions and local peculiarities in each county.

Fourteenth Annual Report of the United States Geological Survey, 1892-93, Part II, Accompanying papers, 1894; octavo, 597 pp.

Contains papers on "Potable waters of the eastern United States," by W J McGee; "Natural mineral waters of the United States," by A. C. Peale; and "Results of stream measurements," by F. H. Newell. Illustrated by maps and diagrams.

(Continued on third page of cover.)

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CHARLES D. WALCOTT, DIRECTOR

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LETTER OF TRANSMITTAL.

Department of the Interior,
United States Geological Survey,
Division of Hydrography,
Washington, February 15, 1899.

Sir: I have the honor to transmit herewith a manuscript entitled "Wells and Windmills in Nebraska," prepared by Erwin Hinckley Barbour, professor of geology in the University of Nebraska and acting State geologist. The data for this manuscript were obtained by Professor Barbour incidental to his studies of the geology of the State, and have been rounded out by special work carried on under his direction. The original manuscript as prepared consisted of two parts—the first upon wells, and the second upon homemade windmills—but owing to delays in printing the first part, it has been considered advisable to combine the two papers into one and thus secure earlier publication. The manuscript as thus combined is offered as one of the water-supply and irrigation papers.

In the earlier numbers of this series considerable space has been given to the subject of windmills and discussions of the results obtained by experiments. These facts have been presented in the hope of stimulating the development of more economical and efficient methods of raising water for irrigation. In the present paper another phase of the matter is presented, and it is shown that by the use of material at hand a thrifty and ingenious farmer can produce results worthy of imitation. It is not to be supposed that homemade devices will be as efficient as those made for competition in the open market, but in the country, far from centers of population, it is not always practicable for the farmer to obtain such machinery. Lack of ready money and difficulty of transportation may prevent his obtaining the best windmill or pump. Under these conditions it is infinitely better for him to use the means at hand rather than go without. It has been shown by Professor Barbour that where one man in a community invents and builds a useful device of this kind others are quick to imitate, so that one homemade windmill or pump is copied on neighboring farms for miles around.

It is pointed out in this paper that the homemade windmill is not necessarily a contrivance incident to poverty or hardship. Many of the mills of this kind have been made by men who might afford to buy shopmade mills, but who, having sufficient ingenuity and possessing the necessary materials, have preferred to combine these to produce effective machinery. They have merely exercised in this direction the thrift whose existence is shown by countless other tokens about their farms. The homemade windmill must not, therefore, be considered an indication of poverty, but rather the reverse, since it is usually accompanied by progress in all lines.

The subject matter of this paper is related to water conservation in the small way. Throughout the Great Plains region the supply of water is so scanty and so widely disseminated that as a rule it will be impracticable to provide great storage reservoirs or other works of considerable magnitude. On the other hand, for the utilization of the resources there must be innumerable attempts to employ the small amount of water almost everywhere available; and this can be done most economically through the use of the ever-present force of the wind. Thus windmills throughout at least one-fourth of the United States must ever be inseparably connected with the utilization of wells and with the development of the country.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

WELLS AND WINDMILLS IN NEBRASKA.[1]

By ERWIN HINCKLEY BARBOUR.

IMPORTANCE OF WATER RESOURCES.

In Nebraska, as in other portions of the Great Plains region, the principal source of wealth lies in the soil. The fertility of this section is marvelous and agricultural possibilities are such that subsistence may be obtained for a population of several millions; yet this domain is for the most part sparsely populated, the progress of settlement has been checked, and the tilled areas are increasing in extent but slowly. This apparent cessation of progress during 1894, 1895, and 1896, especially in the western half of the State, is due mainly to one cause, the insufficiency of rainfall.

Except the soil and its products, the natural resources of Nebraska are few. The consolidated rocks are deeply buried beneath clays, sands, and gravels; there are few, if any, minerals of commercial value, no beds of coal nor veins of ore, no fields of gas nor oil, but water, owing to its comparative scarcity and its importance in agricultural economy, rises to the rank of a mineral resource of the greatest importance. The development and employment of all of the supply flowing on the surface or percolating underground necessitates a study as thorough as that given by other States to coal, iron, or precious metals.

This paper has been prepared as a preliminary study of the water problem in Nebraska. In it the attempt is made to review briefly the general subject of the water supply, to bring together the more obvious facts, and to state these so that they may be understood by the farmer or citizen not skilled in technical or scientific practice. The facts on which the paper is based were gained in part by personal observation, and were supplemented by correspondence carried on by printed schedules and letters. The discussion is general in character, treating of the behavior of water underground, and particularly of the methods of bringing it to the surface for domestic use and for use in agriculture. Reference is also made to the surface waters of the

[1] Notes and data respecting wells have been brought down to the spring of 1897; those respecting windmills to the spring of 1899.

State and the amount of rainfall, some facts are given concerning the salt or saline waters and their utilization, and the peculiar blowing or breathing wells are briefly described.

ACTION OF WATER UNDERGROUND.

Air, which is the vehicle for moisture, can carry a greater load when it is dry, warm, and in motion. If the air is cooled, it can no longer carry its burden, which is dropped from the clouds as rain. Follow the course of the raindrops, or the circulating water, as it is aptly called, from the moment of impact with the surface and it will be seen that (1) a portion runs off, washing eastern soils badly, but washing western less; (2) a portion soaks in, since the soil is sandy, as it does not in clay soil; (3) a portion is evaporated, the average annual evaporation in Nebraska amounting to 4 or 5 feet; and (4) a portion, insignificant in amount, is taken up by plants and animals.

The portion that soaks into the soil sinks by its own weight deeper and deeper through the capillary or hair-like passageways and is lost

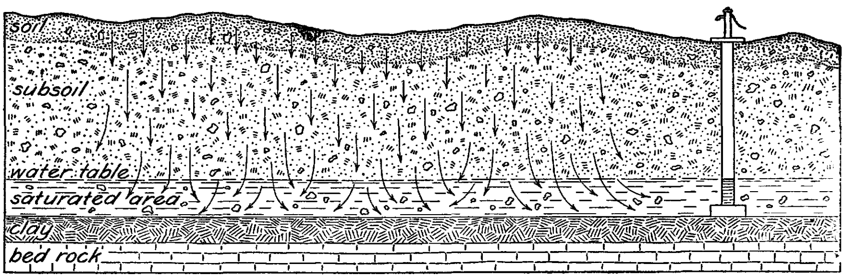


FIG. 1.—Course of water percolating from surface of soil down to saturated area.

to sight. It is universal experience that the soft, permeable surface material may change below to harder or even impermeable layers. Then it is that the water in its downward course is turned aside to flow laterally in all directions. Friction, however, greatly retards its movement. Constant additions are received as the rains continue, so that the creeping waters pile up, as it were, and gradually rise higher and higher; that is, the water table or water plane is rising.

As the process continues the creeping layer must rise to or near the surface of the soil, and thus the ground becomes water-logged—that is, soaked or saturated with water. (See fig. 1.) At such times springs are flowing, the ponds and streams fed by them are full, wells are inexhaustible, and vegetation is luxuriant and continues so during dry weather or even moderate drought. Let the season of drought continue and the creeping waters eventually steal away, and the saturated area is reduced to nothing; that is, the water table is settling. At such times ponds, springs, wells, and streams may fail—the more superficial first, the deeper last. Fresh showers cause them slowly to rise again, or perhaps they may rise without precipitation by accessions of water at some more remote spot, or from the seepage of some river swollen by floods at its source. Or, in still a third case, they may rise in an apparently mysterious manner without the intervention of showers or flood, simply because of hydrostatic connection with some other region which is flooded.

The water table, then, is subject to rise and fall because of water received at home or from abroad. It is not an entirely stable body preserving a constant level, but is subject to seasonal variations and variations incident to cycles of dry and wet years. The water table is not necessarily level, but is usually so, for instead of following the rocky floor the water table may run parallel with the surface. The floor, as well as the surface, is apt to be undulatory and the water plane or table higher or lower, according to the material passed through, to the escape of the water, and to other modifying causes. (See fig. 2.)

The ground water or free water, as it may be called, is evidently in circulation and subject to fluctuation. The wells of the region likewise vary, although this is scarcely worthy of mention in the case of Nebraska, from the fact that nearly all of the counties report an unlimited water supply, with inexhaustible wells. When the water table rises to within half a yard of the surface, vegetation suffers or is drowned out. On the other hand, when the water settles too far, plants may suffer equally from lack of water to carry soluble plant food to their roots and rootlets. When, however, the water table stands at a mean level between these two extremes, the fields of the State, with an annual rainfall of but 23.3 to 25 inches, produce crops and withstand droughts in a manner astonishing to the citizens of regions possessing double the annual precipitation. At first it seemed incredible that such magnificent yields could come from so insignificant a rainfall. Nevertheless the fact stands. There are two apparent reasons for this. The rainfall in many eastern regions amounts to 35 or 40 inches, but one-half is lost by running off and carrying with it valuable soil fertility, the other half soaking into the ground, while in Nebraska the water lost as run-off is only about one-tenth. Hence, here a far greater proportion of storm water is stored for future use. This is largely due to the sandy nature of the soil. Even some of the so-called clay soils, though looking and acting like clay, are in fact exceedingly fine sand.

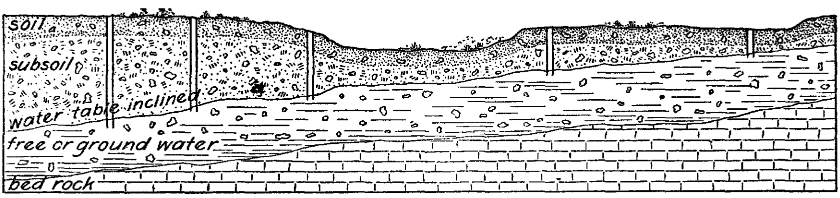


FIG. 2.—Inclined water table on eroded rocky floor.

From the mechanical analyses of soils and subsoils made thus far it is shown that Nebraska soils are peculiarly rich in sands and poor in clays. The amount of sand—including in this term coarse, medium, and fine sand and silt—runs as high as 97 to 98 per cent. The lowest percentage thus far is about 66 per cent, while the average is probably about 78 per cent, based on the analyses made by Prof. Milton Whitney, of the Department of Agriculture. In a word, there is a preponderance of sand in Nebraska soils, which renders them at once light and capable of readily imbibing a larger proportion of rainfall than is possible in eastern States. This is a very significant fact.

The more one cultivates the virgin prairie, which when hard packed sheds water like a roof, the greater will be the amount of storm water caught and stored in the soil and the less the run-off and evaporation. Increased cultivation tends toward the conservation of soil moisture, and this in turn reacts, making it possible to catch more moisture, since soil already damp imbibes more rainfall than a dry soil. Thus as settlement goes on the amount of precipitation absorbed increases and the amount lost becomes even less. This statement must not be confounded with the popular but erroneous belief that the annual precipitation is increasing.

But when the spring rains cease and a season of settled weather or possibly drought sets in, and the surface soil dries, a force of great interest and of profoundest importance begins to act. This force is capillarity, by virtue of which water is drawn up through the minute, hair-like passageways of the soil and subsoil, rising automatically as much as 6 or 7 feet. This, then, is a second way by which water is held in the soil, and its far-reaching importance is instantly apparent when one considers that the very passageways up which this water is drawn are those down which rootlets grow. Soil moisture laden with soluble plant food is thus carried up to the rootlets or feeders of growing vegetation. Crops and grasses are nourished by capillary water and saved by it uninjured in time of drought, even during seasons of long-protracted dryness (if not accompanied by hot winds), such as could not but blight crops and grasses elsewhere. However, it is not to be forgotten that this force works equally well both ways, thereby carrying moisture up or down, according as the surface soil or the deep subsoil is the drier. This only emphasizes the importance of utilizing all available rainfall in saturating the deeper soil as completely as possible, in order that the full energy of capillary attraction may be expended in drawing soil moisture to the rootlets.

Thus far two means have been considered by which water is held by the soil—first, as ground water, sinking by gravity, and, second, as capillary water. There is another means so subtle and concealed as to merit little more than passing notice—hygroscopic water, which is inherent in many minerals, rocks, soils, and substances, and may be obtained by long-continued roasting.

SHEET WATER.

There is in common parlance a rather indefinite and puzzling use of the terms, first, second, and third water, and sheet water. By first water is meant the first surface water that seeps into the well; a supply often weak and readily exhausted. By second or sheet water, as it is commonly called, is understood the deeper ground water, which is unlimited in amount, since it is contained in porous material that delivers water rapidly. Third water, as the term is popularly used, is doubtless the same second water struck at a lower level, after passing through a local layer of fine material of slow delivery.

Sheet water is a greatly abused term, about which has gathered false impressions not easily dispelled. It carries with it wherever used the idea of subterranean water, flowing at an exaggerated rate under the ground. It is perfectly true that ground water flows and that it has certain channels, naturally decided by the coarseness or fineness of the material, but one hears repeatedly of well diggers striking subterranean currents of sheet water flowing at the apparently incredible rate of 4 or 5 miles an hour, a faster rate than that of the Platte itself. This fallacious statement is made repeatedly in all sincerity and good faith. A very popular conception of this torrential sheet water is that it is the angry and pent-up floods of subterranean caves, which are seeking outlets to the sea. This erroneous conception is worse than fallacious; it is entirely misleading.

There is no such current in the sheet water, and there are no such extensive caves and underground lakes, and can not be in the sandy soil of Nebraska. Caves are formed in limestones, not in sands, for naturally the sand would cave in and fill any great underground passageways as fast as formed. This misconception comes about naturally enough in some cases, and is cherished with a faith not to be shaken. The well digger, who, while bailing or pumping out the water on one side of the well, sees water flowing in from the other, can tell without hesitation in which direction the water flows, for he "has seen it himself;" but let him set his pump on the opposite side of the well and the current will set in from the other direction.

Of course there is a current whose rate is regulated by the coarseness or the fineness of the material through which it flows, but this same current is inconceivably slow. Coarse material with rapid delivery of water may have a current as slow as a fraction of a foot a day, or as rapid as several feet a day, while in fine-grained, compact soil the rate is reduced to little or nothing. A better understanding of the power of delivery of various materials would correct many of these errors.

If an old pail or keg, having holes in the bottom, is filled with clean, coarse pebbles, and a stream of water poured in, the rate of delivery is practically as rapid as the rate at which the water is poured. Its rate is so rapid that the water flows down through the gravel in a column, scarcely wetting the other pebbles. With the sand, however, the water spreads out or is diffused through much or all of the mass, and is delivered slowly at the bottom. In the silt, which is impalpably fine sand, the rate is still slower and the whole mass is saturated with water. In clay—the fineness of which is extreme—there is no delivery at all in experiment and practically none in nature. Mix together gravel, sand, silt, and clay, about as they occur in nature, and the rate becomes about the same as that of the finest material—that is, water is delivered with extreme slowness.

This set of experiments tends to show the rate at which water can flow through soil or rock of various degrees of porosity, and disproves the statement that the velocity of underground currents is in any way comparable with that of surface streams.

ARTESIAN WATER.

Ground water is almost universal and is the source of the supply of common wells. In addition to this there is the extraordinary subterranean water which supplies artesian wells. In the common house well the water seeps in and stands quietly at a certain level. In the artesian well it comes in under pressure. This is the only essential difference between the two. The artesian wells in Artois, France, from which the name "artesian" is derived, were the first dug and observed. These were spouting wells from deep sources; hence the term artesian presupposes in the public mind a spouting well from deep-seated sources.

This early conception, however, is not the true one. Many artesian wells are shallow, not over 60 to 80 feet in depth, but yet are true artesian wells. Many throw fine streams from a few inches to several feet high, and are unquestionably artesian wells; but a short distance away at a higher level the same water will rise in the well under the same pressure and is likewise artesian, even though the head is not sufficient to force it above the surface. The one is an active, positive, flowing artesian well; the other a negative, passive, or standing artesian well.

In Johnson and Seward counties the shallow artesian wells are beautifully represented. They occur in valleys where the surface has been washed away and lowered, thus enabling the pressure or "head" to force the water above the surface 10 to 12 feet. On this level flowing wells are everywhere to be found, which are already put to many economic uses, and farms which are models of their kind draw their water for irrigation from this source with no cost. These are positive or flowing artesian wells. On farms a few feet higher precisely the same water is struck. It rises to the surface, but can not flow over it.

It is universal experience that rocks, some soft and porous, some dense, are found in the State arranged in horizontal beds. The denser

A RIVERVIEW PARK ARTESIAN WELL, NEAR OMAHA, NEBRASKA.

Depth, 1,060 feet; capacity, 114,427 gallons a day; 6-inch pipe; water but slightly saline; temperature, 62°; cost, $1,000 This well supplies annually to the park system of Omaha a volume of water which, at the lowest wholesale city water rate, would cost $5,000 a year, and illustrates the use of artesian water for the beautifying of parks. In addition to the fountain and stream a small lake is supplied by the well.

B. ARTESIAN WELL IN HOLT COUNTY, 18 MILES SOUTH OF O'NEILL, ON THE FREMONT, ELKHORN AND MISSOURI VALLEY RAILROAD.

layer will constitute the impervious jacket around the more porous layers. The layers which are deeply buried here, and but inappreciably tipped, may come to the surface elsewhere and form a catchment basin, perhaps at a point far distant, as is the case presumably with the deeper wells found along the northern and northeastern boundary of the State.

The artesian wells, as far as reported, fall into four rather natural groups, as follows: The deep wells of the Carboniferous, such as those at Beatrice, Lincoln, and Omaha, varying from 556 to 2,463 feet; the artesian wells of the Dakota sandstone, 300 to 400 feet deep, being a continuation into Nebraska of the South Dakota artesian basin; the shallow wells in glacial sands and clays, such as those at Cook, Beaver Crossing, and elsewhere; and other shallow wells not in the drift, such as those in Holt and Rock counties. (See Pl. I, *B*.)

There are local artesian basins in the State which are more easily compassed than the deep wells. There are small basins of 10 to 15 square miles each in the valleys of streams, depressed noticeably below the general level of the surrounding hills. Within this circumscribed area, wherever the impervious roofing or encasement of clay is pierced—the depth varying from 40 to 100 or more feet—there comes a strong and constant flow. Such wells are too shallow to come from strata which draw their water supply from a distance, so that it is necessary to look for some other explanation.

It is at once apparent that this artesian supply is drawn from beds of alternating gravel, sand, and clay, deposited by glacial action during the ice age, and that it is rather limited and local, though none the less important, as has been sufficiently demonstrated by its multifarious uses at Beaver Crossing and adjoining localities. Farther downstream the wells, instead of growing stronger, grow weaker. This is due to some leak or escape of the water through the impervious clay roof, which results in a reduction of head or pressure in all adjacent wells.

The alternating and confused arrangement of these beds comes about naturally, because of the way in which the glacier and iceberg deposited coarse, medium, and fine material together into heterogeneous piles—clay here, sand there; sand, gravel, and pebbles elsewhere. The porous gravelly layer, incased above and below by layers of clay, is not necessarily of uniform texture, but, instead, there occur among the coarser material patches or islands of finer material. Hence as the well is in this patch or that, its head or pressure will be accelerated, retarded, or stopped outright, according to the rate of delivery of water in coarse, fine, or clayey material. One farm at Cook, Johnson County, in the midst of flowing wells, has failed, and always must fail, to furnish artesian water, and there is apparently nothing anomalous in the case. The farm is over what is called a "clay island." All the wells dug on this farm penetrate clay only, and, of course, one can not hope to strike artesian water there.

List of artesian wells.

Name of well.	County.	Town.	Depth.	Remarks.	Year.
			Feet.		
Lincoln test well	Lancaster	Lincoln	2,463	6-inch pipe; throws water 5 feet above surface; salt water.	
Artesian well, Government square.	do	do	1,060	Bed rock at 95 feet; salt water 160 feet; first flow 560 feet.	
Sulpho-saline bath	do	do	556	Strong flow; salt water; 100,000 gallons per day.	
David Swaney	do	5 miles west of Lincoln.	240	Slight flow	
Willow Springs distillery or Iler's well.	Douglas	Omaha	1,700 to 1,800	First flow at 700 feet; second flow at 1,700 feet; pressure 37 pounds per square inch; used for boiler.	
Pickard's or "Well No. 1."	do	6 miles west of Omaha.	1,383	Heavy flow at 517 feet, 676 feet, and 894 feet; strongest flow at 1,080 feet; pressure 150 pounds.	
Courtland Beach or Cut-off Lake well.	do	3 miles northeast of Omaha.[a]	998	6-inch pipe; throws water 40 feet; 86,000 gallons per day.	1894
Riverview Park well.	do	2 miles south of Omaha.	1,064	4-inch pipe; 114,427 gallons per day; slightly saline. Feeds a lake of 2 to 4 acres. Temperature, 62°.	
Omaha Packing Company.	do	South Omaha	1,800	Negative artesian, rising 70 feet to surface; strongly mineral. Temperature, 62°. Too warm for condensers.	
Elkhorn	do	Elkhorn	65	Soft water; cost, $45	1887
Lloyd Lunn	Adams	Near Hastings	114	6-inch pipe; cost, $31	1886
William Kearville	Boyd	T. 34, R. 8	760	Cost, $2,000; used for irrigation; 100 gallons per minute.	1895
Cal. Moffett	do	Sec. 2, T. 34, R. 12		Used for irrigation; 15 barrels per minute.	
G. L. Emmons	do	Sec. 18, T. 33, R. 8		Used for irrigation; 2,000 barrels per day; cost, $1,000.	1895
L. M. Short	Brown	5 miles from Ainsworth, in Sec. 9, T. 29, R. 22.	32	8-inch pipe; 40 gallons per minute; soft water; cost, $6. (?)	1895
C. W. Conkling	Burt	Tekamah	103	Three wells, 3, 4, and 8 inch, for city water supply.	
Craig	do	Craig	126	Flowing water at 120 feet. CO_2 blown off for several days.	

[a] Really in Iowa, because of meanderings of Missouri River.

List of artesian wells—Continued.

Name of well.	County.	Town.	Depth.	Remarks.	Year.
			Feet.		
A. E. Johnson	Cass	Weeping Water, sec. 16, T. 10, R. 12.	8	Ceased to flow, 1894	
Numerous wells	Cedar		*a* 363	Average cost, $146; hard water.	
C. A. Johnson	Cherry	Woodlake, sec. 21, T. 31, R. 28.	100	Slight pressure; cost, $50; hard water; 100 gallons per hour; railroad well.	1892
A. Strong	do	Sec. 21, T. 31, R. 28.	17	Soft water	1892
B. A. Jones	Cheyenne	Near Sidney, sec. 20, T. 13, R. 45.	94	Negative artesian; cost, $75; by aid of pump. *b*	1886
J. E. Melcher	Cuming	Wisner	97	Used for irrigation; 2 barrels per minute; hard water; cost, $97.	1895
P. G. Cooper	Dawes	Crawford	86	12-inch stream, easily lowered; hard water; cost, $50.	
H. E. Grant	do	Sec. 25, T. 32, R. 52.	82	600 gallons per day; soft water; cost, $100.	1888
James Mozeller	do	Sec. 13, T. 32, R. 52.	18.5	2-inch pipe; soft water; good pressure until filled with sand.	1891
F. P. Ryan	Dixon	Ponca	407	60 gallons per minute	1885
Do	do	do	265	do	1894
Geo. Mattison	do	7 miles from Ponca.	484	Flowed three weeks and stopped; stands 6 feet below the surface; cost, $50.	1888
Fred Heine	Dodge	3 miles north of Hooper.	304	40 gallons per minute; hard water.	1892
Beatrice	Gage	Beatrice	1,260	Very salt; dug for city supply and abandoned; intermittent flow.	
J. J. Connoly	Garfield	Erina	110	Flows 6 feet above surface; soft water; cost, $11.	1894
P. A. McDonald	do	Sec. 15, T. 24, R. 14.	140	Soft water; constant flow; cost, $30.	1894
Benjamin Jones	do	Sec. 22, T. 24, R. 14.	175	3 feet above surface; soft water; 5 gallons per minute; cost, $37.	1894
A. J. Plumer	Grant	Hyannis, sec. 23, T. 25, R. 28.	450	4 gallons per minute; soft water; cost, $225.	1895
Numerous wells	Holt		55 to 120	Soft water; average cost, $10 to $30.	
Edward De Merritt	Hooker	Mullen			
Herman Kracker	Johnson	4½ miles from Elk Creek, sec. 34, T. 4, R. 12.	146	Cost, $200	1894
J. J. Wilson (3 wells)	do	4 miles from Cook, sec. 1, T. 6, R. 10.	80	3 wells cost $90; fine soft water. *c*	1893

a Average depth.
b Used to water 2,000 sheep and to irrigate garden.
c One well from 4-inch nozzle keeps a 1-acre pond, 4 feet deep, full all the time.

List of artesian wells—Continued.

Name of well.	County.	Town.	Depth.	Remarks.	Year.
			Feet.		
J. W. Holden	Johnson	4 miles from Cook, sec. 6, T, 6, R. 11.	....	Cost, $20	1895
Many wells	Knox		504 to 770	Cost from $225 to $3,600; majority hard water.	......
John Coker	Lincoln	9 miles from Sutherland, sec. 6, T. 14, R. 34.	22	Soft water; doubtful if this is really artesian.	......
Lew Williams	Logan	Gandy	81	Cost $80; soft and only artesian well in the county; pipe often choked up; good pressure.	1891
Hy. Rainer	Loup	Taylor	80	Hard water	......
R. E. Haskell	McPherson	Lena	42	Cost $25; soft water; 4 gallons per minute.	1895
White Water ranch	do	Sec. 32, T. 20, R. 35.	30	Cost $15; 15 gallons per hour; soft water.	1888
August Tannehill	Madison	6 miles from Norfolk, sec. 27, T. 25, R. 1.	125	Cost $90; 30 gallons per minute; medium hard.	1892
E. D. Gool	Nance	8 miles from Fullerton, sec. 14, T. 17, R. 8.	28	Cost $100; says water rises through 3-inch gas pipe for 24 feet.	1892
Geo. Young	Nemaha	2½ miles from Brock.	52	Cost $32; soft water	1892
J. G. Burriss	Otoe	½ mile from Cook.	75	Cost $20; one barrel per minute; used for irrigation; about 25 such wells in vicinity.	1891
Chas. Dorneau	do	4 miles from Unadilla, sec. 28, T. 9, R. 10.	282	Salt water; 30 gallons per hour; cost $282.	1889
Capt. S. V. Moore	Pawnee	6 miles from Pawnee, sec. 8, T. 2, R. 11.	10	Cost $15; said to flow in wet seasons; has sufficient water for 200 head of stock.	1888
Will Patterson	do	3½ miles from Burchard, sec. 36, T. 2, R. 9.	85	Cost $85; unlimited amount of hard water; slow flow, about 20 barrels per day.	1891
J. F. Wenzl	do	Steinauer, sec. 33, T. 3, R. 11.	11	Cost $40; flows in wet seasons; soft water.	1892
John McKenzie	Perkins	5 miles from Madrid, sec. 19, T. 10, R. 36.	150	Used for irrigation; cost $150; soft water.	1894
Many wells	Platte		12 to 100	Majority shallow; cost from $50 to $100; one salt and others soft water.	......
John Beckstrom	Polk	Stromsburg	104	Cost $75; unlimited amount of hard water.	1887

List of artesian wells—Continued

Name of well.	County.	Town.	Depth.	Remarks.	Year.
			Feet.		
Frank Nichols	Redwillow	McCook	405	Cost $200; oily water and weak flow, but flow has increased; experimental well.	1895
Many wells	Rock		95 to 143	Most costing from $30 to $40; all soft water.	
Dr. Geo. L. Miller	Sarpy	7 miles from Omaha, sec. 2, T. 14, R. 12.	1,430	Cost $5,000; pressure 15 pounds to square inch; soft water; fine artesian; supplies a 30-acre lake for ice and fish.	1891
Dr. Jos. Miller	Scotts Bluff	Gering	330	Cost $200; at first had a flow of 1,000 gallons per day, but filled up with sand and a pump is now used; soft water.	1894
Many wells	Seward		13 to 100	Used for irrigation; some hard and some soft water, ranging in cost from $18 to $65.	
Dr. S. Person	Stanton	8 miles from Pilger, sec. 6 T. 2, R. 3.	96	Used for irrigation; cost $77; hard water; declining flow, about 4 barrels per minute.	1895
R. C. Schwann	Valley	7 miles from Ord.	70	Cost $52; soft water; 15 gallons per hour.	1893
William Fetch	Washington	Herman	76	Cost $75; soft water; good flow.	1897
William Rutledge	do	do	38	Cost $25; hard water; free flow.	1894
Solomon Sheets	do	do	37	Cost $25; hard water; 3 gallons per minute.	1894
Many wells	Wheeler		8 to 124	Cost from $8 to $75; all soft water.	
A. B. Codding	York	York		Unfinished; cost $300; flowed 5½ hours, then 9 hours, and stopped; drill is fast in sand rock 600 feet deep. Water to be used in mill pond.	
Eugene Wright (two wells).	do	do	240, 590	Cost $200; power wanted for flour mill, but flow at 500 feet too weak.	1895
Harry Hill	Otoe	Palmyra	280	Salt water; 15 barrels per day.	

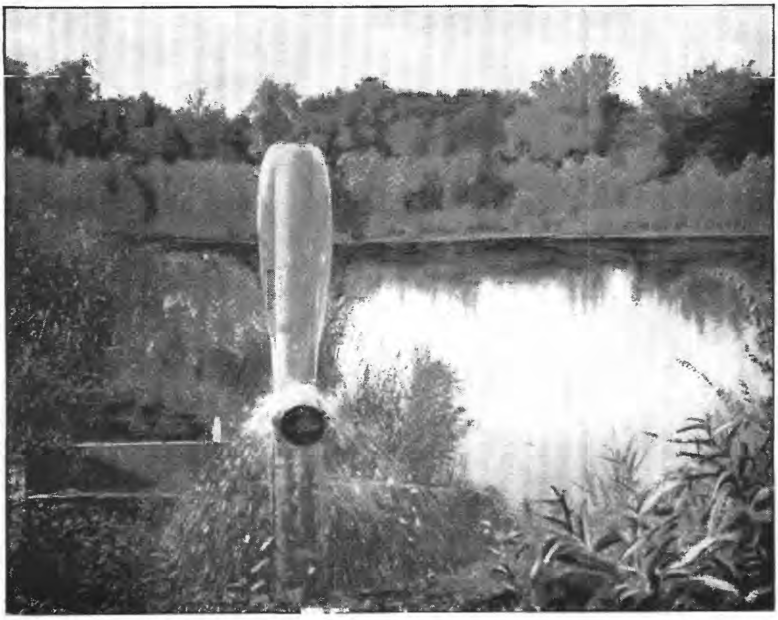
These local artesian wells are already turned to admirable account in supplying ponds for fish culture, fountains for school yards and parks, and water for domestic use and for irrigation. (See Pl. II, *A* and *B*.) The last-named use is destined to become of considerable economic importance. Some farmers have already from eight to ten 5-inch wells per farm with which to irrigate over 100 acres each. The number who have tapped the subterranean reservoir and allowed the imprisoned water to escape and to flow away aimlessly and uselessly far exceeds those who have put it to intelligent use. There is enough artesian water wasted thus to irrigate whole farms. What renders this matter all the more deplorable is the obstinacy of many people in insisting that the supply can not be exhausted. This view is wholly fallacious, and if persisted in may result in damaging or destroying altogether an important resource. Every well dug must diminish the head or pressure that much, whether the amount is perceptible or not. Unrestricted abuse of these water privileges can but result disastrously here as elsewhere. All this water should be most conscientiously used and conserved.

In several localities, noticeably in Rock County, near Kirkwood, there are strong springs which boil up with such force that if the water be confined by placing several joints of old stovepipe in the throat of the spring the pressure is sufficient to force the water several feet above the surface. Springs of this kind are numerous, especially in this vicinity. Since the water rises under pressure, the name "artesian spring" is applicable. Similar springs in Johnson County are called "mound" springs, because the water in the center appears to boil up and is higher than that of the edge. This boiling occasionally gives them the name "kettle" springs. Such springs near Sterling are 30 feet across, and the overflow is reported as 3 feet wide and 2 feet deep.

CONSERVATION OF SOIL MOISTURE.

The importance of the conservation of moisture has not yet had the general recognition which the subject merits. But each year brings unmistakable advance in this matter, as is shown by the construction of new reservoirs and dams across streams and draws, and by new methods of cultivation. These are on the increase, and were it not for the difficulties in the way of making water-tight reservoirs in sandy soil and the large amount lost by evaporation (averaging 4½ feet for the State), greater progress might be reported. The matter of conservation of soil moisture by superior cultivation, being a less obvious factor, is lost sight of by many, and yet by this means there have been, to the author's knowledge, some marked examples of success, standing in strong contrast to the failure of others. By pulverizing to extreme fineness a coarse soil, the absorption of water may be increased a thousandfold. Compress or "firm" the soil, and the attraction of capillary water is increased to that extent. Mulch the surface into fine, loose particles, and the capillarity which draws the moisture up to the plant rootlets is broken at that point, and a

A. ARTESIAN WELL AT BEAVER CROSSING, SEWARD COUNTY, NEBRASKA.



B. WELL ON FARM OF T. M. FERGUSON, AT BEAVER CROSSING, NEBRASKA.

Depth to artesian water, 80 to 90 feet. Height of pipe, 13 feet; diameter, 6 inches. Mr. Ferguson irrigates 112 acres from nine such wells, which cost $900.

blanket is formed for the retardation of evaporation and retention of moisture in the soil. By careful and intelligent farming, wide areas now abandoned, or held by indifferent, roving classes, will prove to have ample moisture for agriculture.

The results of close and conscientious farming are astonishing. One aged English couple living near Lincoln were forced to undertake farming in a small way for subsistence. The land was poor and the season was bad. All the neighboring tenants fled, and earned nothing during the entire summer. The aged couple farmed all the more closely, conserving the soil moisture in every way known to them. Starting on nothing, and struggling through the most trying season recorded in the State, at the end of the harvest they deposited in bank $100 above their expenses, which they afterwards spent judiciously in purchasing stock and necessary machinery for another year. These are small earnings, but, nevertheless, the difference between their methods of farming and that of their nomadic neighbors is infinite. It is such farming as this that makes the agricultural reputation of a great State.

During a recent trying summer the agent of one of the railroad companies in Nebraska escorted several parties of Eastern capitalists across the State. Contrary to the advice of those who thought the course injudicious, the railroad company took the tourists through the least promising as well as the most promising parts of Nebraska. In the heart and center of a deserted region in the arid belt, where the cornfields on the right were withered and abandoned, they repeatedly came upon farms on the left with magnificent fields and the appearance of prosperity. They found, on inquiry, that the nomadic neighbors were in their "prairie schooners," seeking easier jobs elsewhere, while the colonists left behind were farming with extreme care and were prospering. On the one farm the finest crops were grown; across the road none at all. The difference was due solely to the farmers, the one farming carefully and conscientiously, the other slothfully. When arid lands respond in most unpropitious times to careful and intelligent treatment, what may not be expected of the best? Confidence in the future of agriculture in semiarid and arid Nebraska was impressed and fixed in the mind of each tourist who saw this admirable and striking example of the results of intelligent farming. Taking advantage of the lessons taught by superior cultivation, the Burlington and Missouri River Railroad Company has initiated a most commendable series of agricultural experiments in the semiarid and arid nonirrigated portions of Nebraska and Kansas. Here a practical test will be made of the actual utility of soil-culture methods for the conservation of moisture. Experiment stations have been established at Holdrege, Alma, Oxford, McCook, Curtis, Broken-bow, Grant, and Hastings, in Nebraska, and at Oberlin, Wheeler, St. Francis, and Bird City, in Kansas.

The method to be pursued is substantially that introduced at Putney, South Dakota, by Mr. H. W. Campbell as early as 1885, a method promising to be even more important than irrigation because of its wider applicability. This process consists essentially of deep plowing, subsequent firming of the soil to increase capillarity, and light surface cultivation to break capillarity and check evaporation, and to this end special machinery has been designed. The method is often known as "dust-blanket farming," the idea being to cut the surface into a soil mulch or powdery condition in order to prevent loss of moisture.

Farmers along the Republican River as far west as Harlan County who have tried this method find that a diversity of crops is possible, and that while the number of acres cultivated is reduced about one-half, the yield is increased several fold. For instance, potatoes, which yielded an average of 212 bushels under this treatment, gave but 25 bushels per acre to neighbors who avoided this system of close farming on the ground that it was expensive and onerous.

During the last five years various means for catching and holding surface water have increased enormously, and now attention is directed to the results consequent upon the better conservation of soil moisture, all of which will aid in the reclamation of important tracts of remarkably productive land now idle and unoccupied. There are table-lands 200 to 300 feet above water where no amount of conservation of moisture on the surface or in the soil can avail; but, on the other hand, there are countless regions to be benefited thereby. Such table-lands, therefore, where grazing is notably good, should be turned over to stock raisers, and the lowlands to agriculturists. Each class would prove of benefit to the other. Community life could be formed in the valleys and the uplands left for grazing.

It is universally conceded that cattle raising is profitable, and that the small herder can make steady gains by watching his cattle more closely instead of turning them loose upon the range as formerly. It is an easy way to turn stock upon the common range, where no care is required winter or summer except at the time of the annual "round up." But by that method the chances for loss are greater. Its day is past in Nebraska, and it is now time for many small cattle raisers to occupy the land once grazed over by the herds of great companies. The grazing lands should be turned to better account, the conditions of the valley lands should be better understood, and many important tracts now deserted should be reclaimed. This will come about by the storage of storm waters, by irrigation, and by the conservation of soil moisture.

POLLUTION OF WATER.

The water for domestic supply is well purified. In the river current the water is exposed to the air, and thus purification by the process of oxidation goes on. The ground water is likewise purified.

But in its descent through the air, in its passage down the streams, or through the soil and rocks, water, which is the universal solvent, takes up certain acids and gases, and dissolves certain minerals, particularly lime (making hard water), iron (making chalybeate water), potash or soda (making alkali water), or salt (making saline water).

These are wholly inorganic ingredients and for the most part harmless. But there are other ingredients not to be detected by the sense of smell, sight, or taste, which come from organic decay. Water in closely settled regions is subject to dangerous pollution. It then becomes a vehicle for germs and contagious disease, and is not fit even for beasts. Wells should be so located and guarded that barnyard wash can not drain into them nor soak through the soil into them. The water filters through many feet of soil, and is pure and wholesome if proper precautions are observed. One may feel great confidence in the purity and healthfulness of water drawn from a well which passes through clay before striking water-bearing gravels.

The writer can not refrain from citing one specific case of well-water pollution. The occurrence of fever in three families in Omaha pointed unmistakably to the dairyman who supplied them with milk. On visiting the dairyman the city physician found three in his family suffering from the same fever. The seat of trouble seemed to be the well, which was so injudiciously located as to receive surface wash directly, and indirectly the offal from the house and barn, rendering the water at once nauseating and dangerous.

The cities of the State should zealously guard against the possible contamination of their water. Good water for city use is so easily obtained from groups or gangs of wells at reasonable depths that no community seems justified in drawing its supply from surface streams, which are subject to progressive deterioration as population increases.

SURFACE AND SEEPAGE WATER.

The marshes, ponds, lakes, and cut-off lakes are relatively few, and need no further mention at present. The rivers, however, are of growing economic importance, and the time seems near when they will be diverted from their channels into irrigating ditches. On this point many persist in cherishing the error that rivers can not be drained, maintaining that as rapidly as water is drawn off as much more rushes in to supply the loss.

The Platte River flows east across the entire State, and is presumably of greater importance than the Missouri River. Though becoming entirely dry in certain seasons, the Platte nevertheless supplies important areas with water for irrigation during the growing season. More important than this is the underflow water of the Platte. It is a singular and highly interesting river. Overloaded and taxed beyond its power, it can not carry its burden of sand out of the State. Accordingly its energy is spent in shifting its sand bars from side to side and in forming a lace work of channels through its broad bed; but beyond this, it is receiving constant additions of fresh sand. Accordingly it has built up its bed with sand 50 to 200 feet or more. Through this alluvial material there is an underflow of broad extent on each side of the Platte throughout the State, which spreads out and constitutes in part the important underflow, or even some of the sheet water of the State. After the surface water of the Platte has been diverted for irrigation the underflow in its gravels can be drawn upon without limit if mechanical difficulties can be overcome. (See Pl. III, *A*.)

FLUCTUATIONS OF WATER LEVEL.

The years 1892, 1893, 1894, and 1895 were years of exceptional drought. The whole water table was lowered, and springs, ponds, streams, and many wells failed. During the winter of 1895 there was virtually no rain or snow. That is to say, there was no precipitation by which to account for an unexpected rise of water (apparently real) which began early in the winter, and reached a point in February and March which aroused general comment. Many, for the past three years, had knots tied in well ropes whereby the well buckets might be lowered each time into the shallow water without roiling it. It was soon noticed that the wells were filling unexpectedly, because the ropes were wet some 10 to 12 feet above the usual point. Water began to flow in channels hitherto entirely dry. The dry beds of ponds began to fill. Excavations for railroad embankments became lakelets. Springs which three years previously had supplied fish ponds, but had become dry, began to flow again; and damp spots began to appear in some farms. So many cases were reported in person or by letter that the author took pains to send out several thousand inquiries over the State. Two-thirds of those who answered had noticed an unexpected rise of water; one-third had not. The evidence is almost conclusive that this is real, and is a matter of annual occurrence.

One explanation is that the decreased evaporation and the increased cohesion of water in winter allows more ground water to accumulate. The majority reported the rise as occurring in February. Stockmen in the most arid portions of Nebraska depend implicitly upon this rise of water, which they assert is of annual occurrence, and independent of precipitation. This matter seems as worthy of critical study as any problem connected with our ground water.

METHODS OF RAISING WATER.

Peculiar and characteristic systems of hoisting water are found in vogue in widely separated counties. Some methods are very primitive and crude, while others show thought and ingenuity. It is very evident that the first simple windlass or pump put up in a community becomes the model after which others of precisely the same type are

A. VIEW DOWN NORTH PLATTE RIVER FROM THE WYOMING-NEBRASKA LINE

B. DAM ON THE BLUE RIVER AT MILFORD, SEWARD COUNTY, NEBRASKA.

patterned. Sometimes windlasses and pumps of communities, and even of towns, are built as if from one model, heedless of faulty design and poor construction. Two forms are illustrated below. (See figs. 3 and 4.) Occasionally one sees water drawn hand over hand by bucket and rope, but a much more common form, which is virtually the same with the direction of motion changed, is the rope and pulley. Were it not that this method is laborious and slow, men might draw water for stock and women for domestic use for years. As it is, these are soon replaced by windlasses having a mechanical advantage. In the construction of these there is an occasional display of thought, and one man will make one stick of timber answer where three, four, or five sticks would have been used by another. Others are elaborated until the cost exceeds that of a good pump. Many prefer the open well and windlass to pumps, on supposed sanitary grounds, assuming that the iron pipe is unhealthful.

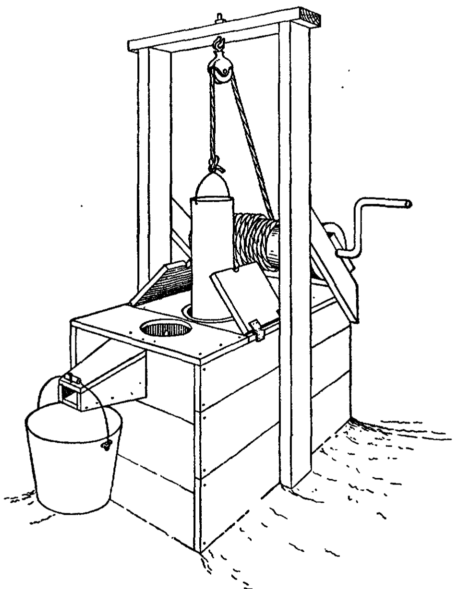


FIG. 3.—Open windlass and well curb.

In regions of high tablelands, where the wells are deep, the labor of drawing water, even by windlass, is such that hand power is replaced by horse power. Half barrels are used instead of well buckets and a boy and horse can soon draw the water necessary for the family and stock. The author has seen the old-fashioned horsepower and tumbling shaft in use pumping water for the house and for irrigation.

The windmill has long been the popular means of raising water for domestic use and for watering stock, and now, in addition, it comes to enjoy the recognition it deserves as one means of irrigating land where other means are wanting. It is the windmill which has enabled the farmer to introduce into his home some of the modern conveniences of the city. Thus one finds farmhouses supplied with hot and cold water, with bath, lawn sprinklers, and fire protection, and that, too, more cheaply than in a city home. The windmill feeds a steady stream of cold water through the milk house, and thence to the stock trough, a matter so small as to be often forgotten, yet so large as to be of great economic consequence. When the water around the milk pans is cooled, a greater percentage of cream rises by gravity to the top. Where cool water is readily available the loss of cream may run low, but in less favored States where the water is naturally warm the loss may reach one-fifth. This, in a State whose butter products may amount to several million dollars annually, is a large sum. The difference of a single degree in the temperature of water in a State as large as Nebraska means a difference of thousands of dollars in the total dairy products. Here the windmill effects a great saving, and on well-regulated farms, while pumping water for the stock trough by way of the milk house, it may nearly pay for itself annually.

The windmill has replaced the town pump, and in villages and towns is now seen a sightly and well-kept mill and tank, supplying water to the public by the energy of the wind. (See Pl. IV, *A*.)

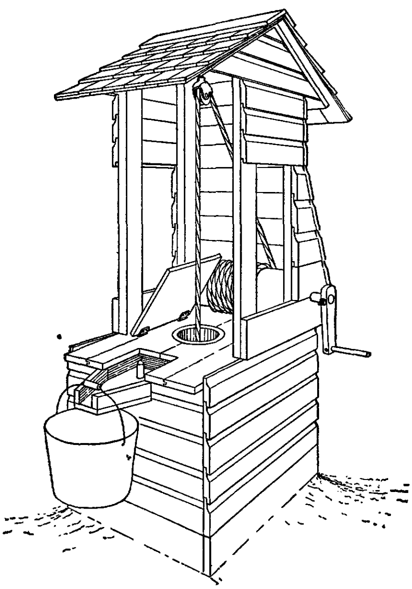
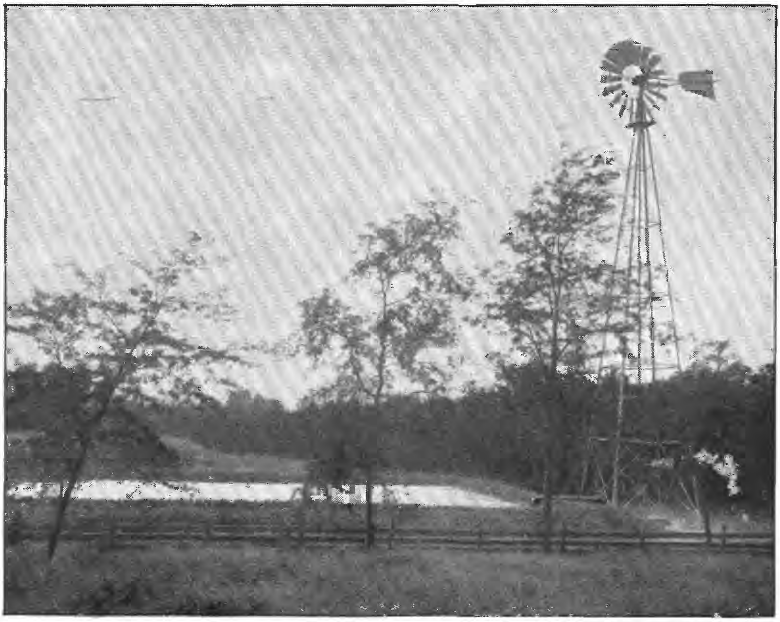


FIG. 4.—Partly inclosed windlass and well curb.

In supplying water for village use, pressure sufficient to throw water above the house tops may be had by placing the tank or reservoir upon high ground, or by erecting a suitable tower, which is the common method in the level prairie towns. Occasionally towers are built of exceptional height, to carry a second water tank for use in giving increased pressure in case of fire. (See Pl. XXII, *B*.)

The whirling mills are necessary accompaniments of Nebraska scenery. Their work is admirable, though impossible feats are often expected of them. As the matter of windmill irrigation is agitated the receptive mind of the progressive farmer seizes the idea. Not having experience and placing too confident reliance in the claim of the local agent, who is not a wholly disinterested party, he undertakes to raise water for irrigation from impossible depths. This must not be taken as a reflection upon the indispensable device, the windmill, which in many cases is as nearly perfect as skill can make it. The pump, not the windmill, is at fault; but the main trouble lies in the depth to water. Water can be pumped 32 feet. Below that point it must be forced, and from that point down mechanical loss increases at a rapid ratio. When one attempts to force a 60 or 70 foot column of water to the surface for irrigation his undertaking is barely within the limit of possible profit; below that point the enterprise is doubtful, if not dangerous. Farmers are urged to an immediate recogni-

A. WINDMILL AND TOWER. TOWN PUMP AT VERDON, NEBRASKA.



B. EXPERIMENTAL WINDMILL AND POND ON FARM OF THE UNIVERSITY OF NEBRASKA.

tion of the chances of discouragement, failure, and loss, resulting from any attempt to force water over 70 or 80 feet for irrigation, although this will undoubtedly be changed somewhat by improved pumping devices still to be invented.

At present every community in the State can furnish examples of misguided attempts to irrigate by means of water pumped by the wind from wells of unreasonable depth. This must not place in doubt or compromise in any degree the utility of windmill irrigation, which promises to become one of the important factors in the development of the agricultural resources of the State. Already farmers are irrigating with profit from 1-acre to 50-acre tracts by means of one or more windmills. Conversation and correspondence has brought out from many farmers in semiarid and arid Nebraska the plain avowal that during the exceptional season of drought, 1893–1895, the profits from the small patch irrigated by the windmill exceeded that from the rest of the farm.

HOMEMADE WINDMILLS.

Homemade mills are, of course, of low efficiency from a physical and mechanical standpoint; yet they are capable of doing all that is demanded and more. They cost little, wear well, and do all the work that is laid on them, so that it makes little practical difference whether some of them are mills of low or high efficiency. Of all the homemade mills which the writer has visited, he has yet to hear even a mild criticism offered against one by its owner.

What a contrast may be presented by two farms—one with cattle crowding around the well, waiting for some thoughtless farm hand to pump them their scant allowance of water, the other where the cattle are grazing and the tanks and troughs are full and running over to such an extent that the hogs have their wallows to which to resort in the heat of the day. Nowhere in his travels has the writer seen empty or dry troughs on farms where the homemade mill was found.

The windmill has an important effect on population. In many homes it is professedly the sole dependence, especially so with cattlemen living in regions where grazing is the very best and where the grasses are capable of sustaining great herds free of care or cost, summer and winter alike. The prerequisite is the irrigation of one acre on which to raise garden truck for the family, and this the windmill renders possible. Without this, emigration would result, and the State would lose not only important industries, but desirable citizens with their retinue of helpers. In many places where the dairy interests are important the windmill has rendered possible the production of butter. This is noticeably so in the western or butte region along the Wyoming line. Here in one instance, in a region of bare buttes and sand hills, is a ranch with no other improvements than a low sod house, a corral, and a windmill, with a rude milk house at its base. Here is produced and sold annually $900 worth of butter (without the burden of taxes or rent) incidental to cattle raising, which is the primary occupation.

In this same region sheep raising is an important industry. A sheep herder's camp consists essentially of a windmill and a sod house, a tent, or a covered wagon. Around each mill are several thousand sheep. On these high lands wells are deep and the hand pump inadequate. It is apparent from inquiry that the windmill decides the fate of this extensive industry, and the author has been particularly interested to note its relation to the percentage of increase in the flocks. The rate of increase reaches and occasionally passes 100 per cent where ample water is provided, and falls below 80 per cent where the mill is out of order and neglected. In their distress for water the sheep neglect and even desert their lambs. A single case may seem unimportant, but viewed as a whole by one who has seen many square miles of such surroundings and conditions, the subject is exalted, at least in the mind of the writer, to one of great importance.

So far the windmill has been considered in its relation to the necessities of life, but its relation to some of the luxuries is not unimportant. The sight of a sod house with flower beds and a lawn sprinkler is unexpected and almost incongruous. Very different from the prevailing idea of frontier life are hot and cold water faucets. With the picture of cowboy life as the half-informed press paints it one would never expect to find in a ranch house marble basins and porcelain tubs. Such things exist, and are due wholly to the agency of the wind utilized by the windmill. The barest and bleakest spot is often the site chosen for the district school, but a windmill constructed by the pupils will change this barren scene—not common to the far West alone—in five years, and in nine years the sunburned spot may be so completely reforested that the district school itself will be concealed, and the entire place and its young occupants be shaded in summer and shielded in winter.

The author would not be misunderstood. The homemade mill is not the equal of the shopmade mill. But the homemade mill is an exceedingly important adjunct to the farm, and its cheapness is such that many men who can not afford a shopmade mill are able to construct one or more homemade mills. If necessary, there may be a mill in each field or at every well on the farm. The advantage of the homemade mill is its cheapness, and unless it can be put up at a small cost it defeats its object. In many extensive frontier regions freight rates seem necessarily so high as to preclude the use of shopmade mills. Native lumber is cheap, so that the homemade mill is entirely practicable. In Arizona there is promise that important tracts of waste but rich land may come under cultivation through the agency of the Nebraska windmill. The windmills supply the only element of fertility lacking—moisture.

In many countries, old and advanced in the arts, the use of the windmill is unknown; water is raised by hand, grain is ground by horse power, by water power, and by hand, and machinery is driven in much the same way, while the wind, with all its potential energy, is neglected. Our Eastern, Middle, and Southern States would also profit by the more general use of wind power. Those States, too, must learn that water, intelligently conserved and applied to the garden, truck patch, and small fruit at the right time, means superior crops with corresponding profits. The writer believes that the people of all States should come to realize that it is a much finer boast to claim advantageous facilities for irrigation than that there is no need of it.

There is often as much need of irrigation in Ohio, Indiana, and Illinois as in Nebraska. Wherever crops are drought-stricken from time to time irrigation is desirable. It is in these very humid regions that the windmill and reservoir would be especially efficacious, for a very little water run into the furrows at a critical moment would rescue the crop. In the Eastern States, where the thin, clayey soil is not fitted to withstand drought as are the soils of the Great Plains, a reservoir of water could flush a given patch with marked success. The writer anticipates the time when the lessons of irrigation in the West will be taught in the East, not only as a means of averting failure and loss by drought, but as a means of greatly increasing the quality and quantity of the yield. The windmill is one means to this end, not to be relied on solely, but to be available in any emergency.

On the Great Plains, where humidity decreases as rapidly as evaporation increases and where the available surface water is limited and the wind must be depended on, the windmill becomes a necessity. In traveling through Kansas and Nebraska 20 or 30 mills may be easily counted at one time from the car windows. At first the author believed that the windmill stimulus here was the product of necessity during recent years of drought, but he finds that more mills, both homemade and shopmade, have been going up during the present humid years than before. They are used as luxuries rather than necessities, and the present inference is that these winged specters are harbingers of prosperity.

At certain times and in certain places, however, they are still necessary, especially toward the less humid portions of the State, particularly in the broad river valleys, where wells are shallow and the supply of water inexhaustible. The rivers of Kansas, Nebraska, and the Dakotas are numerous, and some of them are important, but they are steadily being diverted from their channels into the irrigation ditches of States to the west. The total available surface supply is barely sufficient for the irrigation of 6,000 square miles out of nearly 77,000, one-half of which would be greatly benefited by irrigation. Recourse must be had, then, to such other means as superior cultivation, or soil culture, for the catchment and retention of moisture; the impounding of water in ponds, lakes, draws, and canyons; tunneling into the sand hills and buttes; tapping the underflow of rivers; and raising water by means of current wheels, and by pumps driven by some motive power, preferably the wind. This outlook has given the windmill increasing notice of late.

COST.

The homemade windmill is supposedly built during unemployed hours by the owner or by his sons; so the cost of labor is not reckoned in these estimates. Old wire, bolts, nails, screws, and other odds and ends of hardware, old lumber, poles, and braces such as are common to every farm, enter largely into its construction. Even neglected mowers, reapers, and planters, old buggies, and wagons contribute material. Here are to be found good journals with oil cups, cranks, sprocket wheels, and chains, gear and bevel wheels of various combinations. The farmer who is inventive enough to build a mill is competent to see quickly the adaptability of certain parts to his ideas. It is this use of old and neglected material which is particularly recommended in this connection, for in making a mill of low efficiency, such as most homemade mills are, cheapness is the main object. Many mills have cost nothing whatever. Others cost $1, $2, and $3, and occasionally as much as $50, $75, and even $150. The average mill, such a mill as is needed for ordinary purposes, can be built for $2.50, which is an average from a large number, and its cost should not, and seldom does, reach $10. The writer considers $3 a liberal allowance for everything needed on the ordinary farm for the construction of a strong, satisfactory, and lasting mill large enough to pump for the house or stock. Such a mill, if rigidly made—inattention to this matter being the cause of more accidents among homemade mills than any other—ought to stand five or six years of uninterrupted service.

CLASSIFICATION.

However modified to suit the fancy and caprice of various builders, the mills may be divided into four groups: Go-devil or jumbo mills of the overshot type; merry-go-round mills; turbine or opened-faced mills, including battle-ax, Holland, and mock-turbine mills; and reconstructed mills. These may be tabulated as follows, in inverse order of efficiency:

Classification of the principal types of homemade windmills in Nebraska.

(1) Jumbo mills (see page 35)	Baby jumbos.	
	Medium jumbos	With 4 fans.
		With 6 fans.
		With 8 fans.
	Giant jumbos.	
	Screw jumbos.	
(2) Merry-go-round mills (see page 44)	Unmounted.	
	Mounted.	

- (3) Battle-ax mills (see page 47)
  - With 2 fans.
  - With 4 fans.
  - With 6 fans.
  - With 8 fans.
  - Giant mills.
- (4) Holland mills (see page 54)
  - With 4 fans.
  - With 6 fans.
  - With 8 fans.
- (5) Mock turbines (see page 56)
  - Giant turbines.
  - Set turbines.
  - Revolving turbines.
    - Without rudders.
    - With rudders.
- (6) Reconstructed turbines (see page 64).
- (7) Shopmade turbines (see page 65).

DISTRIBUTION.

Nebraska seems to be the heart and center of the windmill movement. The famous Platte Valley, with its broad expanse and shallow wells, is a veritable windmill arena. From Omaha west through the State, a distance of 500 miles, and even beyond to Denver, there is a constant succession of these creations of a sturdy population.

During the summer of 1897 the writer engaged the services of three students, who were provided with teams, saddle horses, camp wagons, cameras, and camp accouterments in general, and drove from Lincoln to Denver, following roads south of the Platte going and north of the Platte returning. They found these unique and interesting mills everywhere. Going over the same ground in person the following year eight to ten mills were commonly found clustered about a town, each widely separated town having a dominant or prevailing type. Sometimes the mills were found on every farm and were too numerous to visit and report on. They are also found in the Republican Valley and the valleys of the Loup rivers and their tributaries. The State rises gradually from 900 feet in southeastern Nebraska to 5,300 feet in the butte region of the western boundary line, where the wind is often unreliable over considerable tracts, so that difficulty is experienced in running the most approved steel mills. The distribution of homemade mills is confined chiefly to river valleys and to certain sand-hill regions, where wells are shallow.

JUMBO WINDMILLS.

This is the lowest form of windmill. The jumbo, also known as the "paddle wheel" and the "go-devil," is simply an overshot wheel which bears the same relation to the air that the overshot wheel of hydraulics does to the water. It is a stationary mill, consisting of four or more paddles fastened to a horizontal axis set squarely across the direction of the prevailing wind, with the lower half boxed in. The smaller mills of this type are appropriately termed "baby jumbos." The larger jumbos are planted on the ground and baby jumbos on towers or buildings.

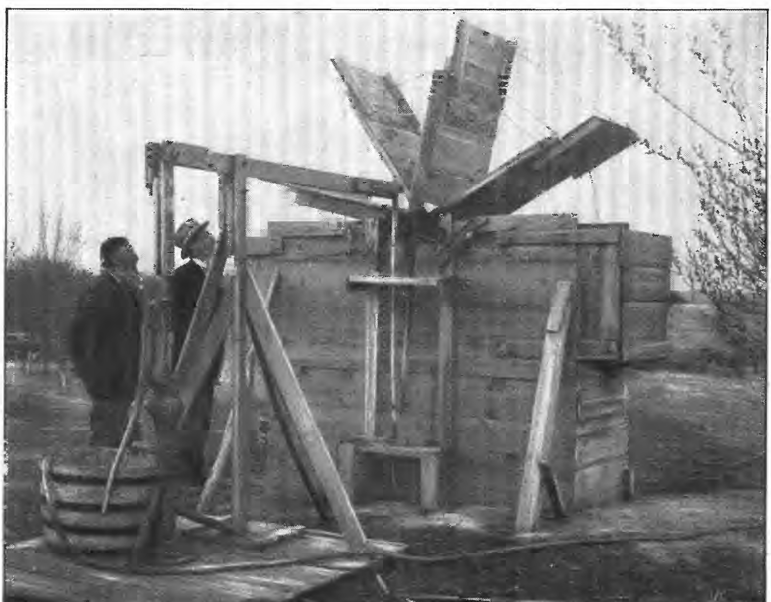
Being mills whose method of construction is obvious, they are favorites, particularly in the portion of the State lying east of Grand Island. West of that point the jumbo is usually replaced by the battle-ax mill, which the author considers a superior type. The jumbos are mills of low efficiency, but that matters not in the present discussion. They are efficient enough for all practical operations; that is the real question here, and theoretic considerations may be fittingly postponed. Those who have decided preferences for the jumbo need not fear disappointment. If the mills are well built they give satisfaction. If poorly made their efficiency may run as low as 15 or 20 per cent; but if built on the most approved plan they may register 40 per cent, as Professor Hood[1] has shown. In practice the poorest can pump a great deal of water, probably more than the ordinary family will use. In this connection it may be well, for the sake of comparison, to state that the efficiency of a good shopmade mill is at least twice as much as that of the jumbo, but the cost is ten to twenty times as much. For the capital invested the jumbo is probably more efficient than the best steel mill. The jumbo gives from one-eighth to one or two horsepowers, more or less, according to the wind, the size of mill, and other modifying conditions.

Professor Hood and his students in testing a 14-foot eight-fan jumbo found that in a good breeze it gave from one-tenth to one-fifth of a horsepower, and in a 38-mile wind it gave 1 horsepower. The power will vary according to the construction and position of the mill, and according to the wind and other factors. In Nebraska and Kansas the shafts of jumbos stand east and west, so that the fans may be struck by the prevailing wind, which blows from south to north, or at times in the opposite direction. The jumbo runs equally well whether the wind is from the north or south, but is motionless in an east or west wind. If from the intermediate points of the compass, the fans are, of course, struck obliquely, but not altogether ineffectually. This virtually covers all winds, except rare and exceptional ones; hence daily working is assured, regardless of shifting winds. Nevertheless, some take the precaution to build jumbos with spiral or screw fans, in which event they do good service with winds from any quarter.

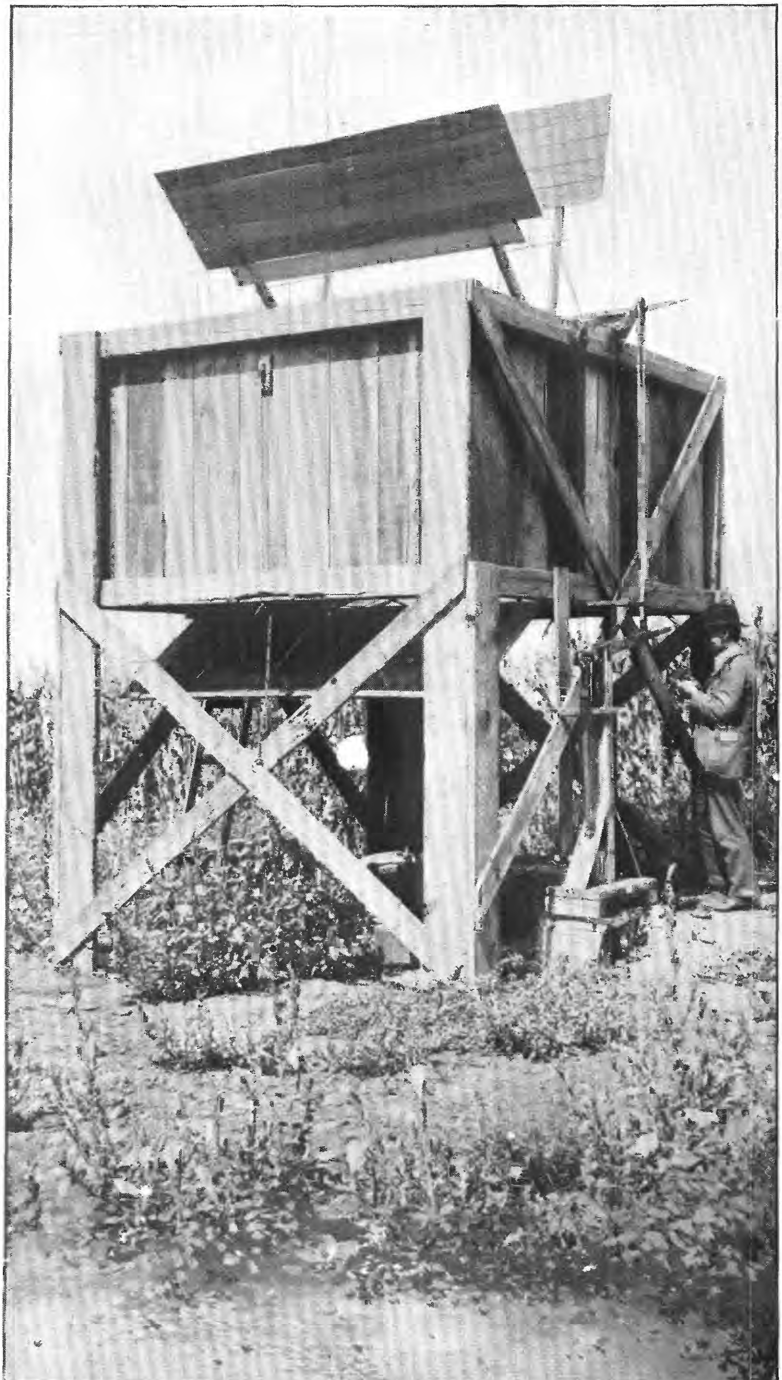
Jumbos are not wholly ornamental, but that is unimportant. The jumbo has served useful purposes on hundreds of frontier homes, and has many undeveloped possibilities awaiting the genius of succeeding generations of farmers. The average cost of such mills is about $4, and they are sometimes used to singular advantage. Such mills, veritable toys, which cost nothing whatever, and were built in play by boys on the farm, have been put to work in earnest pumping water for the stock.

[1] New tests of certain pumps and water lifts used in irrigation, by O. P. Hood: Water-Supply and Irrigation Paper No. 14, U. S. Geol. Survey, 1898.

A. BABY JUMBO WINDMILL ON GOODRICH FARM, NEAR BETHANY, NEBRASKA.



B. BABY JUMBO BUILT BY J. L. BROWN, KEARNEY, NEBRASKA.



MOUNTED JUMBO WINDMILL ON GOODRICH FARM, NEAR BETHANY, NEBRASKA.

BABY JUMBO WINDWILLS.

The baby jumbo on the Goodrich farm, near Bethany (see Pl. V, *A*), is one of those referred to. It stands about 12 feet high, on the abandoned support of an old tank, and pumps water for the stock. Old parts from a discarded self-binder were ingeniously adapted to the existing needs. This small mill, with arms 2½ feet long, with four board fans each 4 feet long, and geared by sprocket wheel and chain in the ratio of 2 to 1, cost nothing, and pumps from an ordinary well water enough for the stock. This is an attractive and showy little mill, especially to those who are studying such matters, and is a credit to the boys who built it; it is introduced here, however, to show what can be done in this line rather than to encourage mills of this size or of this particular make. It is only a toy, but boys who can build one of this size are capable of building a larger one and of constructing it on approved lines if models are before them.

It is a safe assumption that, having at hand illustrations and descriptions of various windmills suited to home construction, many idle moments would be profitably employed in this work, both by men and boys on the farm and in the villages. Accordingly numerous examples, seemingly repetitions, will be reproduced in order that each prospective builder, without compromising his own individuality and personality, may have the right of accepting and rejecting plans, so as to embody in his own designs the desirable features of others.

The baby jumbo on the Goodrich farm was considered the smallest of its kind, but before a description of it could be penned a mill smaller by 1 foot, which, however, stands on a higher base, was found in the neighboring town of Havelock. This baby jumbo, built by Mr. W. W. Iler, has four fans 3 feet long, with arms 2½ feet long. It is attached by a 16-inch crank and rod directly to the handle of the pump. In a good wind (probably a 16-mile wind) this little mill, perched on a tower 16 feet high, discharged from a 60-foot well 400 gallons of water in forty minutes, or at the rate of 10 gallons per minute, as measured and reported by the owner. It supplies water for a boarding house and for the stock and cost only $3.70.

The remarkable little jumbo designed and built by Mr. J. L. Brown, proprietor of the Midway Nursery, 2 or 3 miles east of Kearney, Nebraska, is shown in Pl. V, *B*. It cost only $1.50, but pumped sufficient water to irrigate and save the garden truck, the strawberry patch, and the small fruit during the most trying season of drought recorded in the State. This is a surprising record for so small a mill, but it was carefully planned and well built. Differing from the ordinary proportions this mill is higher than broad. Its box is 3 feet wide, 9 feet long, and 6 feet high, with fans mounted on a gas-pipe axis. The axis and its crank, cost $1.50, while the rest was made out of the sides and ends of old coffee boxes, in accordance with the rule: Build the jumbo cheaply or not at all. It is connected with the pump by a lever arranged in the ratio of 5 or 6 to 1. While means were not at hand to test this mill, in a good breeze it pumped water and was probably not overloaded by the weight of 200 pounds.

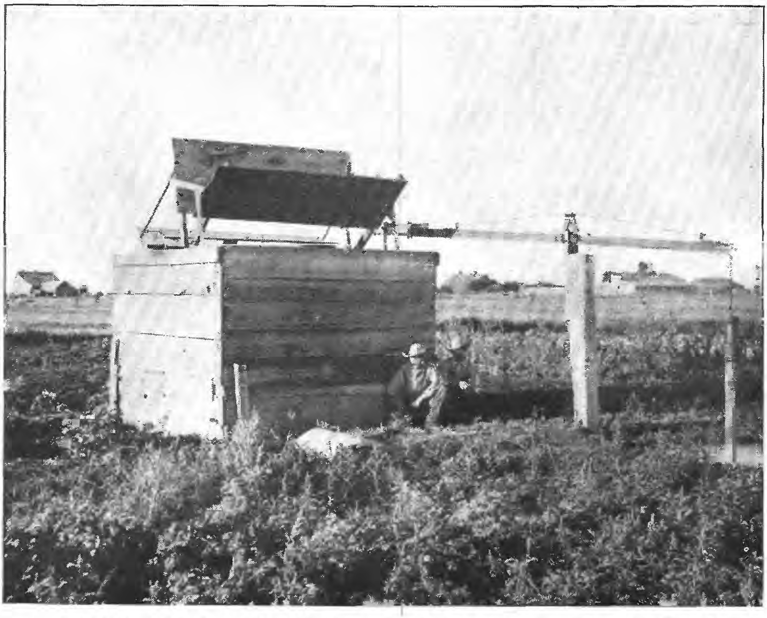
The practical benefits resulting from the mill are indisputable, and are well expressed by Mr. Brown, its builder, who says that the profits from the mill during the three years of drought and crop failure exceeded that from the rest of the farm. The claim is not that the profits are great, for such can not be expected from a small mill and about an acre of garden; but when this is all that is left it becomes relatively large. Let no one be deceived by this and grow too sanguine and overexpectant. The mill may not net its owner over $100, but if the rest of the crop is a total failure, this is worth more than one hundred cents per dollar. A case is known of a cucumber patch saved by a small stream from a windmill. This patch netted its owner $100 for pickles, cut and marketed during the month of September. The mill may easily exceed the profits of the rest of the farm during exceptionally poor seasons. The windmill is not the redemption of agriculture, but is an important aid at all times, and sometimes the only source of revenue.

This mill teaches a timely and suggestive lesson in economy in such work. Here by the exercise of a little foresight in securing an occasional packing box instead of lumber, an excellent mill was produced at a nominal cost, and could have been built without outlay by adapting an iron axle from some farm implement. This goes to show that baby jumbos, large enough to pump for the house, barnyard, and stock, are within reach of the poorest. The young farmer can often profit by picking up, almost at his own price, discarded wagon axles and old rods of iron, which are common at the village blacksmith's or at the city junk shop. A buggy or wagon axle, with the hubs or thimbles used for journals, will prove especially convenient to prospective builders.

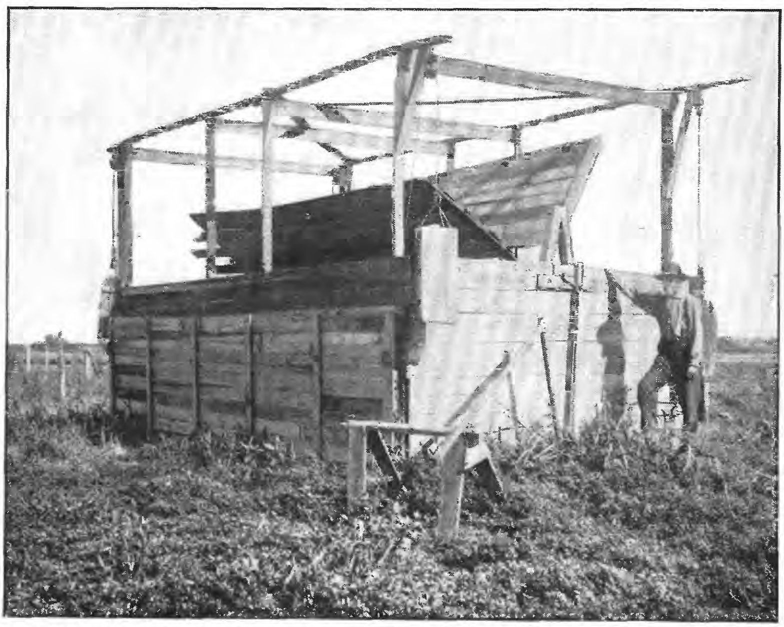
JUMBO WINDMILLS OF INTERMEDIATE SIZE.

Baby jumbos are the least efficient of the homemade mills. Those of intermediate size, such as are commonly built by farmers and small market gardeners, will now be considered. These mills average about 8 by 12 feet; some cost nothing, others $6 to $8.

A good example is furnished by Dr. Boardman's jumbo mill on the edge of Overton. This mill was built to replace an old one put up three years before, and it was not necessary in this case to study strict economy either in the use of help or in the purchase of material. Good, new lumber was purchased, and a carpenter and smith engaged to do the work. When finished, this mill, with a box 6 by 12 feet, supporting four fans on an iron axis, each fan 5 by 6 feet, with a radius of 6 feet, was capable of supplying water for 100 head of stock; its cost was $8. The same mill could have been built by a man of



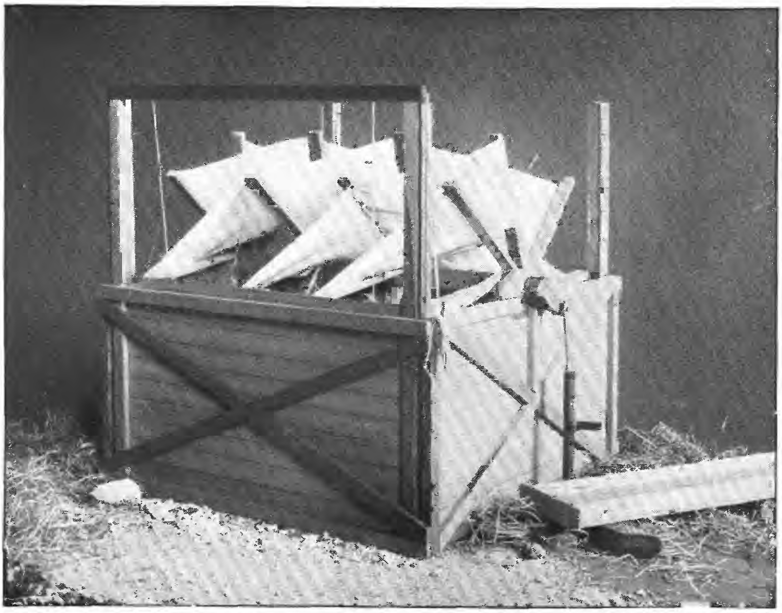
A. MEDIUM-SIZED JUMBO WINDMILL IN GARDEN OF M. J. OLSON, COZAD, NEBRASKA.



B LARGE JUMBO WINDMILL AT CUSHMAN PARK GARDENS, LANCASTER COUNTY, NEBRASKA.

Size of mill 20 by 14 by 14 feet.

A. JUMBO WINDMILL (NO. 1) IN TRAVIS GARDENS, NEAR LINCOLN, NEBRASKA, SHOWING PORTION OF RESERVOIR.



B. SCREW JUMBO WINDMILL.

Photographed from model built by the author.

limited means for $2 or $3. Had it been a mill of six fans instead of four, it would have been a good model for others. It is a good mill, serves its purpose, satisfies its owner, and according to his estimate will pump water for 100 head of stock and continue in good order for five years or so to come. At that rate he is paying for his water service scarcely more than $1.50 a year.

The trouble with all four-fan mills is that but one or at most two fans are in the wind at any one time, while the six or eight fan mills may expose three or four times the surface to the impact of the wind. Accordingly, if other things are the same, the mill with more fans is apt to respond more readily to light winds.

Comparable with this, in point of size, is the mill of Mr. W. W. Goodrich, at Bethany, shown in Pl. VI, which he believes was unnecessarily well made. Extra expense was incurred by purchasing a hardened Damascus steel axis, with good bearings and oil cups, which cost $5, and made the mill when complete cost $8. It has six fans, each 9 feet long, with a radius of 5½ feet, mounted on a box about 9 by 11 feet and 6 feet high. As the fans revolve there is a resisting cushion of air in the box, which must in a measure retard the fans. To overcome this the designer has raised the mill above ground, and has made the bottom movable in two parts or doors, which can be lowered to allow the escape of compressed air when the mill is revolving rapidly. When the wind is from the south the north door is opened, and vice versa. Mr. Goodrich says that a gas-pipe axle would serve his purpose as well as the more expensive steel one, and that with it he could build the same mill for $4. The baby jumbo on this farm, already described, pumps for the stock. The medium-sized mill irrigates a portion of a 6-acre tract set with egg plant for the Lincoln market. Mr. Goodrich has gone to considerable expense in attempts to raise water by horse power for the improvement of his farm, and especially for his extensive market gardens, and the present experiment is an attempt to use the wind as a much more economical means to that end.

At Cozad there is a jumbo of medium size, which is sensitive to light winds and is used in irrigating the market garden and small fruit of Mr. M. J. Olson (see Pl. VII, *A*). The box, which was about 9 by 13 by 6 feet high, carried six fans, having a radius of 6 feet and a length of 8 feet, mounted on a 1-inch iron axis with metal bearings and oil cups from old machinery. A 12-inch crank with friction roller was attached to the longer arm of a lever, 9 feet long (as shown in fig. 5), the shorter arm, 6 feet long, being attached to the pump rod. It pumps water with a 16-inch stroke from an 18-foot well with 3-inch casing without cylinder. It has pumped 1,200 gallons in an hour, as measured by its owner. The mill and all incidentals cost $20.

The jumbo may be constructed out of almost any waste or idle property. The axis may be of wood, gas pipe, or solid shafting, and the framework may be of poles cut from the place, the box of old lumber, the sails of duck, burlap, sheeting, fencing, weatherboarding, store boxes, barrel staves, or old tin and sheet iron. All these adaptations are seen.

Two jumbo mills on the market garden of the Travis Bros., of Lincoln, afforded the writer an opportunity to see the workings of these

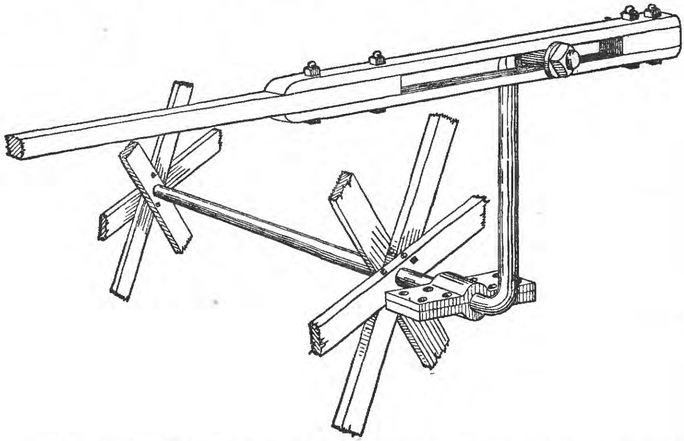


FIG. 5.—Jumbo windmill of M. J. Olson, Cozad, Nebraska, showing 9-foot iron axis, 2 by 4 inch arms, journals, 2-foot crank, and walking beam.

mills and their practical results. Though hastily and poorly built, they demonstrated their usefulness, and are easily worth their cost. One cost $8, the other $11. The two mills irrigate, as far as it is

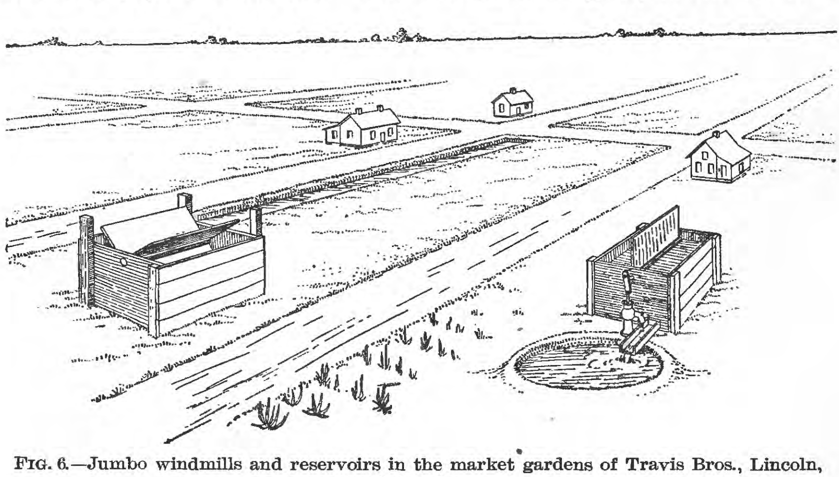
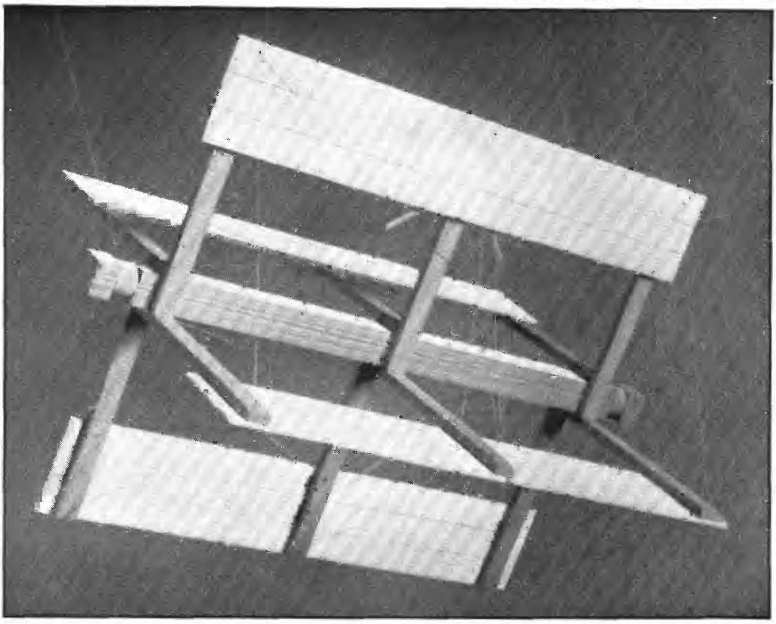


FIG. 6.—Jumbo windmills and reservoirs in the market gardens of Travis Bros., Lincoln, Nebraska.

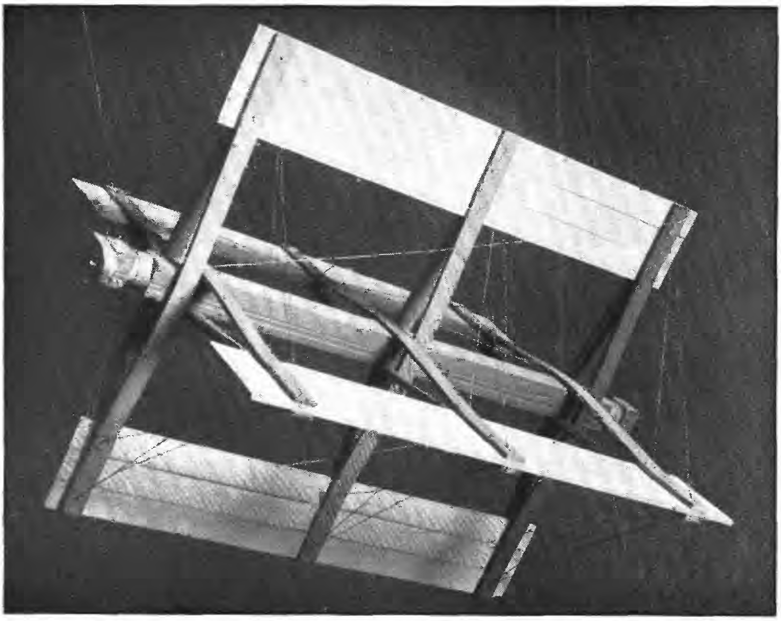
desirable to irrigate in this region, about 8 acres of garden. According to the gardeners the yield was ahead of the demand of the market.

Mill No. 1 (shown on the left in fig. 6), with a box 9 feet wide, 13 feet long, and 8 feet high, carries four fans of burlap, each 9 by 4 feet, stretched on arms 6½ feet from the center, and pumps water into a long,



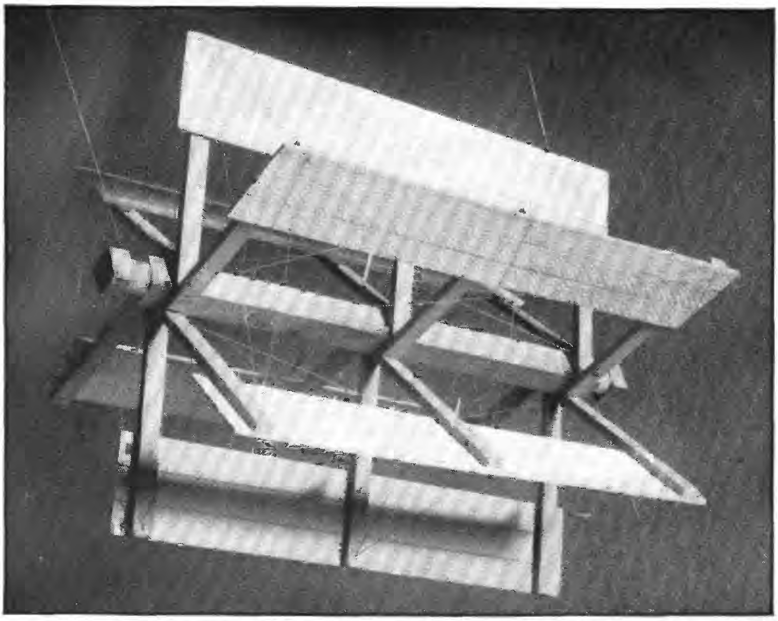
A. METHOD OF ATTACHING ARMS OF JUMBO WINDMILLS TO AXIS.

Photographed from model built by the author.



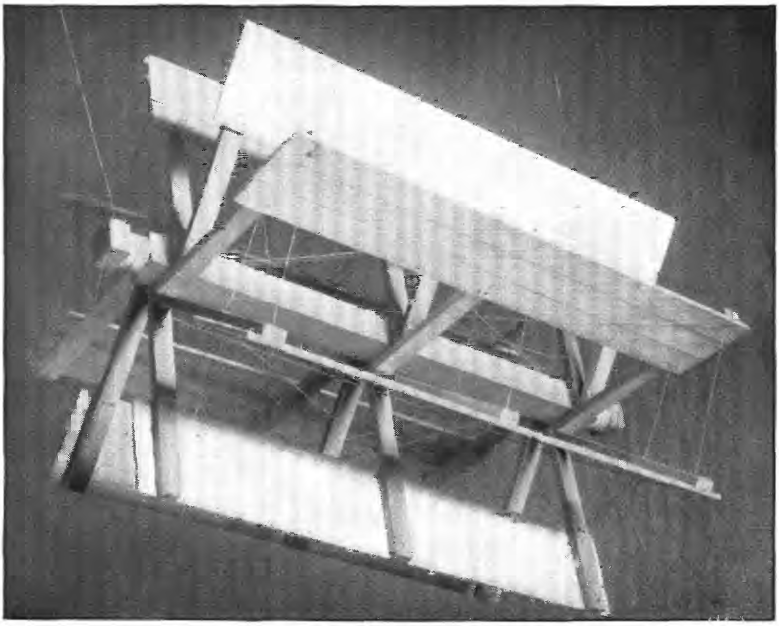
B. ANOTHER METHOD OF ATTACHING ARMS OF JUMBO WINDMILL TO AXIS.

Photographed from model built by the author.



A. METHOD OF CONSTRUCTION OF SIX-FAN JUMBO WINDMILL CROSS-BRACED BY TWISTED WIRE.

Photographed from model built by the author.



B. METHOD OF CONSTRUCTION OF EIGHT-FAN JUMBO WINDMILL CROSS-BRACED BY TWISTED WIRE.

Size: 12 to 14 feet long, 10 to 12 feet in diameter. Photographed from model built by the author.

narrow reservoir, 150 by 4 by 2 feet deep, skirting the higher edge of a 5-acre patch. The grade was such that the rows of vegetables were quickly flushed with water when necessary. At the four corners of the box are four uprights or standards, carrying on top a pulley with rope attached to a sliding cut-off or wind guard, to be raised and lowered in adjusting the mill to winds of varying velocity. These guards, constructed on a wrong plan, greatly increased the expense for lumber. Mill No. 2 (shown on the right in fig. 6), of about the same size, cost $11, and irrigates an adjoining 3-acre tract successfully, but is capable of doing more work.

In the case of these two mills a defense is found for the adoption of the cheap homemade mill. The position of these two gardens in the outskirts of Lincoln made two mills necessary. The enterprise was in the nature of an experiment; accordingly from a business standpoint it was assuming much less risk to erect two cheap mills than to put up two steel mills, each of which would probably have cost twice as much as the two jumbos together. If successful when well established and past the experimental stage, the enterprise may deserve a better type of mill, whether homemade or shopmade. (See VIII, *A*.)

The argument for the jumbo on the ground of experiment is further exemplified in the case of the John Tannehill nursery and garden at Columbus. Finding that his orchard thrived and that it was well set with fruit, which, however, fell off before reaching maturity, he inferred that this was due to insufficient moisture, and proceeded to experiment by building a large jumbo, which has become a sort of landmark. It is a large mill, capable of driving two 6-inch cylinders and of irrigating about 10 acres of orchard. It is built on approved plans, especially with respect to the fans. The six 16-foot fans have long arms (9 feet), not boarded up solidly, but with a space below for the "dead air"—that is, the air which has struck the fan and used up its energy. The object is to get rid of this as quickly as possible, thus making room for fresh air with unexpended energy. There are six fans, well bolted, wired, and braced, mounted high on a box, substantially made and securely anchored. The mill pumps water into a reservoir, from which it is drawn off to irrigate the orchard.

This experiment, which cost $100, was a success. By artificially supplying a little more moisture the orchard holds and ripens the fruit which formerly dropped off prematurely.

SCREW JUMBO WINDMILLS.

The screw jumbo (see Pl. VIII, *B*) is of rare occurrence, the author having found but two in the State—one at Trenton, Hitchcock County, and the other at Ainsworth, Brown County. While it is altogether probable that they are not so efficient as their enthusiastic builders believe, they are successful and are not lacking in interest to the student of windmills.

Perhaps one claim to superiority is well grounded. The screw jumbo—also known in the vernacular of the Great Plains as a "regular stem-winder"—receives wind from the east and west almost as well as from the north and south. Their builders say that they respond to wind from every quarter. The sails, which are of duck, although thin wood might be used, are not stretched on a line parallel with the axle, but pass diagonally from one arm to that next behind it, and so on, producing a twisted or auger-shaped effect in the mill. The claim that the mills run with great steadiness is doubtless true, for it is readily seen by a glance at the cut that each fan receives the advantageous wind progressively throughout its entire length, and that the fans are not alternating between advantageous and disadvantageous positions in the wind. A glance will be sufficient to show that some position of the fans will be struck, no matter in what direction the wind may blow. The boxes for screw jumbos are boarded up on the sides, but left entirely open at the ends.

CONSTRUCTION OF JUMBO WINDMILLS.

The jumbo, as before stated, is a mill of low efficiency at the best, a fault made more pronounced by careless construction, lack of rigidity, and poor anchorage. The mill, as well as the farm sheds and outbuildings, should be strong enough to weather the blast and storm. Lack of rigidity is another fatal oversight. The round wire nail when first driven home seems strong, but constant vibration may draw it slightly, or the hole may be enlarged so as to allow too much play, foreshadowing ultimate destruction. This may be avoided by the use of an occasional bolt. Bolts are cheap and may be obtained at any hardware store. The fans should be bound together by fencing wire, rendered taut by doubling and twisting. Good anchorage is readily obtained by burying posts with crosspieces on the bottom and stamping the earth firmly around them. These measures of precaution should always be observed, especially in the case of large mills. The probability of failure and disappointment should be forestalled by rejecting the popular four-fan mill and accepting the six or eight fan design instead. One of the worst errors of construction

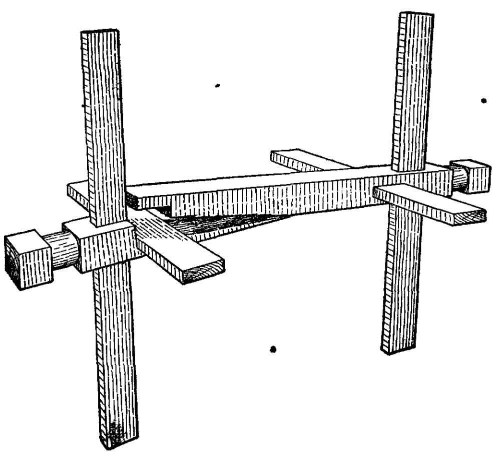
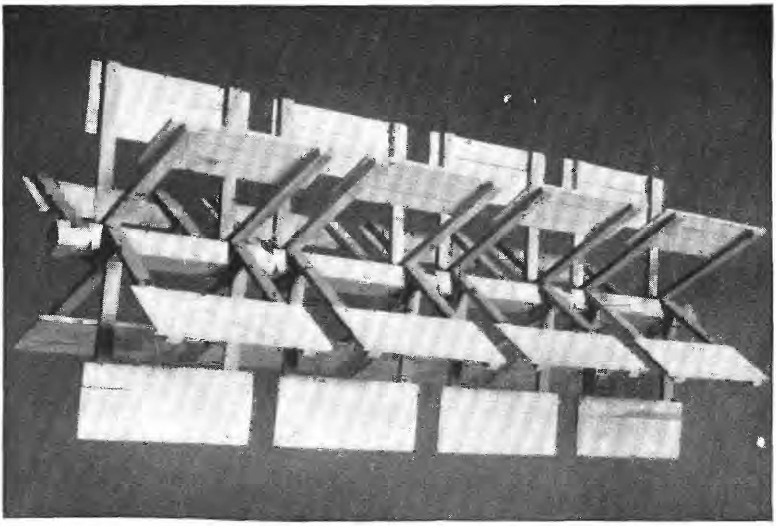
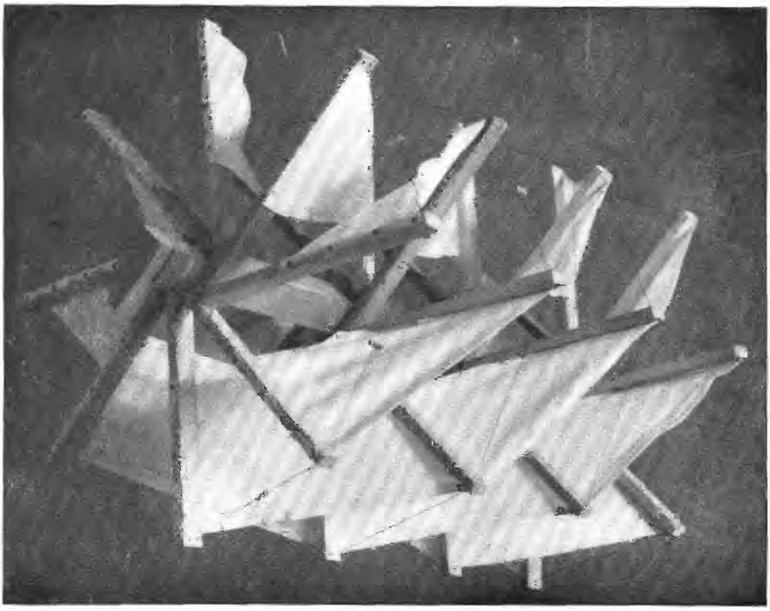


FIG. 7.—Break resulting from improper method of fastening jumbo windmill arms on the axis.



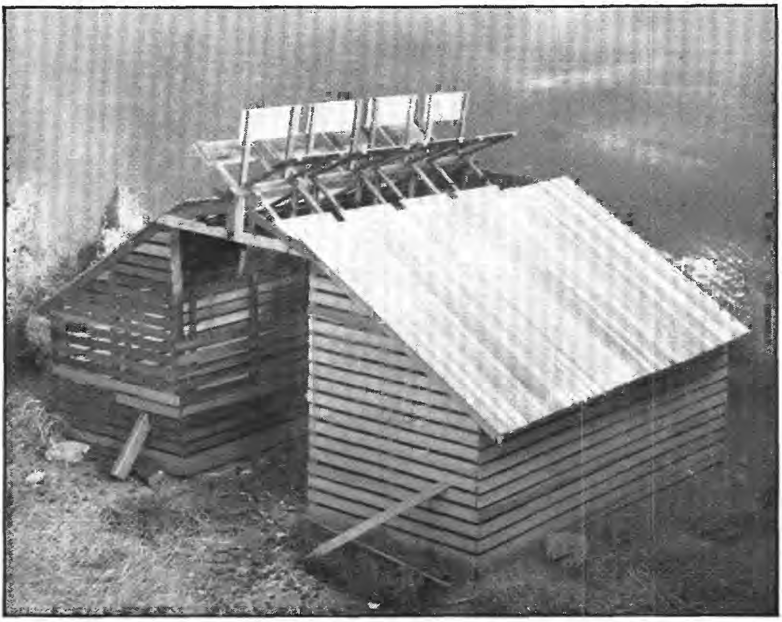
A. METHOD OF CONSTRUCTION OF GANGS OF JUMBO WINDMILLS.

Photographed from model built by the author.



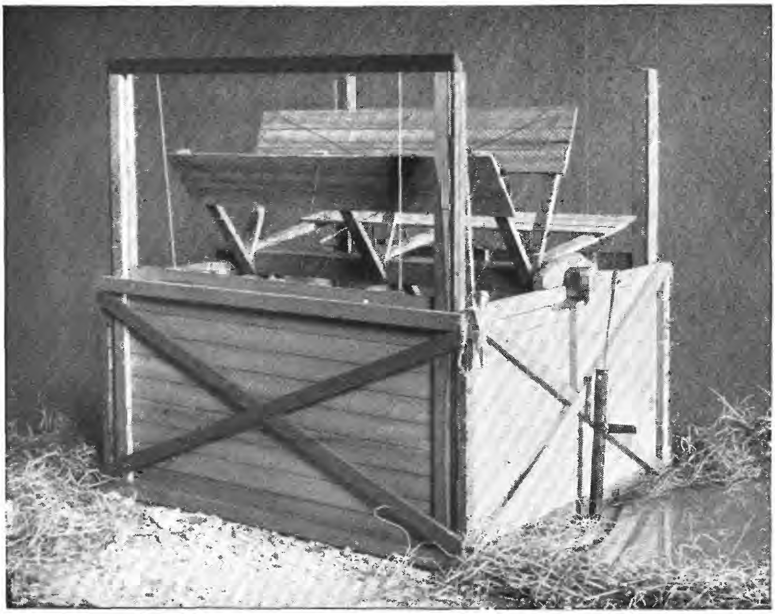
B. METHOD OF CONSTRUCTION OF SCREW JUMBO WINDMILLS, WITH CANVAS SAILS AND ARMS BRACED WITH TWISTED WIRE.

Photographed from model built by the author



A. GANG OF JUMBO WINDMILLS ERECTED ABOVE CORNCRIBS OR SHEDS.

Photographed from model built by the author



B. JUMBO WINDMILL WITH WIND GUARD OR CUT-OFF.

Photographed from model built by the author.

is to weaken a part which is subject to stress and strain. An example of this is found in the way holes are mortised through axes for the arms, as shown in fig. 7. When an 8 by 8 inch axis, having a span of 18 feet, is cut through at each end to admit 2 by 4 inch arms, it is disqualified for long use.

Methods of attaching the arms are shown in fig. 7 and Pls. IX, X, XI, which are self-explanatory. When loaded down with heavy arms and fans it is a severe test for any stick of timber or gas pipe or shafting to span 15 or 18 feet. Accordingly the author proposes what he may call twin, triplet, and quadruplet or multiple jumbos. By this means a jumbo of any length and of almost any strength is possible, for the axis has support every 8 or 10 feet. (See Pls. XI, *A*, and XII, *A*.) This, the writer believes, is the means of making powerful jumbos, especially if a chain and bucket are used instead of a pump. In regions of shallow wells these gangs of jumbos might be used for irrigation on a larger scale than is possible with the ordinary jumbo.

It seems so essential that the jumbo should be cheap that the author would minimize expense by doing away with the box and by adapting sheds and buildings to this use. Every well-regulated farm has its complement of sheds. It will cost no more to arrange them with reference to carrying the fans of a jumbo or multiple jumbo. Corncribs which are built in pairs facing each other with a driveway between seem suited to this purpose, as shown in Pl. XII, *A*. In the mill illustrated the fans are slowed down by a brake and are then tied, as is the common practice. In this case the cut-offs or wind guards are omitted, it being assumed that the mill is well enough built to resist storms and wind. Rafters could be extended to support the axis. The labor and expense in that case would be confined to the construction of the driving parts or fans. Many mills could be built without cost. By the multiple plan mills might be built of sufficient strength for shelling and grinding as well as for pumping.

Many men increase the cost of their mills by wind-breaks, guards, or cut-offs in use. Some allow their mills to run in whatever wind blows, others adjust breaks in such a way as to regulate them, others build sliding guards, which run up and cut off the wind wholly or in part, as need be. The author would suggest that it is as easy and less expensive to let the sides of the box itself be adjustable, as shown in Pl. XII, *B*, instead of building cut-offs, one on the north side and the other on the south side of the box. If balanced, the sides could be raised and lowered with little exertion. Or, simpler still, the north and south sides of the box might be hinged so as to be let down; then the wind, striking equally against the top and bottom fans, would stop them. If objected to on the ground that the fans thus unprotected are exposed to too much wind, it may be rejoined that there is no reason why they should not be made strong enough to resist it as easily as the cut-off. One could check the mill or stop it outright, according as he lowered the door a little or dropped it flat.

The arms should be of good length, say 5 to 7 feet, thus securing leverage with light fans, which seems better than to use a fan of less radius and greater length and weight. The fans should cover about one-third of the length of the arms. If the axis is of wood it must be rounded at the bearings, care being taken that as little as possible be cut away, otherwise the axis will be weakened. The crank is easily made, and if the size of the mill warrants it there should be one at each end. Some prefer wood, others metal; it is a matter of indifference which is used, so that it is rigid.

PUMPS.

Mechanically the best pump is faulty. Other things being equal, the endless chain of buckets is doubtless better. Here the pressure is not intermittent, but is constant at all times. These buckets are adapted to sprocket wheel and chain, and where the lift is not too great these are to be recommended. The pump, however, is the familiar water lifter and the one generally adhered to. When the mill is large enough to warrant it, two pumps of sizes suited to the mill should be used, but it should be remembered that it is probably as great waste of energy to overload as to underload the mill.

MERRY-GO-ROUND WINDMILLS.

Windmills of all makes have natural limitations, and the merry-go-round is a realization of an attempt to devise mills of unlimited size and strength. The larger ones are of rare occurrence, but are seen in several parts of the State. The smaller ones are mounted on towers, the larger ones on the ground, as shown in Pl. XIII. The former are the more common and look like elevated water tanks, for which they are often mistaken.

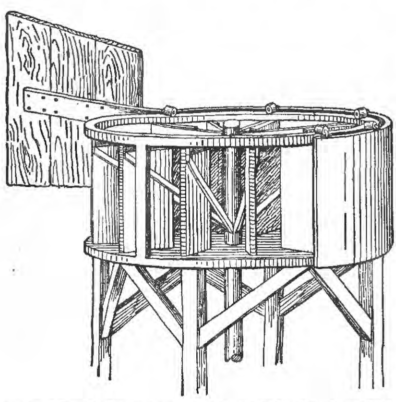
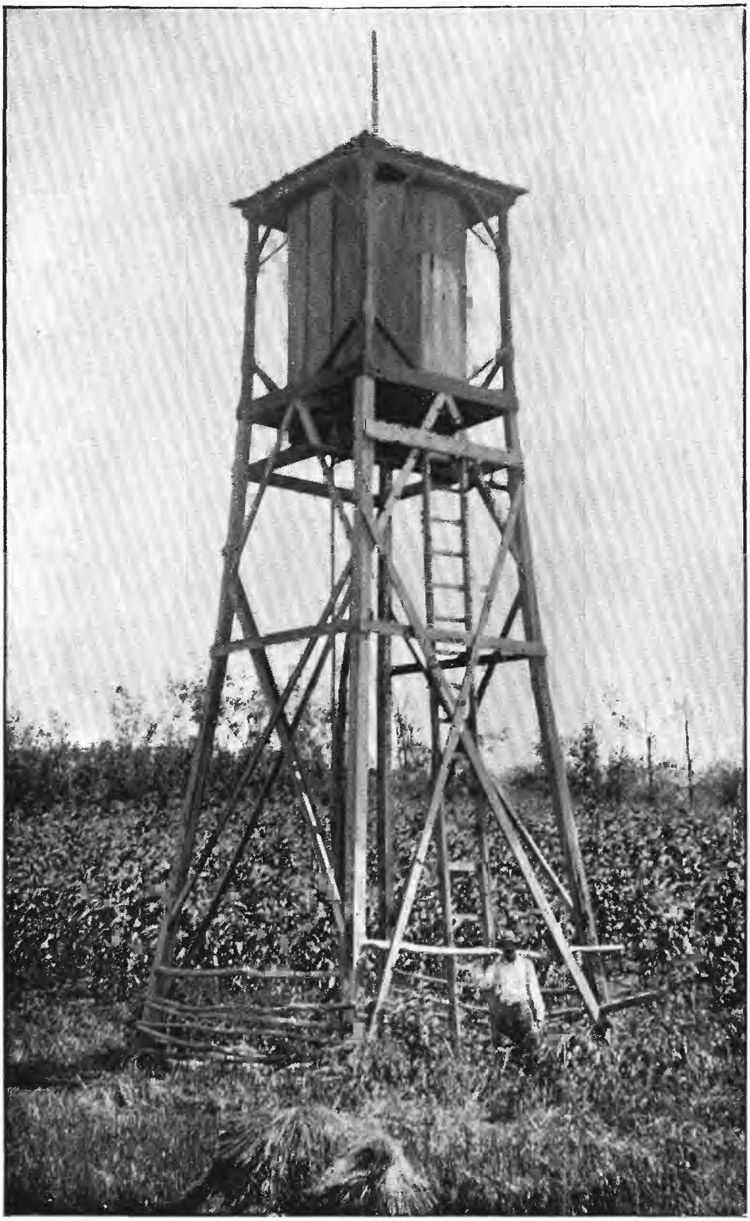


FIG. 8.—Hooded merry-go-round built by William Winn, Berwin, Nebraska, showing semicircular hood on rollers guided by large rudder.

The fans revolve about a vertical axis, and surrounding all is a series of movable shutters, which come together and form a sort of closed cylinder when the mill is out of gear. When in action they are partly opened, admitting air to the fan on one side and excluding it from the other. But these are quite as limited in size as other mills, and so defeat one important purpose of the merry-go-round. This kind, which is



SMALL MOUNTED MERRY-GO-ROUND WINDMILL NEAR LINCOLN, NERRASKA.

taken as the lowest of its order, is generally small, perhaps 6 to 12 feet in diameter and 6 to 12 feet high, exclusive of the tower. It is of doubtful efficiency, though in active operation, and is intricate enough to require skilled labor and expensive material, which in part unfits it for general adoption. One seen at Grand Island, on the farm of Mr. Henry Joehnck, when built fourteen years ago, rendered important service in irrigating garden truck for the Grand Island market. At Greeley Center a similar mill, 20 feet in diameter, is used for grinding, there being a lack of water power.

The merry-go-round mill of Mr. William A. Winn, of Custer County, consists simply of a series of fans radiating from the central axis. Around the same axis revolves a great semicylindrical hood or cut-off, shown in fig. 8, running on friction rollers and guided automatically by a large vane. When in action half of the fans are exposed and half protected, as shown in plan (fig. 9). The mill is thrown out of the wind by swinging the shield fully around in the direction from which the wind comes, thus covering all the fans.

These are mills capable of many modifications and adaptations. They are easily built, braced, and supported, and no mill perhaps lends itself more kindly to unlimited extension, all of which should bring them into prominence that they have not yet enjoyed; important results may be expected from these mills. This type of mill is worthy of development.

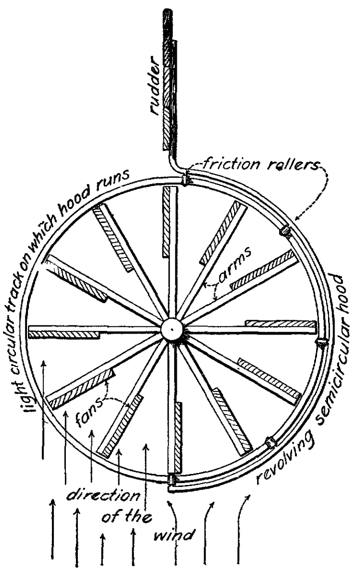


FIG. 9.—Plan of hooded merry-go-round windmill built by William Winn.

In western Nebraska, near the Colorado line, where the precipitation runs as low as 12 to 15 inches and evaporation as high as 6 feet, irrigation begins to be imperative. Here 10 acres have been successfully irrigated by Mr. E. E. Blackman's merry-go-round, and this is more of a test than it would have been in a more humid portion of the State. This mill, as he describes it, is 24 feet in diameter and carries numerous swinging door-like fans of light wood 6 feet high by 4 feet wide. The fans are free at one edge, as shown in plan in fig. 10, and, like a flag floating from the mast, they swing edgewise against the wind, this being the line of least resistance. But the moment the center is passed each fan in turn swings back against the immovable arms and exposes its 24 square feet of surface to the impact of the wind. Half of the fans are continually in the wind and half out of it. Such a mill, well made, might be an engine of strength, but careful work and well-considered plans are necessary to avoid resistance and loss of power. Mr. Blackman insists that this is the cheapest and most efficient mill for its weight that can be built. His mill cost $4.75, exclusive of home labor, pumps an 8-inch stream, and irrigates 10 acres.

A similar, though larger and much more elaborate mill, designed and built by Mr. S. S. Videtto, may be seen on a ridge near Lincoln. (See Pl. XIV, *A*.) The mill is probably 40 feet in diameter and 12 to 14 feet high. It runs on a circular steel-rail track, and is connected by cogwheels to a tumbling shaft which drives the pumping machinery.

These mills are broad of base, and correspondingly stable. There is no apparent limit to their size, and they may embody important ideas.

It is certainly desirable to have some powerful windmills, and the author has designed several which, though too large, perhaps, to be practicable, were conceived in the hope that some available means of raising the underflow waters of the Platte and other rivers might yet be found. Here, at a depth of 4 or 5 feet in coarse pebbles, is an inexhaustible supply of water, of which but meager use is made. The advent of a good water lifter will revolutionize all this. At present but an occasional seepage or underflow ditch is dug, such as the Gould-Hollingsworth ditch at Ogallala. The trouble lies not in the supply, but in the fact that one must go upstream 4 or 5 miles to get the required fall. For private ownership the expense is often prohibitive. It requires no engineering feat to devise and construct windmills powerful enough to do this work, and the author confidently hopes for its realization.

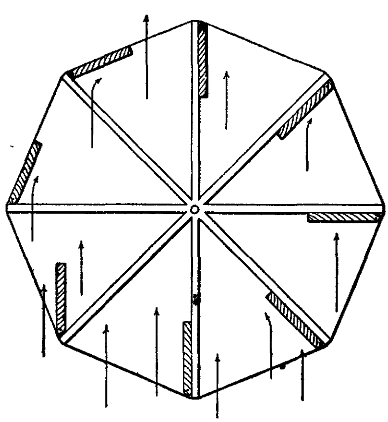
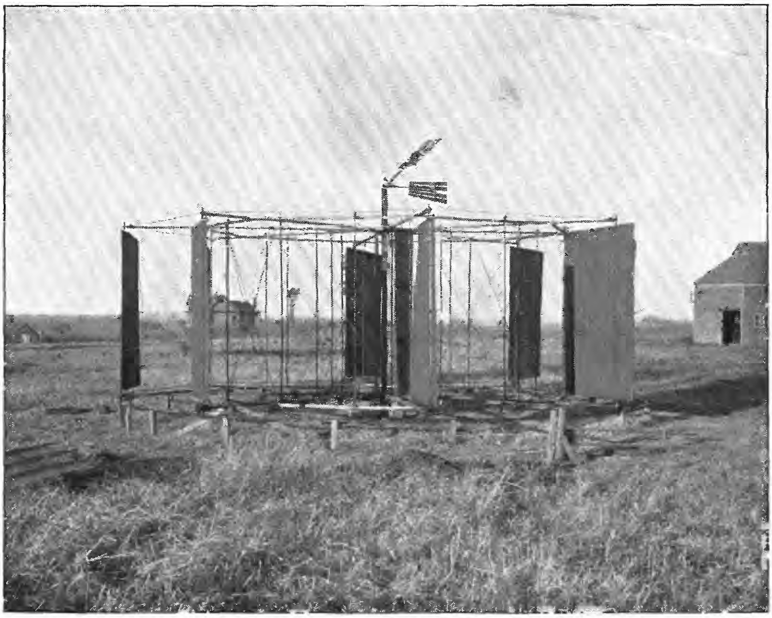
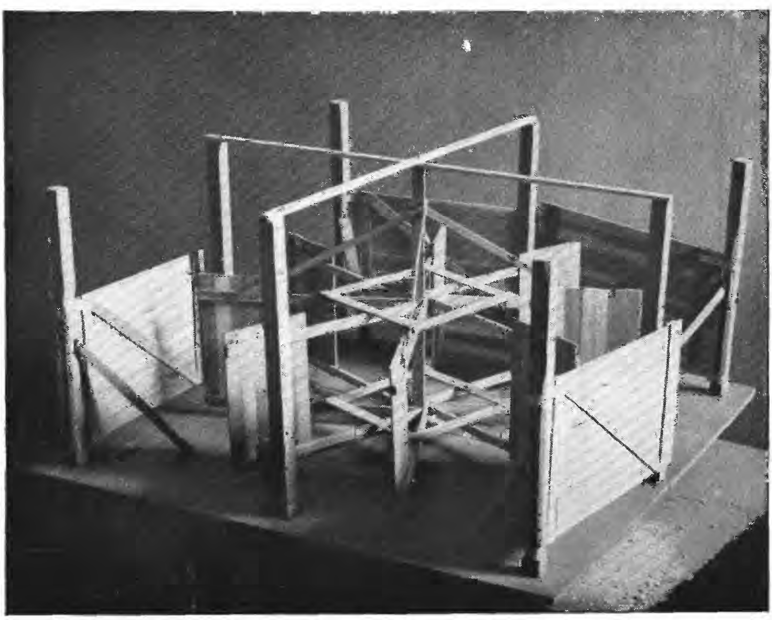


FIG. 10.—Plan of large merry-go-round windmill of E. E. Blackman.

The merry-go-round, when perfected, gives great promise. In the construction of these mills the importance of rigidity is again to be emphasized, for especially light material enters into their make-up. Bolts and twisted wire should be used freely. Where cogwheels and shafting are not at hand, they can be obtained in the market. The axis may be a suitable pole cut from the place and guyed securely by wires in several directions, and the mills may be so set between sheds as to shield part of the fans; or swinging doors, as shown in Pl. XIV, *B*, may be used to possible advantage. They may also be mounted on sheds. The arms ought to be made of new lumber, but packing



A. MERRY-GO-ROUND WINDMILL BUILT BY S. S. VIDETTO, LINCOLN, NEBRASKA.



B. SUGGESTED FORM FOR EIGHT-FAN MERRY-GO-ROUND WINDMILL.

Photographed from model built by the author.

boxes would furnish material good enough for the fans, which may be made of wood, duck, or sheet metal. Pl. XIV, *B*, illustrates an eight-fan merry-go-round windmill designed by the writer. The diameter is 20 to 25 feet, and the fans 6 to 9 feet. Four gates or wind guards, each of which is so hung upon the corner post as to swing through 270°, easily throws the mill in or out of action. The high-geared wheels and shafting below are not shown.

OPEN-FACED OR TURBINE WINDMILLS.

Open-faced or turbine mills may, for convenience, be divided into five distinct kinds, as follows, arranged in inverse order of their importance: Battle-ax windmills, Holland windmills, mock turbines, reconstructed turbines, and shopmade turbines.

These are the windmills of preeminent importance. They represent the most specialized type of windmill, and the man who is about to construct a mill of some other form, though in great favor locally, may well afford to consider the possibilities which this kind of mill affords. The simpler mills are easily constructed, and are inexpensive, efficient, and altogether superior, in the estimation of the writer.

BATTLE-AX WINDMILLS.

In its simpler form this mill consists of a tower for the support of a horizontal axis and crank, to which arms are attached bearing at their extremities fan-like blades, which have a real or fancied resemblance to a battle-ax; hence the name.

Justification for this is found in the fact that the arms—which are the handles—each carry a fan, shaped in some instances like a battle-ax. It is certain that their keen edges cleave the air in a belligerent fashion. When viewed from the side an optical illusion is produced, and these revolving blades seem to be slashing wildly at space in opposite directions. However, they fight their way through, and are victorious mills, worthy of praise.

Like the jumbo and set turbines, the battle-ax mill has its axis set in the direction of the prevailing wind—that is, north and south. The axis may be of wood, rounded to fit in wooden bearings, or it may be of wood, but with metal ends or bearings, or it may be gas-pipe shafting, or, as is not uncommon, the axis of a buggy or wagon. This is the fundamental part, and to it are attached the four fans, six fans, eight fans, or many fans, as the case may be. The jumbo itself can not exceed the battle-ax in simplicity, cheapness, or power. The battle-ax mill is presumably the superior of the jumbo in all respects. These are mills of simple, cheap, and easy construction, and are efficient. In size they run from 8 to 10 feet, the more common sizes, up to powerful mills 16 feet in diameter.

Grand Island, in the Platte Valley, about 90 miles west of Lincoln, is a center for windmills. They are found in the town and for miles around. Irrigation in this portion of the State is not strictly necessary. It is simply a way of increasing the ordinary quantity or quality of the yield, and is resorted to sparingly. Some of these mills were so nearly indistinguishable from the shopmade mills that they need not be reproduced. The majority are of the battle-ax type, and are especially commended to the attention of farmers and stockmen.

The four-blade battle-ax, about 8 feet in diameter, is the favorite type around Grand Island and farther west. Such a mill, with pumping capacity sufficient for 100 to 125 head of cattle, may cost $2 or $3, but should not cost $10, and may be built by those who are inventive without any outlay. Poles and strong limbs answer the purpose as

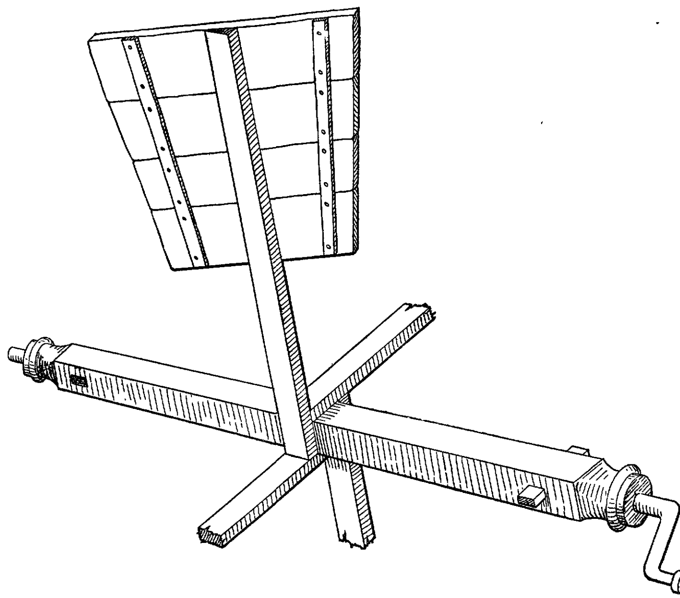
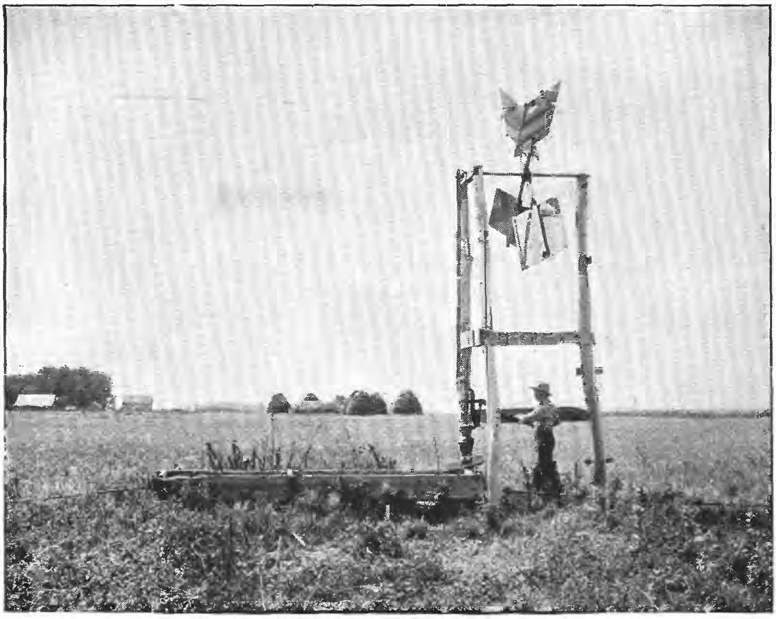


FIG. 11.—Details of construction of battle-ax windmills, showing axis 8 feet long, 6 or 8 inches square, iron bearings, arms 6 feet long, fans about 3 feet square, made of thin lumber.

well as new lumber, old dry-goods boxes furnish material suitable for fans, and old wire, nails, and bolts are common on every farm. The majority of the mills are made in this way, although some are much more elaborate. The principle of the adaptation of discarded machinery is particularly exemplified in the construction of the battle-ax mills. In most of them the journals, gearings, rods, springs, wheels, nuts, bolts, braces, and lumber of discarded machinery are used. Accordingly they are provided with well-made and fairly frictionless bearings, which help to render them sensitive to light winds.

The mill of Mr. Jacob Geiss, near Grand Island, which may be regarded as typical, is a 12-foot four-fan battle-ax, with an axis 8 feet long, mounted upon a suitable tower. It pumps from a shallow well more than is required for 125 head of cattle. (See fig. 11.)



A. BATTLE-AX WINDMILL ON FARM OF MATTHEW WILSON, NEAR OVERTON, NEBRASKA.

B. BATTLE-AX WINDMILL ON FARM OF FRED WOULF, NEAR GRAND ISLAND, NEBRASKA.

From Grand Island westward to Ogallala the battle-ax is the dominant type of homemade mill. At Overton, on the farm of Mr. Matthew Wilson (Pl. XV, *A*), are found two battle-ax windmills, each on a quarter section of a beautiful and improved farm of 1,600 acres, and each pumping water for 50 head of cattle. This is a large farm, and with several hundred head of cattle, as many hogs, and a barn full of milch cows and horses, it was found convenient to supplement the work of two large Perkins mills with two battle-ax mills. The two

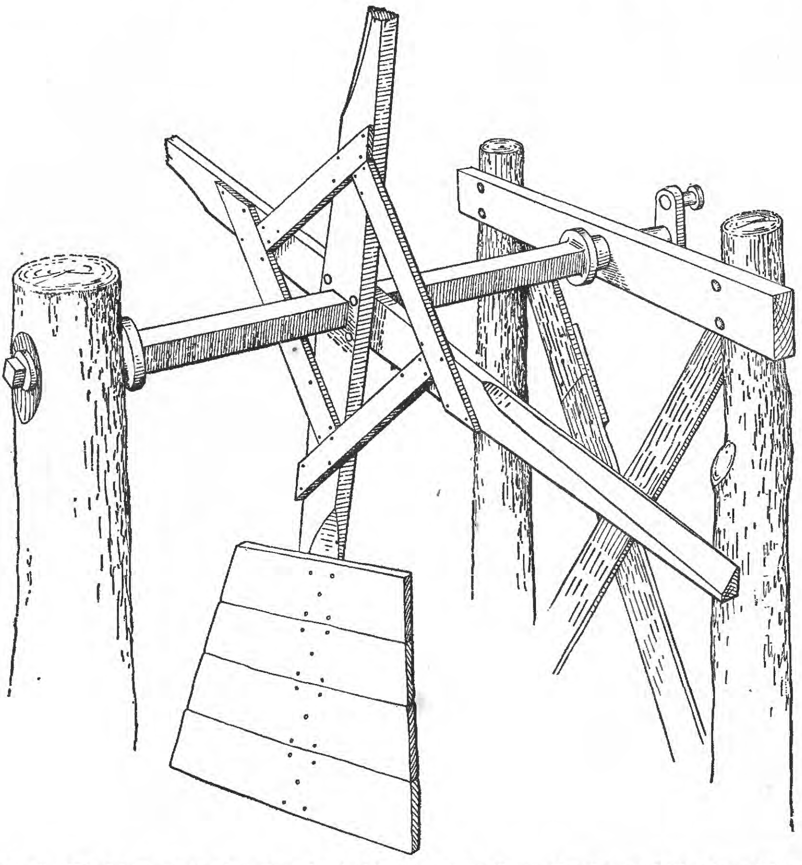


FIG. 12.—Working parts of a four-fan battle-ax windmill on the farm of Matthew Wilson, Overton, Nebraska.

latter were built at a cost of $1.50 each, and each pumps for its quarter section. In addition, one pump irrigates successfully 1 acre of garden, the water being conducted from the pump to the rows by 1-inch galvanized-iron pipe. Nowhere is there a more intelligent use of material. Three cottonwood poles, as shown in fig. 12, properly anchored and braced, constitute the tripodal tower, a buggy axle and thimbles the axis, and thin lumber the fans. In these bearings—kept well oiled—the mill runs as smoothly as formerly did the carriage wheel on its spindle. The crank is adjustable to an 8-inch or 5-inch stroke, as desired. (See Pl. XV, *A*.) In Pl. XV, *B*, is shown the battle-ax wind-mill, tower, milk-house, and stock troughs of Fred Woulf, near Grand Island, Nebraska. The diameter of the wheel is 10 feet, and the cost \$3 to \$5. This mill pumps water for 48 head of cattle. The method of construction is shown in fig. 13. To stop the mill the rope attached to the long crank is made fast to a cleat at the base of the tower.

Six- and eight-fan battle-axes differ from four-fan mills chiefly in numbers. However, they are usually considerably larger and variously modified, and worthy of special mention, at least in several instances.

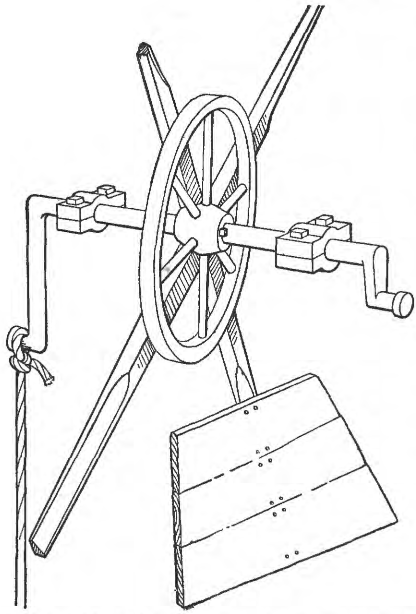
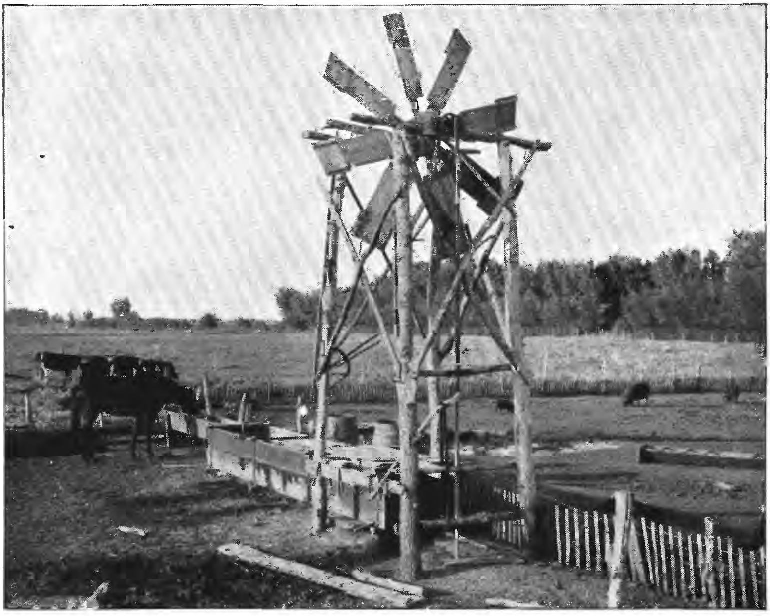


FIG. 13.—Method of construction of the battle-ax windmill of Fred Woulf, near Grand Island, Nebraska. Brake rope and crank to the left.

The six-fan battle-ax windmill of John Harders, near Grand Island, Nebraska (see Pl. XVI, *A*), is 8 feet in diameter, and cost, including tower, pump, and pipe, \$12 to \$14. It is used for irrigating a small market garden, and is mounted on a firm tower of cottonwood poles, broad at the base. The brake, managed by the brake rope, rubs against a cogwheel keyed to the axle, and thus controls the wheel.

The eight-fan battle-ax windmill of Mr. Diedtrich Huennecke (Pl. XVI, *B*), near Grand Island, attracts special attention, because it is made of old material, at a cost of but \$14, including the mill and an unusually large and well-ironed water tank. The mill alone cost \$6 to \$8, and in efficiency is a rival of the steel mill costing ten or twelve times as much. The diameter of the wheel is 10 feet, and the stroke 8 inches. The mill was located in the stock yards, bordered by stalls and pens, and pumped from a shallow well all of the water needed by the stock. It was supported by heavy cottonwood posts, on which was bolted the framework from a thrashing machine, with journals and cogs in place. The cogs were geared in the ratio of 3 to 1. The fans, which are 3 feet long, 14 inches wide below and 20 inches wide above, were made of the sides and ends of boxes. Advantage was taken of the fact that an old pulley was attached to the shaft (fig. 14). A friction brake, managed

A. SIX-FAN BATTLE-AX WINDMILL OF JOHN HARDERS, NEAR GRAND ISLAND, NEBRASKA.



B. EIGHT-FAN BATTLE-AX WINDMILL OF DIEDTRICH HUENNECKE, NEAR GRAND ISLAND, NEBRASKA.

by an old wagon brake, was cramped on the pulley, checking or stopping the mill.

The largest and most remarkable battle-ax mills in the State are probably those of J. S. Peckham, 5 miles southwest of Gothenburg, and of his son, E. L. Peckham, a mile distant.

These are veritable wind engines, and they probably illustrate what may be done by the homemade mill better than any of the other mills visited. On this splendid farm, of a thousand or more acres, there is an interesting array of windmills, houses, barns, grain houses, sheds, cattle yards, orchards, vineyards, and the young but lofty trees of a timber claim. There were four shopmade mills, one Dempster, two Perkins, and one Aermotor, pumping water for the stock and for the

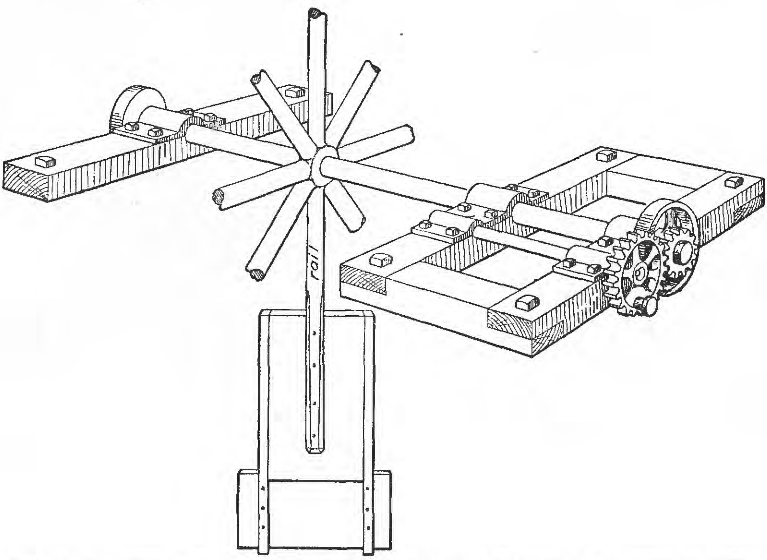


FIG. 14.—Working parts of the eight-fan battle-ax windmill of Diedtrich Huennecke, near Grand Island, Nebraska, with one fan in position.

house, and two giant battle-ax mills, driving two pumps each for the irrigation of 15 acres of orchard, vineyard, and small fruit.

These mills were designated Mill No. 1 and Mill No. 2, shown on the left and right, respectively, of Pl. XVII, *A*. Both were mounted on the same kind of tower, and were identical in size and make. No. 1, however, worked two pumps with $3\frac{1}{4}$-inch cylinders, and No. 2, two pumps with 4-inch cylinders, so that the results, as shown by the amount of water discharged, were quite different.

The towers, each about 20 feet in height, were made of timbers 2 by 4 inches with pieces 4 by 4 inches for the corners. They were broad at the base, about 16 feet square, and well cross-braced. The wheel, 16 feet in diameter, consisted of eight heavy wooden fans $5\frac{1}{2}$ feet long and 5 feet at the top, tapering to $2\frac{1}{2}$ feet below (about 25 square feet of surface on each fan). These were cross-cleated and very rigidly made and then securely bolted on a slant to the double 2 by 4 inch arms. The arms were made by springing and bolting into position pairs of 16 feet 2 by 4 inch timbers over the axis, which was 8 inches square, and had a span of 16 feet. The axis was not solid, but consisted of

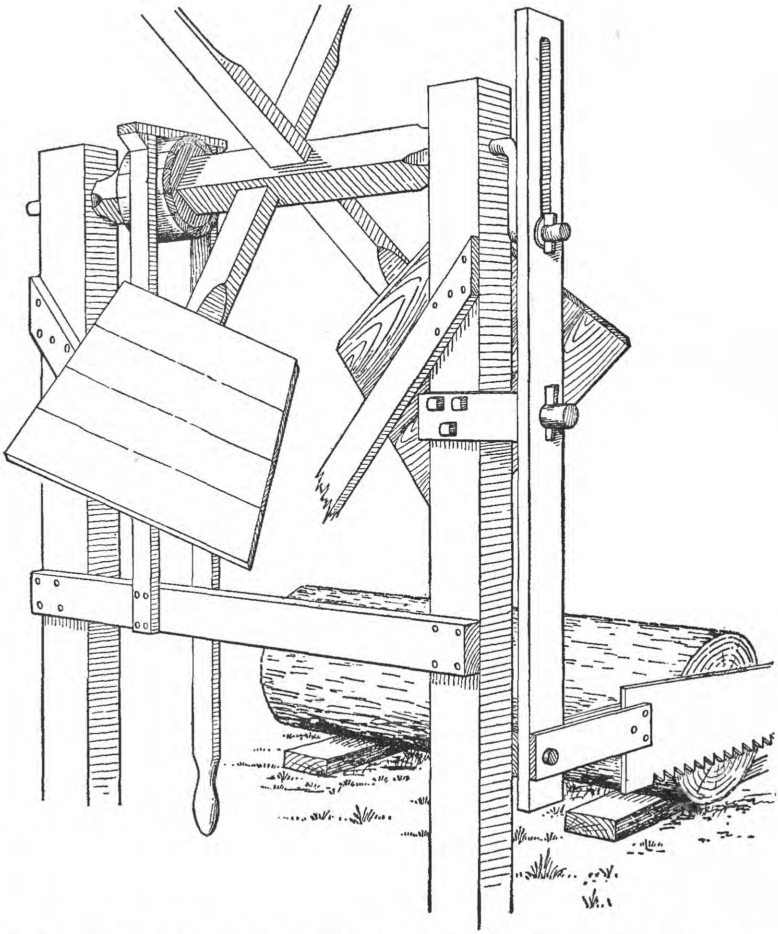
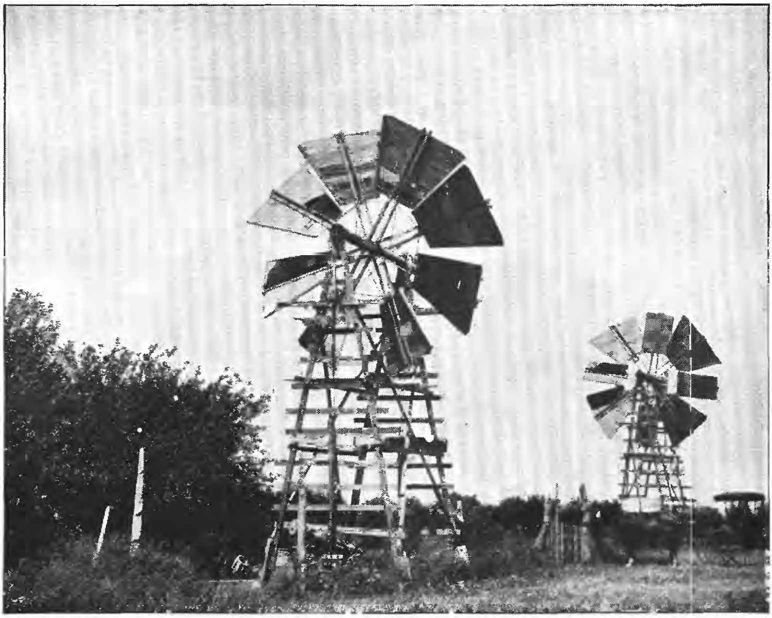
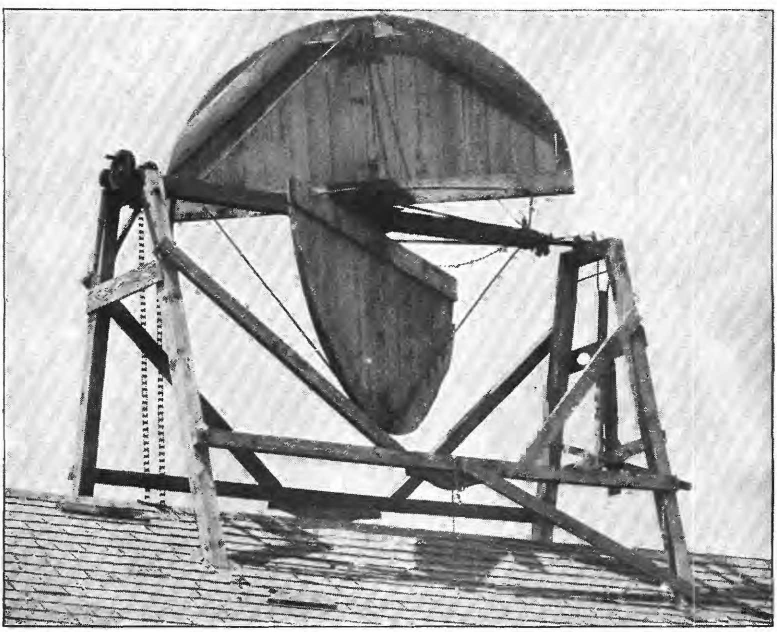


FIG. 15.—Battle-ax windmill driving crosscut saw, built by A. G. Tingley, Verdon, Nebraska.

two planks 4 by 8 by 16 feet, spiked and bolted together. This offered an advantage in the judgment of the designer, in that it allowed the adjustment and keying in place of the 2-inch iron bearings which carried the cranks and on which the axis was to turn. Their size demanded special rigidity, which the designer did not overlook at any point. They were admirably constructed, and ran as smoothly and as noiselessly as a steel mill. They cost about $25 each (exclusive



A. GIANT BATTLE-AX WINDMILLS ON FARM OF J. S. PECKHAM, NEAR GOTHENBURG, NEBRASKA.



B. TWO-FAN BATTLE-AX WINDMILL BUILT BY ELMER JASPERSON, ASHLAND, NEBRASKA.

of labor) and partly irrigated 15 acres of orchard, which they are capable of irrigating well when the water is economically and properly applied.

As to efficiency, Mill No. 1, with two 3-inch cylinders and a 10-inch stroke, pumped in a 13.5-mile wind at the measured rate of 14,760 gallons in twenty-four hours from a well 42 feet deep, although one valve was badly out of order.

Mill No. 2 made a better record, both because of the larger cylinders and the better condition of the valves. In a 13.5-mile wind this mill, with a 10-inch stroke, discharged at the rate of nearly 1,000 gallons per hour (or to be exact 930 gallons per hour), or 22,320 gallons in twenty-four hours, from a well 42 feet deep. This amount was greatly exceeded when, later in the day, the wind velocity rose to 15 miles per hour. Though not apparently overloaded, Mill No. 2 ran appreciably slower than No. 1.

From the farmer's standpoint, mills capable of doing such work can not be purchased at a price commensurate with the cost of building them. Thus some have built mills who otherwise would have bought them. These two mills are a credit to any estate, and are commended by the author to the consideration of farmers who prefer to build their windmills for heavy service.

A mile distant is the farm of the son, E. L. Peckham, who owns property almost as extensive as that of the father. The farmhouse looks like a city residence, with its fine green lawn. The young orchard, large vegetable garden, and flower garden, 2 acres in all, are models, due to the water supplied by a mill exactly similar in all respects to the original battle-ax mills Nos. 1 and 2, except that this is more heavily braced and otherwise improved. It lifts water 27 feet by two pumps with 4-inch cylinders, irrigates 2 acres, and sprinkles the lawn. The total cost, including pumps and all incidentals, was $75.

The remarkable two-fan battle-ax mill of Elmer Jasperson may be seen near Ashland, Nebraska, mounted along the ridge pole of a north-south corncrib and wagon house (see Pl. XVII, *B*). Heavy semicircular fans of wood, with a diameter of 10 feet, are mounted on a substantial axis having a span of 12 feet; to this is attached the sprocket wheel and chain for transmitting the energy of the wind to the corn sheller and feed grinder below. These fans are movable, and when brought together form a circle 10 feet in diameter, with its edge to the wind, in which position the fans are not affected by the wind, and are accordingly out of gear; but when thrown aslant the wind strikes their oblique faces, and they revolve with a fine display of force.

This mill is not so sensitive to light winds as shopmade mills, but its momentum is greater. It drives a two-hole cornsheller and feed grinder and a grindstone.

This is one of the most interesting and attractive homemade designs in the State, and for novelty and originality it was awarded a prize by the Nebraska State Journal of Lincoln. It shells and grinds corn at a total outlay of $11; and gives entire satisfaction. The ingenuity which characterizes this novel invention crops out everywhere on the Jasperson farm, in the locks, gates, fences, and implements, and in one irrigated field there is a remodeled turbine, described on page 65, so well made as to be indistinguishable from the original mill.

Regular shopmade mills supplied water for his house and stock, the homemade mill being used wholly for driving machinery. Unfortunately means were not at hand for measuring the true efficiency of this two-fan turbine, but for practical purposes it may be said that it drove the cornsheller and feed grinder with ease. It seemed equivalent to about 1 horsepower.

HOLLAND WINDMILLS.

The Holland mills, with their four slatted fans covered with cloth sails, are so familiar in art that descriptions are unnecessary. However, as introduced into the Great Plains, they have undergone many changes and modifications, and the resemblance is sometimes lost. As viewed in pictures, the great fans are mounted on massive supports. In Nebraska, however, they sometimes stand on slender, spindling towers. They are frequently mounted upon milk houses, corncribs, wagon sheds, and barns. Their identity is further obscured at times in that the customary four fans are replaced by six or eight, and the familiar duck sails by wooden ones.

Some of the strongest and best mills in the State are modifications of these old Dutch mills. Though the picturesque mountings and settings may be wanting, their efficiency and serviceability are not. The smaller Dutch mills stand on towers, the medium-sized on small outbuildings, and the large ones on barns. In size they range from the smallest, 10 to 12 feet in diameter, through medium-sized mills, 15 to 20 feet in diameter, to the largest, which measure 36 feet.

The great Holland mill of August Prinz, 1 mile east of Chalco, Sarpy County, favorably situated as it is for observation from passing trains on the Burlington Route, has become a familiar landmark to travelers on that road (see Pl. XVIII, *A*).

The Prinz mill rises high above the surrounding grove, which, though but twelve to fourteen years old, completely shuts in the house and farm buildings. A closer view shows the large mill, with fans describing a circle 36 feet in diameter, mounted securely upon the large shed which constitutes corncribs and wagon shed, while at the house is seen an 8-foot Gem mill which pumps water from a 40-foot well to the house and stock trough. As a precaution against accident and against insufficient wind velocity, the owner has a horsepower device with shafting and pulley, which can instantly be attached to the house pump.

Ordinarily the small windmill is able to supply ample water for the

A. HOLLAND OR DUTCH WINDMILL OF AUGUST PRINZ, NEAR CHALCO, NEBRASKA.

B. SIX-FAN HOLLAND OR DUTCH WINDMILL OF HENRY BORMANN, NEAR PORTAL, NEBRASKA.

house, for 80 steers, 20 milch cows, 10 horses, 125 hogs, and other stock. Accordingly the large mill has so far been employed solely for the purpose of grinding grain, although it can be easily geared to raise water as needed. In the amount of grist is found an easy measure of the efficiency of this mill, which owes much of its merit to the fact that its projector had built mills in Holland before emigrating to this country in 1871.

With the ordinary wind of winter, when the mill is particularly in use, the capacity of this mill is 200 or even 300 bushels of ground grain a day. It drives an 8-horsepower feed grinder with greater speed than horses could. It elevates the grain and grinds and discharges the grist automatically, demanding no immediate supervision, while the men are engaged about the customary duties of the farm. With a good wind it is unnecessary to use more than two sails, which give all the power that is necessary for ordinary work.

This being a large mill, heavy gear wheels and driving wheels, couplings, brakes, etc., were necessary, and these were procured in Omaha and Chicago. The total cost of the mill was $150. While this may appear to prospective builders a considerable sum, it is not prohibitive. Against this sum must be balanced the efficiency of an 8-horsepower plant, the fact that the mill requires little or no superintendence, and that the grain is ground at home, requiring no expenditure of time and money in hauling to and from the mill. A windmill so well built is capable of rendering service for twelve to fifteen years.

Here, as elsewhere, the author finds that those farmers who have the ingenuity to invent and build mills have well-kept farms, the best gates and fences, improved and excellently kept buildings, and an air of unmistakable prosperity. In twenty years the proprietor has become possessed of 320 acres of fine land set with hedges, groves, and orchards; of herds of well-bred stock and fowls; of substantial, convenient, and well-regulated houses, barns, cribs, tool sheds, and poultry houses, and of all necessary farming implements and vehicles. The author has driven for many miles through this favored agricultural region, and scarcely less can be said of any farm visited. They are large, well kept, improved, and free from mortgage. This is but the beginning of the great windmill area of the State, which extends thence westward for 500 miles in close proximity to the Platte Valley.

On the farm of Henry Bormann, near Portal, in Douglas County, about 3 miles east of the August Prinz place, stands an important mill of home production, which, like the Prinz mill, its progenitor, is a landmark familiar to travelers on that branch of the Burlington and Missouri River Railroad. It is essentially a Dutch mill, but with six instead of the customary four fans, which describe a circle 19½ feet in diameter. Making allowance for customary overestimates, its true efficiency must be between 4 and 6 horsepower, and will run higher when the mill is full rigged. The surprising part is that it runs the grinder without full-sized canvas sails, its designer and builder finding that it was easier, handier, and amply efficient to use wind boards instead. These wind boards are simply thin ¼-inch boards about 7 feet long and 1 foot wide, set at an angle on each arm. They are quickly set in place and secured by wooden buttons. In a strong wind but three of these boards are used.

The capacity of this mill varies according to the wind, from 75 to 100 bushels of ground feed a day. By purchasing shafting, belts, pulleys, bevel gear, etc., at an abandoned elevator, and by making patterns for the revolving head and other parts and having them cast in Omaha, the cost of this mill amounted in all to only $50. Considering that it is well built, that it should last ten to twelve years, that it grinds all the grain for the stock and is capable of pumping and driving other machinery, there is again a decided balance in favor of the homemade mill.

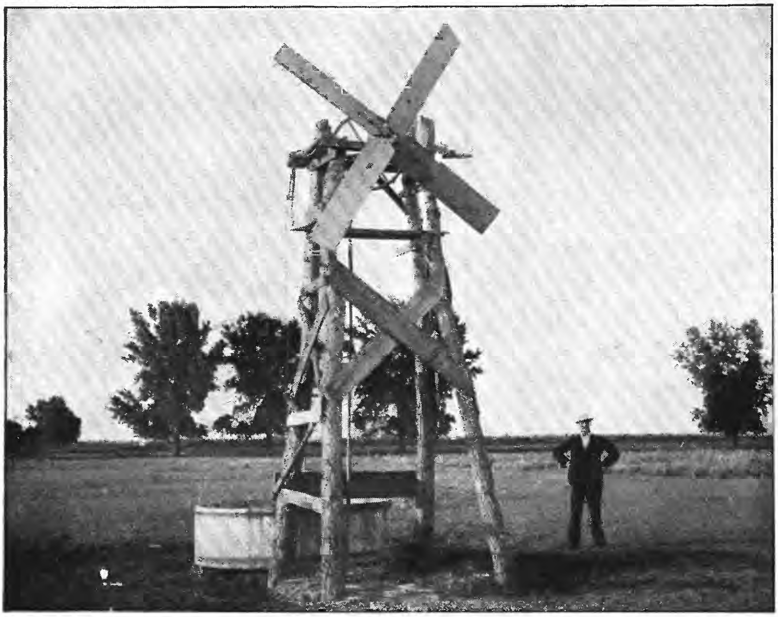
During the summer months when the cattle are at pasture the mill is not in operation, so that the author made no attempt to test its efficiency, believing that the 6-horsepower grinder was a sufficient measure of its strength. This, like the Prinz mill, is so geared as to be useful in driving other machinery or in pumping water, as occasion demands.

TOWERLESS TURBINES.

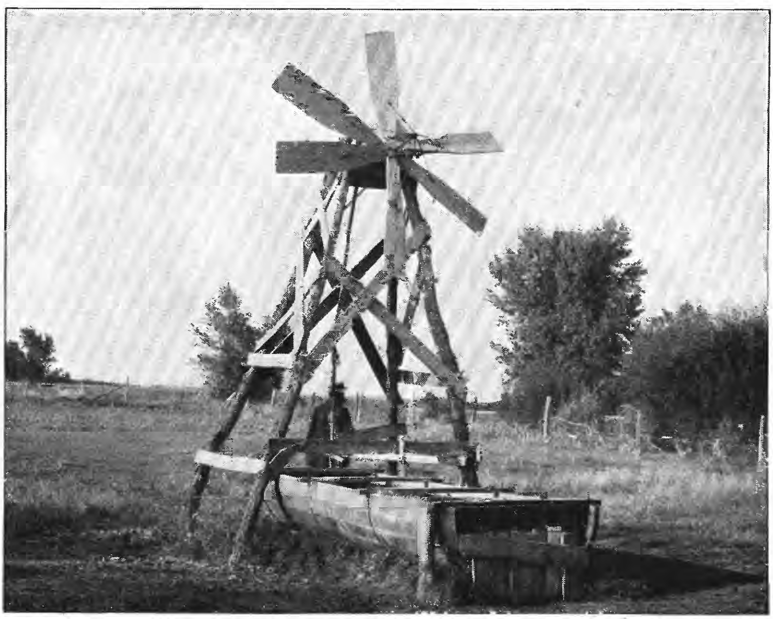
It is doubtful if there is a better general example of the towerless turbines than the one across the Platte, some 20 miles south of Gothenberg. This simplified mill consists merely of a wheel without tower, axis, crank, or other working parts. The axle of an old wagon, with spindle, thimble, hub, and wheel intact, was bolted to beams on the south side of a barn, fans were nailed at a slant to the spokes, and a bolt was driven in one edge of the hub with an eccentricity of 3 or 4 inches, to which the pump rod was attached. The mill pumps water, but is dependent, of course, on south winds. From this simple form there is every conceivable gradation to the best shopmade steel mill, made of the finest material, and wrought with such nicety and precision as to return 90 per cent efficiency.

STATIONARY TURBINES.

The next higher type of the turbine is but little more specialized. It has a tower, usually of poles, a crank and pump rod, and four or more blades or fans. These constitute the whole of a mill which is considerably more efficient than the extreme simplicity of its working parts might imply. These are commonly built without expense, for the crank, which is the only piece demanding outlay, is inexpensive if bought first hand, and is usually supplied from old machinery; and



A. FOUR-FAN STATIONARY TURBINE WINDMILL OF FRIEDERICH ERNSTMEYER, NEAR GRAND ISLAND, NEBRASKA.



B. SIX-FAN STATIONARY TURBINE OF FRED MATHIESEN, NEAR GRAND ISLAND, NEBRASKA.

to the crank arms are attached to which the wooden blades are nailed. The pump rod is often but a sapling. The axis runs on wooden bearings, lubricated occasionally with axle grease. The tower is built of old lumber, usually of poles. Such mills are numerous. Occasionally these mills run on excellent bearings, the builder having detached certain framework with its journals and crank from old machinery, bolting them bodily to the tower, attaching arms to the axis, a pump rod to the crank, and once in a while a brake to regulate the speed of the fans.

A mill of this kind (see Pl. XIX, *A*) used by Friedrich Ernstmeyer, of Grand Island, for pumping water for his stock, was especially well built, and cost only 32 cents—for a 16-foot board for the fans. It was made of the oak frame and sickle driver of an old mower, which was bolted bodily upon the cottonwood tower. This is an 8-foot wheel, with pine board fans 12 to 14 inches wide by 4 feet long. An ingenious brake was made by securely wedging an old cultivator wheel to the axis, and a set of springs and levers were so arranged as to press a shoe of leather against the wheel, thus retarding or stopping the mill as desired.

In the stock field of Fred Mathiesen is a six-fan set turbine (shown in Pl. XIX, *B*), which, though very crude and rustic, runs nicely in its shopmade bearings—the frame and journals of an old self-binder—and cost only a few cents, for welding an extension to the axis and for light rods with which to brace the arms. The brake is nothing more than a fence post, which can slide forward between the fans to stop them and back again to put the mill in gear. The pump rod is a small sapling. The diameter of the wheel is 8 feet and the stroke 6 inches; total cost two or three dollars. The turbine is used for watering stock.

From these elementary forms, which are too numerous to allow detailed description, we pass to the set turbine, with many fans. A typical example, selected from many, is the mill built by Janak Bros., of Sarpy Mills, Nebraska.

First attempts at designing and building mills often give results which warrant larger undertakings, and one may see the first, the second, and the third mill by the same designer, each an improvement on the one before. It is interesting to note this advance, which is marked by improved and enlarged designs and by superior material and make. An excellent example of this is furnished by the Janak Bros., the elder of whom arrived from Bohemia three years ago (in 1896). Seeing that it was important for a neighbor to supply, in a given pasture, water for about thirty head of cattle, he immediately built a turbine mill so simplified that it consisted merely of a 10-foot wheel made of weatherboarding, braced and wired together, mounted on an axis with a 3-inch crank, which ran in journals of wood, bolted to the top piece of the tower (see fig. 16). There was no need for a revolving head or vane, for this was a stationary turbine, with face set to the south, and with its tower well guyed in three directions by twisted wire. This mill cost altogether between $3 and $4, and at the worst is sure to give three or four years of satisfactory service, in addition to three years' service already rendered.

On the farm where poles may be cut for the tower and old lumber is at hand, the expense of a 10-foot stationary turbine mill like the above may easily fall within $2.50 or $3. These are commended to the attention of those needing cheap mills, especially to those who have material on hand. Here the crank and driving wheels of discarded reapers may be put to advantageous use.

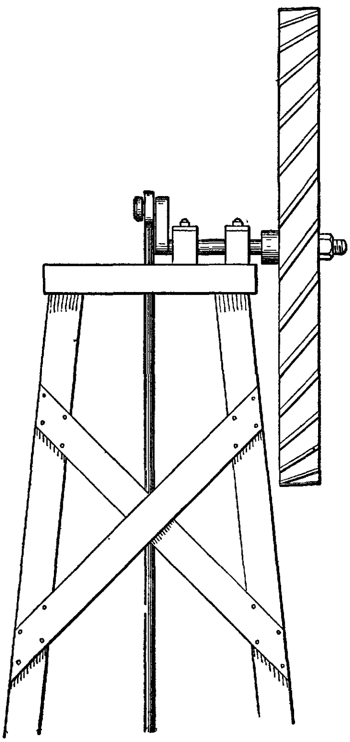
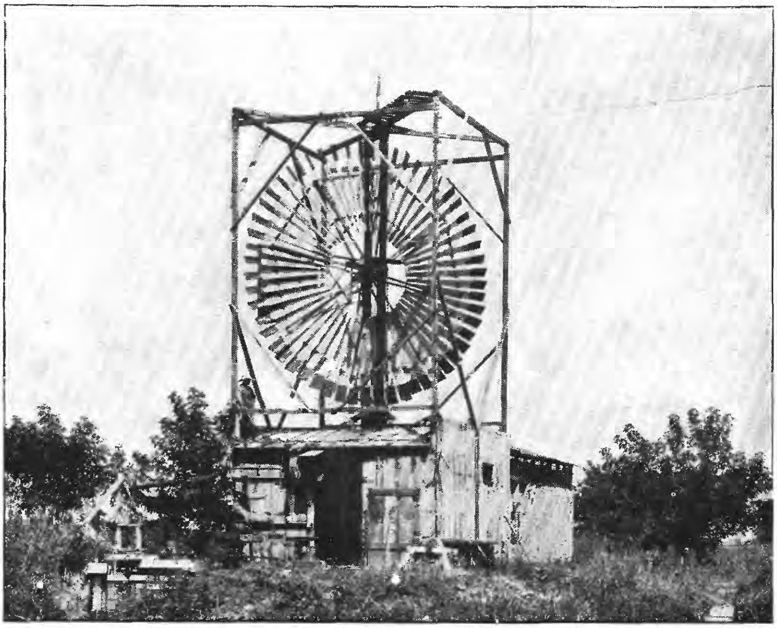


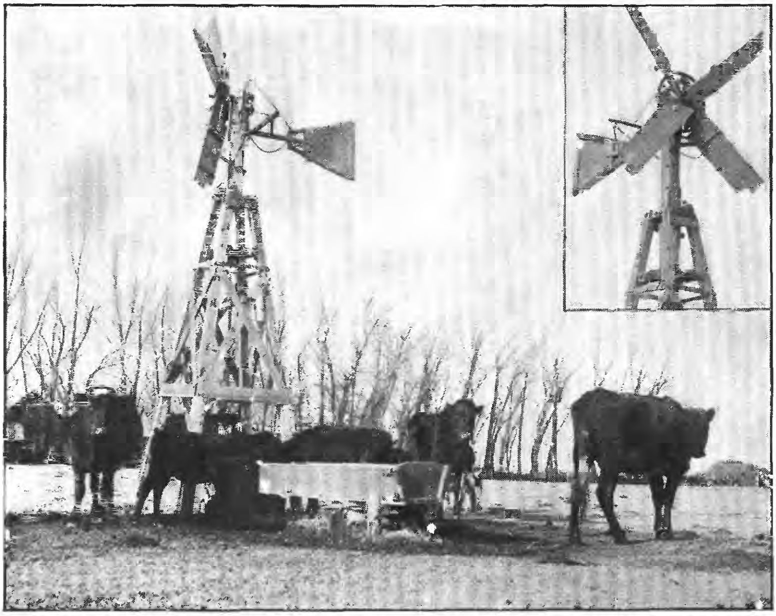
FIG. 16.—Stationary turbine designed and built by Janak Bros., Sarpy Mills, Nebraska.

This crude wooden mill warranted an attempt by the Janak Brothers at something larger, better built, and more complex in its parts. The result is a steel mill 14 feet in diameter, with galvanized-iron fans, mounted with a revolving head upon a 35-foot wooden tower by the side of the blacksmith shop of the Janak Bros. The finely built wheel was spinning without a sound or vibration, and within the shop the emery wheel, grindstone, drill, bellows, lathe, and other machinery, together with the pump, were driven as steadily as though steam was the motive power.

Their prestige as blacksmiths was won largely by the windmill, which not only drove their machinery, but evidenced their ability. This mill, well as it worked, was yet incomplete, a fortunate circumstance, as it illustrates the fact that in a great deal of machinery refinements and accessories are not essentials. The mill lacked a rudder or vane, which necessitated climbing the tower and prying the wheel face to the wind with a lever. This, however, in a region where the prevailing wind is so constantly from the south, occasioned but little inconvenience. At the same time this shows the prospective builder that he can simplify the working parts of his mill and reduce its cost without materially affecting its efficiency. Later on, as time and means allow, vane, automatic regulators, and other parts may be added at will. In the meantime the owner has the use of an efficient mill in which but little cash or time is invested, and though less



A. GIANT TURBINE BUILT BY J. M. WARNER, NEAR OVERTON, NEBRASKA.



B. FOUR-FAN GEARED TURBINE BUILT BY HENRY BOERSEN, NEAR GRAND ISLAND, NEBRASKA.

convenient it seems far wiser to have a mill like this than to be driven from the undertaking by its complexity.

VANELESS AUTOMATIC TURBINES.

The vaneless automatic homemade windmill of W. F. Baldwin, of Ainsworth, Nebraska, when visited September 12, 1898, proved to be

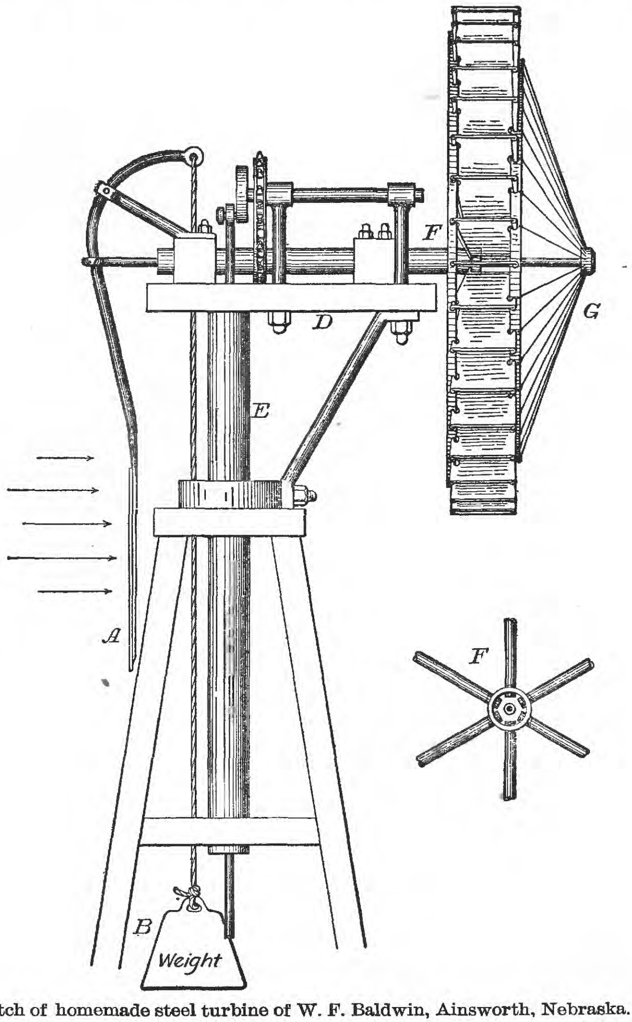


FIG. 17.—Sketch of homemade steel turbine of W. F. Baldwin, Ainsworth, Nebraska. *A*, Regulating fan and lever; *B*, Weight holding the mill in gear; *D*, Platform revolving about gas-pipe axis *E*; *F*, Windmill head with gas-pipe arms.

one of unusual interest (see fig. 17). A principle seems to appear in this mill not thus far seen in other mills.

Mr. Baldwin, who had formerly been engaged in several windmill companies, and had thus acquired experience, considered it a piece of faulty construction that shopmade mills must be subjected to the fury of the wind before they begin to throw themselves out of action. This is a heavy and apparently an unnecessary strain, and to obviate it Mr. Baldwin so arranged his mill that the regulator receives the force of the wind before the fans. The regulating rudder (see fig. 17, *A*) is counterbalanced by a paint keg filled with sand; the rudder, thus becoming sensitive, reacts and responds to every varying breeze, constantly throwing the fans in and out of the wind. When the keg is removed the lever, falling of its own weight, pushes against a rod passing through the hollow axis, and thus sets each fan in the wheel edgewise, catching no wind. When the weight is applied each fan is thereby set to catch the wind to the best advantage. Between these two points there is every gradation, the blades constantly turning and adjusting and accommodating themselves to every breeze. Nine mills of this kind have been built and set up on farms around Ainsworth, and their owners are enthusiastic in their praise.

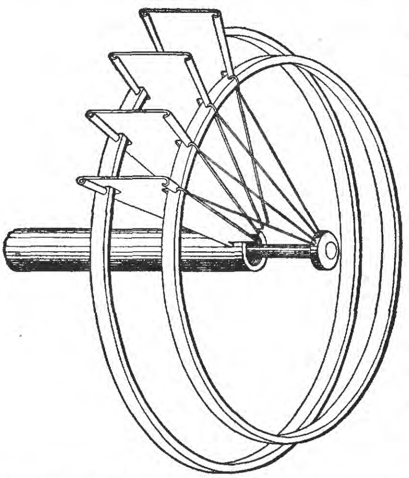


FIG. 18.—Method of regulating the fans of the homemade steel turbine of W. F. Baldwin.

The galvanized iron blades are reinforced with heavy wire on the edges, the back edges being hinged to a fixed metal circle, and the front edges to a slightly movable rotating one, which turns the fans according as the adjusting rod moves forward or back.

The working parts, consisting of a 2-inch gas-pipe axis to which the fans are attached, carrying sprocket wheels geared in the ratio of three revolutions to one stroke, were supported on a small platform, braced by rods, which revolved about a 3-inch gas pipe fixed in the tower. The tower consisted of staight cottonwood poles, bolted to anchor posts in the usual way. The axis runs on friction rollers, like the ordinary grindstone. By using pieces from old machinery the cost of this trial mill was but $5. It has been in service pumping water for the house and stock for three years.

GIANT TURBINES.

The giant turbine of J. M. Warner, 4½ miles southeast of Overton, Nebraska, is one of a size rendered possible by the method of mounting it inside the tower rather than upon it (Pl. XX, *A*). This arrangement so far extends the base of support that the tower can probably never be overturned, except by winds that would move buildings. In addition it is securely guyed in four directions by

A. RECONSTRUCTED WINDMILL OF E. M. SEARLES, JR., AT OGALLALA NEBRASKA.

B. IRRIGATING POND AND RECONSTRUCTED WINDMILL ON FARM OF ELMER JASPERSON, NEAR ASHLAND, NEBRASKA.

heavy twisted wire, anchored at a distance. This giant turbine, which has no rival in size or strength, is an efficient innovation. It propels the machinery of a 4-horsepower feed grinder. However, the work is done with less dispatch than by four horses, and Mr.

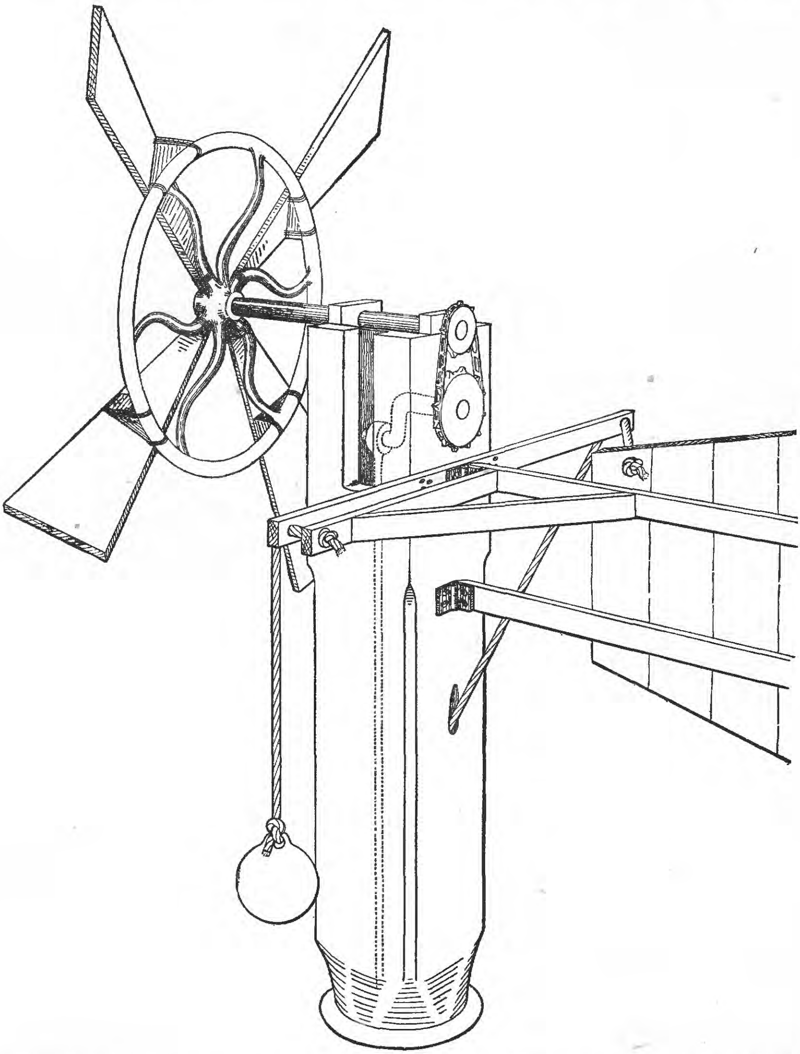


FIG. 19.—Method of construction of four-fan turbine mill of Henry Boersen, near Grand Island, Nebraska. General view on Pl. XX, *B*.

Warner is disposed to attribute to the mill an efficiency of 3 horsepower and possibly a fraction more.

In addition to grinding, this mill runs the grindstone and other machinery by means of a system of overhead shafting with pulleys and belts. It can also be connected to a walking beam, which drives two pumps with a 12-inch stroke, one having a 5-inch cylinder, the other a 4-inch cylinder. These are too small for the mill, as Mr. Warner finds, and 6-inch cylinders should be substituted. The lift is but 7 to 8 feet, and the endless chain and buckets might replace the pumps with marked advantage. No reservoir has yet been built, but with one Mr. Warner estimates he could irrigate 20 acres sufficiently for that region. As it is, he has successfully irrigated 8 to 10

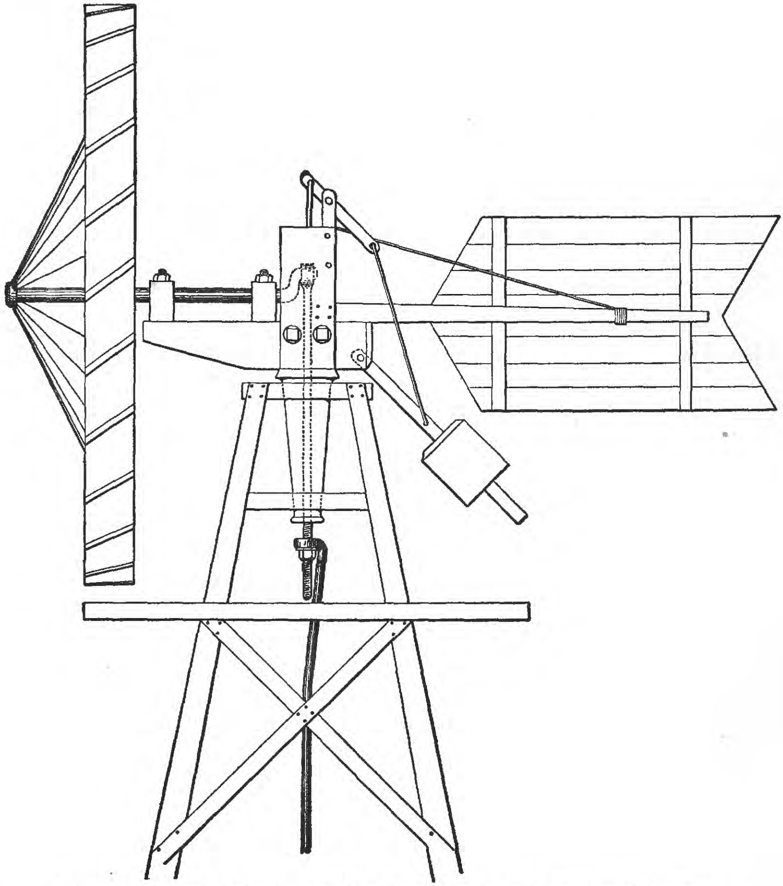


FIG. 20.—Homemade turbine mill of Lewis Jardee, of Newport, Nebraska.

acres of alfalfa and 6 to 8 acres of corn. The mill is large, and its cost, about $60, is not disproportionate to the work performed. A large rudder, held in place by a weighted nail keg, guides this giant wheel, which runs on a 2-inch iron axis, supported by a vertical rectangular frame. This principle is apparently new and worthy of development.

Plate XX, *B*, illustrates a four-fan geared turbine designed and built by Henry Boersen, near Grand Island, Nebraska. The head of

A. RAILROAD WATER TANK AND WINDMILL.

B. ELEVATED TANKS FILLED BY WINDMILL FOR TOWN SUPPLY; USED AT FAIRMOUNT, FILLMORE COUNTY, NEBRASKA.

an old wooden pump constitutes the revolving parts, while the fly-wheel and sprocket wheels of an old cornsheller were used for the driving parts. But few bolts or screws were used, the parts being very ingeniously wired together. Examination of fig. 19 will make the working parts and plan of rudder apparent. The wheel is 8

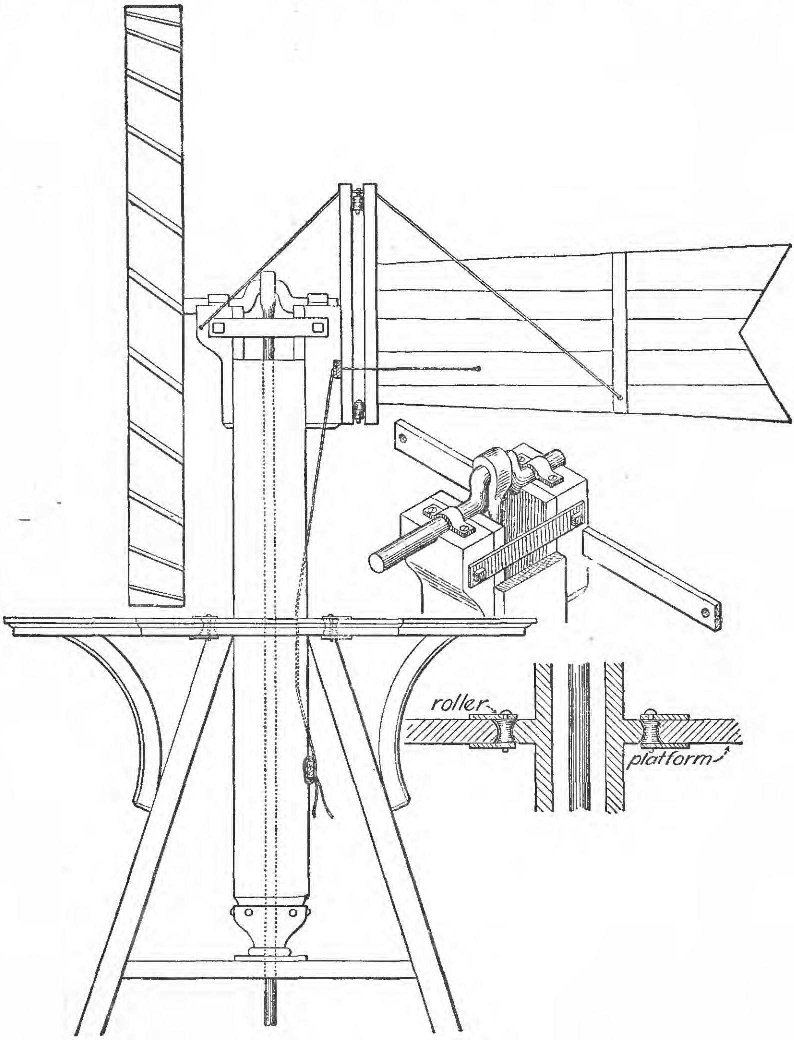


FIG. 21.—Side view and details of revolving parts of homemade turbine windmill of W. F. McComb, Grand Island, Nebraska.

feet in diameter; cost of mill, $2; cost of mill, pumps, and trough, $9.50. The pulleys over which the gear ropes pass are made of spools. This turbine raises water from a shallow valley well 7 or 8 feet and supplies 60 head of cattle. The timber shown in the background is 26 years old.

The homemade windmill of Lewis Pardee, Newport, Nebraska, shown in fig. 20, consists of the thimble of an old wagon—on which the mill turns—to which are bolted for the driving parts oak supports detached from an old reaper. The mill pumps about 500 gallons an hour, or 12,000 gallons in 24 hours, and cost $6.

Some homemade mills are such close imitations of the shopmade, that the casual observer fails to see the differences which are apparent on closer inspection.

The mill of W. F. McComb, of Grand Island, shown in fig. 21, is an example. In appearance it is a shopmade mill; in fact every portion of it is homemade. The fans are of metal, the rudder of light wood, hinged, and adjustable from the ground to throw it in and out of gear like ordinary mills. The mill acts directly on the piston, giving a 10-inch stroke. The head and axis are supported on a vertical wooden box, which, guided by friction rollers set in the platform of the tower, revolves upon a conical casting at its base. It is a 10-foot wheel, pumps water by a 3-inch cylinder into the tank, a lift of 44 feet, and irrigates the garden and lawn. It cost possibly $20, and has run since the spring of 1897.

RECONSTRUCTION OF WINDMILLS.

In the provisional classification of homemade windmills, the reconstructed mill is placed next in importance to the shopmade mill.

There are great possibilities here, which have been and may be taken advantage of many times. In every community are neglected or fallen mills and towers which might be reconstructed at a merely nominal cost, either by the owner or by the purchaser of such idle property. The essential parts are often intact, and it is a simple matter to substitute homemade fans and rudders for those missing. Many mills are standing in disuse year after year, while rough boards nailed to their bare arms would start them going.

Many take advantage of this opportunity, and that others may be reminded of the possibility a few reconstructed mills will be figured and described, in the belief that this small number will sufficiently represent all.

Reconstructed mills are to be found in every county in the State, but nowhere are there better examples than at Ogallala, in western Nebraska. Within the town at least five reconstructed mills are in use, pumping water mostly from shallow wells.

At the livery and feed stable an old mill which has lost all its fans and its rudder has been so rejuvenated by simply nailing 6-inch boards to the bare arms that the mill is pumping water for 25 horses. This entailed no expense and but little time and labor.

Near by stands a reconstructed mill still doing duty in pumping for the house and lawn, though furnished with six rough blades. The mill which formerly occupied its place upon the substantial tower had

ARTIFICIAL PONDS OF THE MOULTON ICE COMPANY, LINCOLN, NEBRASKA. SUPPLIED WITH WATER BY TWO TURBINE WINDMILLS.

been racked by gales and storms, and had been allowed to lose its woodwork and so fall naturally into disuse. However, the essential parts remained as a base, to which homemade parts could readily be attached without cost. (See Pl XXI, *A*.)

Within a few blocks is to be seen the most interesting one in the place. It stands on a slender steel tower, like a veritable toy mill, but it pumps water for the house, for four horses, and for the irrigation of the lawn and garden.

The success of this toy turbine is due in a measure to the fact that it is a reconstructed aermotor. Two sets of galvanized fans and rudders had been demolished, and the last time the iron fans were replaced by thin boards 5 inches wide and 2 feet long wired firmly to the six iron arms. The rudder was left off; accordingly, instead of standing face to the wind, it swings around automatically (because slightly eccentric) and stands back to the wind. Thus the motion is reversed, and the fans run backward, but with no apparent disadvantage.

On measuring the wind velocity with an anemometer, and measuring the water pumped, the following results were obtained: In a 15.5-mile wind this toy mill lifted from a shallow well (12 feet deep) a trifle more than 270 measured gallons in an hour, or at the rate of 6,500 gallons in twenty-four hours, its efficiency being one-eighth horsepower.

Near Kearney is a reconstructed mill whose arms have been slightly lengthened, and to their extremities were nailed light fans made by boys of the farm from the thin sides of boxes. Although this gave a rough and unnatural looking exterior, the small irrigating reservoir stood full of water. The admirably constructed mill of Elmer Jasperson near Ashland, Nebraska (shown in Pl. XXI, *B*), seems to differ in no respect from the best shopmade type, although it had been a total wreck. It was purchased for $3 as it lay on the ground twisted and broken, and hauled to the Jasperson place. At an additional outlay of $7 the bent parts were straightened, the tower rebuilt, and the mill reinstated as good as new, so far as outward appearance and action are concerned.

SHOPMADE TURBINES.

The highest type is the shopmade mill, which is so closely allied to every well-regulated Western home. These mills are inseparable features of every landscape, of every farm, village, and town. One may count as many as twenty-five or thirty mills in view at one time from the car window in passing, and thirty or forty in any town. These mills have given to the country home many of the comforts of the city. They enable small towns to have water systems with standpipes, water mains, and hydrants, a satisfactory domestic water service, and a supply with ample pressure for fire protection at a cost much below that for similar water service in a city.

The windmill and tank are the conspicuous and characteristic landmarks of every siding and station in the prairie. (See Pl. XXII, *A*). Asylums, homes for soldiers, orphans, blind, and feeble minded, and other public institutions in rural districts isolated from city conveniences depend on the windmill. The town pump has given way to the town windmill and tank, which easily furnish water for the public watering trough and the public hydrant.

In villages too small to assume the expense of standpipe, water mains, and hydrants, pressure for fire protection is often obtained by carrying the tower of the public tank as high as need be, and mounting upon it a second tank for use in case of fire. (See Pl. XXII, *B*.) Precaution is generally taken to augment the mill with a good steam, gasoline, or petroleum engine for use in emergency, or in case of a continued calm. This makes an excellent and cheap system. The mill is the main dependence, the engine being pressed into service but occasionally.

In many towns and cities the turbine is used to pump water for fish ponds and ice ponds. In the smaller towns the irrigating pond of summer is turned to good account in winter, in furnishing an ice harvest. In Lincoln, the Moulton Ice Company harvests its ice from three artificial ponds supplied with water by two turbine mills. These same ponds are stocked with several thousand fish. (See Pl. XXIII.)

Under the refining influence of the windmill, the pioneer schoolhouse, first of sod, then of lumber, begins to lose some of its utter barrenness, and sod, trees, and shrubs begin to grow.

ORIGINAL USES FOR SHOPMADE WINDMILLS.

The shopmade mill is often harnessed to homemade water lifters of unique and original design. These are as interesting as the homemade mills themselves, and are worthy of a special report, which the author has in preparation.

One or two examples will illustrate this group sufficiently for the present.

At Milford, on the banks of Blue River, may be seen a large mill and tower (see Pl. XXIV), now in disuse, geared to run an endless chain of 34 buckets, each holding 4 gallons. This method of raising water is one of the oldest as well as one of the best. However, in this instance, the mill is so completely overtaxed as to be rendered useless. Smaller buckets and lighter machinery would doubtless give satisfactory results. The possibilities of this kind of irrigation are great, and every river bank shows some kind of an attempt to pour the water upon the land. Some of these water lifters are driven by the current, some by windmills, and some by horse power or steam power.

At North Platte the natural order of things seems somewhat reversed through the use of a tympanum wheel, run by a large aermotor, instead of by the current. (See fig. 22.) The tympanum is primarily

WINDMILL AND WATER ELEVATOR ON BLUE RIVER, NEAR MILFORD, NEBRASKA.

a current wheel, but in this case, there being no current, its place was supplied by a 12-foot aermotor, which caused the tympanum wheel to revolve once a minute in a good wind and to discharge at each revolution 8 barrels of water through the hollow axis, lifting it 7 feet and irrigating 60 acres. This tympanum is beautifully built and

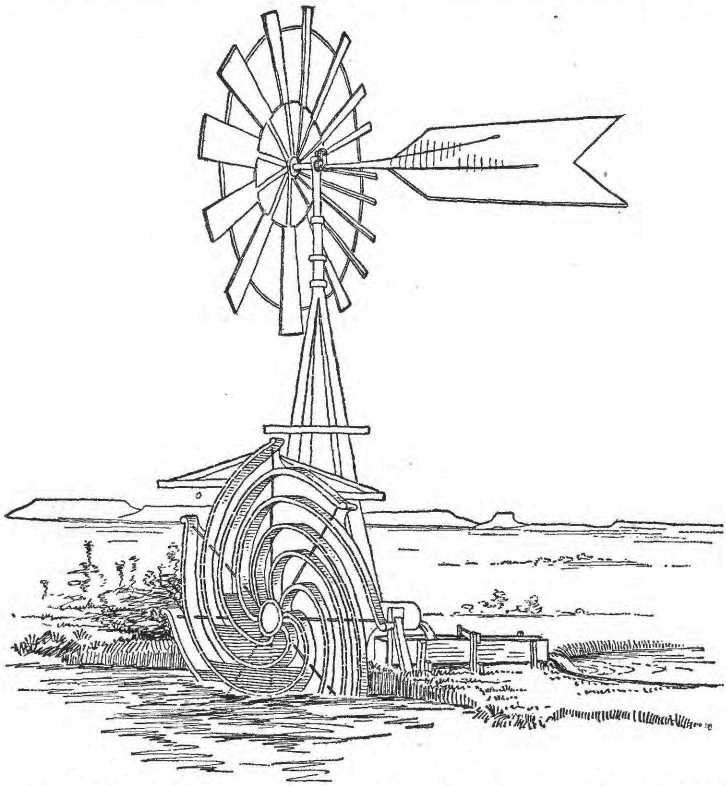


FIG. 22.—Two-foot tympanum water wheel operated by 12-foot aermotor; invented and built by David Thomas, of North Platte, Nebraska.

accurately constructed, but it is not at all unlikely that buckets or even pumps would give equal results at less expense. The cost was $100.

OTHER FORMS OF WATER LIFTERS.

Anticipating a future chapter on the water lifters of Nebraska, the author, knowing the demand for hints on all such matters, can not refrain at this point from mentioning some other water lifters, though foreign to the immediate subject. The principal water lifters other than the windlass, hand pump, windmill, horse-power, gasoline, petroleum, and steam engines are the endless chain and buckets, current wheels of all sizes and makes, Archimedes screws, jacketed screws running at high speed, etc.

The endless chain and bucket, of which there are many makes, is an economic and successful water lifter, easily taken down and set up again, and not easily injured. For short lifts these seem worthy of first consideration.

The water elevator of John W. Karr, 1 mile southeast of Benkelman, Dundy County, is partly homemade and partly shopmade. Taking advantage of the failure of neighbors who had purchased a link-belt elevator at Chicago a few years before, he obtained the working parts for $5, and for about $2 in addition purchased lumber (2-inch plank) for the construction of the woodwork. A second-hand horsepower, with the necessary tumbling shaft, cost $13, and the mill was complete. Digging the well was a matter of a few hours with team and scraper, and the subsequent work was performed with the shovel. A total depth of about 12 to 14 feet was reached, the water standing 6 feet in the well. The well had a diameter of about 8 feet at the bottom, tapering to 5 feet above, tightly curbed with boards. The vertical lift was 7 to 8 feet, and two horses had about the same draft in elevating 27 cubic feet of water a minute as in plowing. The well discharges sand, pebbles, and water in a fitful stream. The sand is fine and works into and fills the well. Over 100 cubic feet of sand and coarse gravel were forced out last summer (1898), silting down the entrance of the irrigating ditch, which had to be dug over repeatedly. The sand here is fine and the delivery of water is too slow to supply the pump, but a few feet lower the gravel is coarse and the supply of water unlimited. This elevator will ultimately be attached to suitable windmill power, so as to use wind or horse power as occasion demands.

Mr. Karr irrigates about 2 acres of garden truck and 10 or 12 acres of alfalfa by contour ditches about 20 feet apart. Though the roots find ample water below, that portion of the field yielded best which was irrigated most, while the portions not irrigated at all were dead at least to the root. The mill has, as it stands—but not at its best—a capacity of 38,000 to 40,000 cubic feet a day according to the owner's measurements, and his claims were verified by the author as long as he watched its operations.

The lift here, which represents the conditions of the region, was scarcely more than 12 to 14 feet. Many failures in the matter of irrigating in this way result, as the author finds, from ignorance and bad management. Those who use intelligence and forethought are successful. Those who dig into fine sand, oblivious of the fact that it delivers water slowly, though the amount is unlimited, abandon the project without attempting to dig deeper or broader, or without tunneling so as to increase the surface for seepage. The fine sand also fills the well rapidly unless proper precaution is exercised. The result is that new elevators are soon for sale at second-hand price, and the man who is capable of maturing his plans gets the benefit of his neighbor's failure.

A. THIRTY-FOOT CURRENT WATER WHEEL ON BRANCH OF HAT CREEK, SIOUX COUNTY, NEBRASKA.

B. THIRTY-FIVE-FOOT CURRENT WATER WHEEL NEAR HOT SPRINGS, SOUTH DAKOTA.

A similar but larger water elevator is that of William James, near Crete, Nebraska. By purchasing Sieman & Schuske's buckets and chains and adapting them to his own power he has a water elevator capable of discharging 2,000 gallons a minute, the lift being 26 feet. Horse power and steam power are used according to the amount of water needed.

Mr. James first began to irrigate by hauling water from the creek and sprinkling it on the land. Finding this work slow and laborious, he built the elevator and soon had 50 acres successfully under ditch. Mr. James at the Nebraska State Fair of 1896 obtained second place for Saline County and received cash prizes to the amount of $300 and other awards to the value of $200.

Wherever there are live streams with good currents the current wheel is very common. Though changed and modified in many ways, the general plan is the same. The force of the current causes the wheel to turn, and in so doing a certain amount of water is caught in boxes or receptacles, carried to the top, and then discharged into a trough. Boxes, paint kegs, barrels, etc., are sometimes pressed into service and attached to the wheel in place of buckets.

The current wheel designed and built by David Hunter near Sutherland, Lincoln County, consists of eight swinging troughs each of 4 gallons' capacity hung to the eight paddles. These are emptied in succession as they come to the top. The cost of construction was $100. Large current wheels are capable of doing extensive work, and are engines of economic importance.

In Sioux County, on a branch of Hat Creek, may be seen a well-built current wheel (shown in Pl. XXV, *A*) 30 feet in diameter and capable of irrigating 15 to 20 acres, and farther north, at Hot Springs, South Dakota, may be seen a magnificent current wheel (shown in Pl. XXV, *B*) 35 feet in diameter, which is said to yield to its owner a cash money rental of several thousand dollars annually. In the figure showing this stately wheel the stream, which is small, though swift, is concealed by the rank growth of weeds and brush.

TRANSMISSION AND STORAGE OF WINDMILL POWER.

It is often found desirable to transmit the energy of the windmill to some other point, perhaps to the milk house or to the barn, in which case the mill, while pumping for the house or barn, may also drive one or more pumps at other points. When the distance is but a few feet the walking beam or the rocker shaft or similar devices are used, but the distance may be too great. The energy of the mill is often transmitted from one field to another, sometimes over hills and down draws. In such cases the energy is transmitted by strong wires attached to wooden quadrants or angle blocks. Though crude, they do good work and are practically as useful as the angle irons. It seems better economy for the busy and well-to-do farmer to purchase these quadrants outright from his nearest windmill house, but for those who can better afford to spend energy and time than money the wooden angle block (see fig. 23) will prove an acceptable substitute for a better article.

If some of the surplus energy of the wind during certain seasons or during the more windy hours of the day could be conserved, it would apparently equalize matters to that extent. The best means to that end at present is literally to bottle it. That is, the windmill must compress the air into stout iron cylinders, or bottles, to be drawn

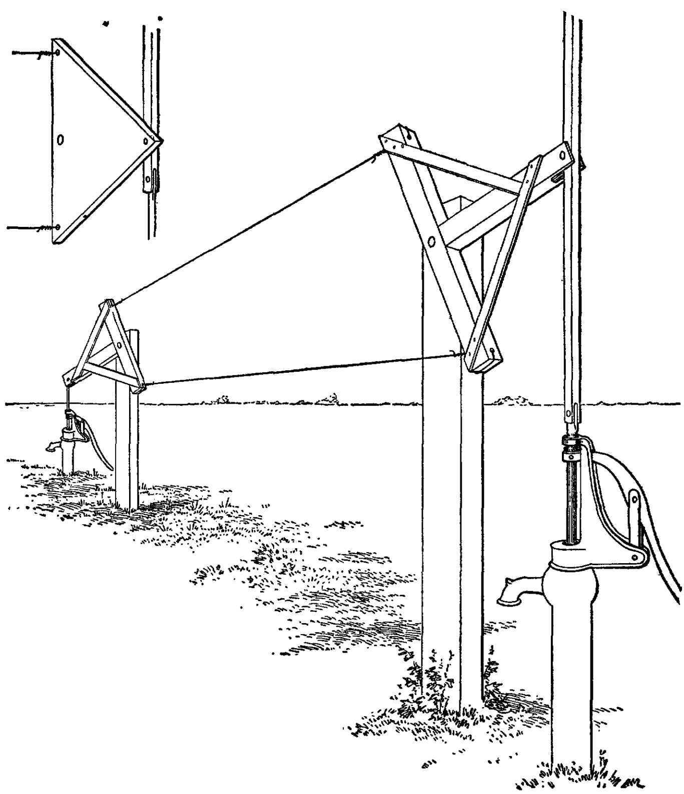


FIG. 23.—Transmission of power of windmill by oscillating wires.

off and used in any way desired. A small stream of compressed air admitted at the bottom of a tubular well often causes the water to flow as if it were an artesian well.

In many of our artesian regions there are countless spots in which water rises under pressure—and in that sense is artesian—but still does not flow over the surface. Such wells, treated to a small stream of compressed air, would flow vigorously like small "spouters." So far as can be learned nothing of this sort has yet been attempted in Nebraska, although it is contemplated. The park board of Omaha has long considered this as a means of converting certain negative artesian wells into positive ones for the improvement of the park system of the city. In the Great Plains, where there is so much energy stored in the winds, a great natural resource seems to be going to waste for lack of development. It may be conserved by using the windmill to charge storage batteries.

PRECIPITATION IN NEBRASKA.

The climate of Nebraska is characterized by a low percentage of cloudiness, by a correspondingly large amount of sunshine, and by a dry and healthful atmosphere, whose chill in winter is less severe and whose heat in summer is less oppressive because of the low humidity.

Situated far inland, there are no great bodies of water to furnish evaporation. Little moisture finds its way from the Pacific slope, because of the Rocky Mountains. The rain-bearing winds come from the southeast, and the ultimate source of precipitation in Nebraska is the Gulf of Mexico. Although rainfall is rather limited, there is compensation in the fact that it comes at the season when crops are growing, and also in the fact that so great a proportion is absorbed and retained in the soil.

Professors Swezey and Loveland, in Bulletin 45 of the Agricultural Experiment Station of Nebraska, have shown that—

of the 23.33 inches of annual rainfall in Nebraska 16.08 inches, or 69 per cent of the entire amount, falls during the five months of the growing season, April to August, inclusive. In order to show how we compare in this respect with other States the following table is introduced. It shows what per cent of the total yearly rainfall occurs/in these same five months in other localities.

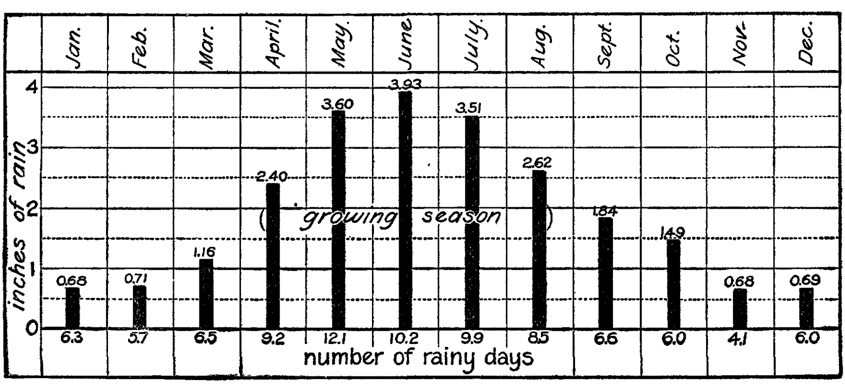


FIG. 24.—Monthly precipitation in Nebraska.

Rainfall during the growing season in various localities.

Station.	Per cent.
St. Louis, Mo	48.00
Cheyenne, Wyo	71.00
Dodge City, Kans	73.00
North Platte, Nebr	72.00
Omaha, Nebr	67.00
Huron, S. Dak	74.00
St. Paul, Minn	61.00
Duluth, Minn	57.00
Davenport, Iowa	55.00
Keokuk, Iowa	54.00
Nebraska in general	69.00

It thus appears that the States of Nebraska, Kansas, Dakota, and Wyoming, with their none too plenteous supply of rainfall, have, on the other hand, the advantage over the States lying farther to the east that a large percentage of this rainfall occurs in the growing season, when it is most useful, and that as we go eastward the percentage gradually falls off, particularly toward the southeast, or, in other words, in the direction toward which the actual amount of rainfall increases most decidedly; so that if we compare the rainfall of the growing season alone in the different localities, Nebraska does not appear in so unfavorable a light as her small yearly rainfall would indicate.

Table showing the annual precipitation in Nebraska and other States.

States.	Inches.
Indiana, to 1894	39.70
Illinois	38.05
Iowa	34.88
Kansas	26.67
Kentucky	45.60
Michigan, to 1896	30.83
Missouri, to January, 1895	37.74
Nebraska	23.33
Six New England States, to 1896	44.51
New York	37.52
North Dakota	18.88
Ohio, fifteen years to 1896	39.46
South Dakota, to 1896	19.97
Wisconsin	32.06
Wyoming, five years to 1896	13.35

SURFACE WATER AVAILABLE FOR IRRIGATION.

The first writer of prominence in Nebraska who advocated irrigation was Mr. Lewis E. Hicks, at that time professor in the University of Nebraska. His paper aroused such vehement opposition from the country press of the State at large that his position in the university was threatened. His opponents even went so far as to threaten the university itself. Hon. William R. Akers, secretary of the State board of irrigation, was among the first to put the question to a practical test, although in the face of open and avowed opposition, by building an irrigation plant in the fall of 1887. Since that time the growth of irrigation in Nebraska has scarcely been surpassed elsewhere; many miles of ditches have been built and many acres of otherwise sterile land brought under cultivation. There are at present in the office of the State board of irrigation 1,000 claims and applications, covering a total acreage of more than 4,375,321 acres for which water is claimed, the increase in land values amounting to ten to twelve million dollars.

Irrigation, wherever it is practicable, settles the matter of subsistence, for it supplies the one and only lacking soil constituent. But expectations must be kept within the bounds of reason, for there is a natural limit to this important element of our soil fertility, because the total supply of available surface water is sufficient to cover but 5,723 square miles, according to careful computation made by Prof. O. V. P. Stout—an area about equal to the combined areas of Scotts Bluff, Banner, Kimball, and Cheyenne counties. Though large, the relative insignificance of this tract as compared with the 77,000 square miles of the State is apparent. This area may be increased somewhat by pumping water from underground sources, which promises most encouraging results.

The development of windmills and other water lifters of all sorts for purposes of irrigation has been also almost as phenomenal as that of the growth of ditches themselves during the last four years, and, because of their wider applicability, bids fair to be of even greater usefulness.

SUPPLY FOR TOWNS AND CITIES.

Surface water, which is an important source of city supply in many of the Eastern States where rivers are perennial and lakes abound, is of little consequence for city and village use in Nebraska, for the obvious reason that few lakes (except ponds) exist and perennial rivers and streams are few. Accordingly but little surface water is furnished for cities and towns, and thus the use of water which must suffer steady and progressive deterioration and contamination is avoided.

The cities and towns along the lower reaches of streams are not condemned to the fate of using the sewage and filth contributed by settlements above, nor of obtaining water from the same lake which receives their offal. Instead, the supply is ground water of almost inexhaustible quantity and superior quality, found in deep, gravelly soils, where extensive sheets of clay preclude the possibility of pollution by surface matter. It is safe to state that this is and must continue to be the source of supply alike for city and country homes.

Cisterns are often built to catch soft water for the bath and laundry, but the use of such water for drinking is very limited. Although the ordinary well water of most of the State is hard, it is not injurious. The hardness is due to lime in solution. Neither is the yellow and turbid water, which has given the Missouri the fitting appellation "The Great Muddy," necessarily injurious. The color is due to clay in mechanical suspension in the water, and its presence affects its appearance rather than its healthfulness. Such inorganic particles can be taken into the system without fear.

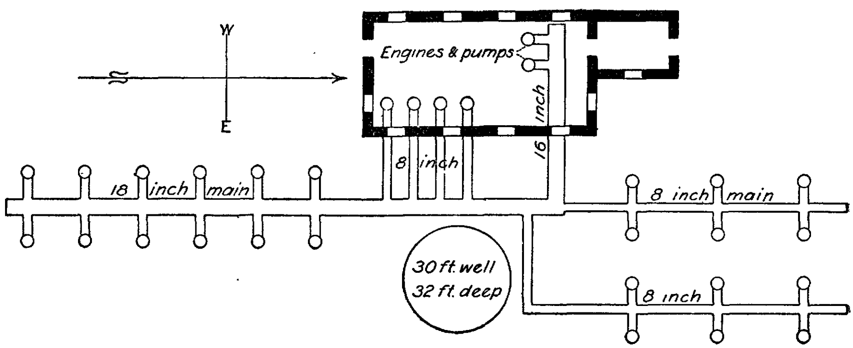


FIG. 25.—Plan of waterworks at Kearney, Nebraska.

The natural and simplest method is to draw city water supplies from streams, as is done in the case of Omaha, where the water is taken from the Missouri far above the city and allowed to stand in settling basins, whence it is pumped into the city mains. Notwithstanding prejudice against the milky color of this water, there is no reason for condemning it, for the upper reaches of this river are still so sparsely settled that the present pollution is unimportant. Interior towns far from any stream, working on the plan that if one well can supply the individual many such can supply a community, dig and connect gangs of wells. On this plan excellent water is furnished to the citizens of Lincoln, Hastings, Kearney, and smaller towns.

Kearney is in the Platte Valley, 22 feet above the level of the river, where an inexhaustible underflow can be had even in shallow wells. From one large 30-foot well, 32 feet deep, and twenty-four tubular wells a supply of water is obtained which can not be lowered and whose quality has given entire satisfaction. (See Pl. XXVI and fig. 25.) This is a source of pure water that can be depended on for years to come.

WATERWORKS AT KEARNEY, NEBRASKA.

At Hastings a 10-inch well, 305 feet deep, yields 40,000 gallons per hour for city use.

The water supply of Lincoln is pumped at three stations—the Rice pumping station, the F street pumping station, and the South street pumping station—from gangs of tubular wells. The Rice pumping station, which furnishes the best water in the city, is situated in the Antelope Valley, at M and Twenty-fifth streets. Water is obtained here from a gang of fifteen tubular wells—in the Dakota Cretaceous—averaging about 135 feet in depth, which supply about 1,200,000 gallons per twenty-four hours.

Mr. Ferdinand Bonstedt, the city engineer, thinks that he notices a slight decrease in the amount of water yielded by these wells. At the F street pumping station a large open well, 50 feet wide by 60 feet deep, was dug through one layer of water-bearing gravel down through clay to a second water-bearing gravel of rapid delivery. In order to increase the water supply a 6-inch tubular well was sunk in the middle of the open well to a depth of 15 feet, and artesian water was struck, but, unfortunately, it proved to be saline. The pipe was capped, but the saline water was under sufficient pressure to force a passage along the sides of the tubing and thence into the open well, rendering the water so salt that a boiler-steel caisson, 5 feet in diameter, was settled around it, and this is pumped out as filled. Nevertheless, the water of this station has grown more salt from year to year, and the well must be abandoned.

About a mile south of this, in the same valley, is the South street station, with a rather complex gang of sixty-eight wells, yielding 1,000,000 gallons per day. Here, too, the salinity of the water has increased to such an extent that the plant is virtually condemned, and test wells are being bored in other parts of the city in the hope of finding water equal in quality to that furnished by the Rice station.

West of Lancaster County there is little fear of encountering saline water unless city wells are dug to unusual depths, although as far west as Hastings, in Adams County, saline water was found at about 1,000 feet in 1887, and the well was necessarily abandoned.

SALT WATER.

Throughout southeastern Nebraska salt wells are so numerous that it is often uncertain how to avoid them. In pools, surface wells, and deep wells a strong brine is often met. The most conspicuous salt marsh is that of the extensive flat on Salt Creek, near West Lincoln, which has been retained by the State as public land.

Here at one time a considerable industry sprang up, and, as the early founders of the State had hoped, salt was produced and shipped to neighboring States. Here the early freighters to the mountains bought their supply. With the discovery of the salt beds of Kansas, however, this industry could no longer survive. This basin, which is a mile or two across, is apparently depressed below the surrounding level, and one side has been cut away by a small drainage line. This has since been dammed so as to form a salt lake and a pleasure resort, and the basin is now occupied by a lake, which is about 1½ miles across. Numerous salt springs rise from its bottom and along its sides, thus supplying it with salt water. In addition, the abandoned test well (bored to a depth of 2,463 feet) is feeding out into it a 6-inch stream of salt water. In ordinary wells it is often found that fresh water can be drawn from the top and salt water from the bottom. The fresh water floats because of its lower density as compared with salt water. Considerable care is exercised in such cases in lowering the well bucket, so that the water may be agitated as little as possible in order to prevent the salt and the fresh water from becoming mixed. In one well the pump is so arranged as apparently to yield salt water or fresh water from the same pipe by placing one pipe inside of the other.

Wells in southeastern Nebraska in the region of the Carboniferous below a depth of 150 feet are liable to be or to become saline. Below this to a depth of 500 to 1,000 feet or more salt water is to be more or less expected. The salinity is greatest at 250 to 300 feet. It is strong at 500 feet, and the water is distinctly salt at 1,000 feet. When the deep well at Beatrice, 1,260 feet, was bored for the city supply the quantity but not the quality of water was expressly stipulated in the contract. When all the requirements were met the city refused to honor the bill because the water was salt. Losing the suit which followed, the contractor proceeded to make the best of a bad job by pulling up the pipe of this artesian well for use elsewhere. This would undoubtedly have saturated the drift of the region, and so have rendered worthless all the wells in and around Beatrice, but this was promptly averted by purchasing the pipe from the contractor. This saline well was still flowing when last visited.

The Riverview Park artesian well in Omaha, 1,060 feet deep, passed almost through the saline layer, but still is noticeably brackish.

At Lincoln a flowing well of very strong salt water was struck at a depth of 560 feet (boring continued to 1,060 feet), and is now utilized as a public fountain. At the Sulpho-saline Baths the water for the great swimming tank rises and flows by its own pressure from wells 566 feet deep. This water is very salt. The F-street and the South-street pumping stations yield water of such salinity as to cause widespread and continued complaint from the parts of the city which are supplied by these stations. Even the Rice pumping station, which furnishes water of high repute, is said to be sufficiently saline at times to cause comment, and a fear, which may not be wholly groundless, is entertained that the city water supply may grow more saline from year to year until it will become a serious question from what source to draw the supply. There has been increasing salinity in the case of two pumping stations, and their abandonment seems to

BURLINGTON BEACH, NEAR LINCOLN, NEBRASKA.

Illustrating the utilization of the saline water of the salt basin.

be but a matter of time. With but three exceptions, the salt wells are confined to those counties of southeastern Nebraska which belong to the Carboniferous.

With the failure of the salt works, due to the discovery of salt in Kansas, the salt marshes went into disuse, and stood as waste public land. Recently they have been leased from the State by an enterprising company and by damming up one side of the salt basin the water is set back about 1½ miles, making a salt lake. Pavilions, bath houses, and restaurants have been built, a small steamer and numerous sail and row boats have been added, and the whole bears the rather pretentious name of Burlington Beach (see Pl. XXVII). For inland people this becomes a pleasure and health resort of importance, and the enterprise promises to be increasingly useful and remunerative. So far as can be learned the first recognition of the hygienic possibilities of the saline water and its first utilization was by a former hotel proprietor in Lincoln, who is reported to have earned a considerable fortune, due largely to the salt baths which his hotel furnished. These salt baths were deservedly popular and enjoyed a local reputation, especially among those afflicted by rheumatism. At the present time their place is taken by the sanitarium of Doctors M. H. and J. O. Everett, called the Sulpho-saline Baths. This is an expensive and important institution, fitted with a great plunge and swimming tank 50 by 140 feet, and 4 to 10 feet deep, with baths and appliances of every description, representing an investment of $100,000. Two artesian salt wells, one 566 feet and the other 450 feet deep, fill the great tank, the water passing first through a heated coil and thence into the tank by its own pressure. This is the most important use to which salt wells in Nebraska have yet been put. In several cases the waters of salt wells are bottled and sold, thus presenting a commercial aspect. The salt well, known as the Lloyd Mineral Well, at Union, Nebraska, is one of the best known in this connection. Its depth is 500 feet and the water is raised by a gasoline engine. Another economic feature is the proposed use of this water in certain manufacturing processes.

Several firms have already visited the region and speak favorably of locating in southeastern Nebraska, where salt wells can be obtained in connection with good shipping facilities. On the Government square in Lincoln the salt water fed from a 1,060-foot artesian well is used to supply the public fountain. This water is carried away in bottles and pails because of real or imaginary curative properties, which almost any mineral water is reputed to have. The slightly saline water of the Riverview Park well at Omaha is put to a similar, though much larger use, because of the greater volume of water supplied. It supplies a public fountain in the park, from which a lively little cascade falls into a lake. The economic importance of this one well to the city of Omaha may be better judged when it is learned that an equal amount of water supplied by the water company at the lowest possible wholesale water rate would cost the city $5,000 annually.

A rather novel if not unique method of irrigating by means of salt water is in vogue with market gardeners along Salt Creek. The water of this creek being too saline for direct application to the land, it is used to turn paddle wheels, which at sight might be mistaken for current wheels. Here is an example of the utilization of salt water in running undershot wheels and pumping fresh water for irrigation.

BLOWING WELLS.

One rather phenomenal class of wells found throughout a large portion of the State, especially south of Platte River, deserves particular notice, and is worthy of the critical and long-continued study which it is hoped it may yet receive. These wells are known by various names, "blowing," "roaring," "breathing," "singing," or "weather" wells, according to the widely separated communities in which they occur. It goes without saying that these wells are held in doubt elsewhere, but the fact of their existence is established beyond all question. In some communities, noticeably those of Jefferson County, all such wells are readily distinguished at a distance because of the mound of earth heaped up around the curbing and pump to check the wind. Frequently they are banked up with snow instead, and this soon becomes melted and riddled by numerous blowholes.

The attention of the author was first called to this matter by the numerous inquiries sent to his office for explanation of and the remedy for the freezing of well-protected pipes in wells at the apparently impossible depth of 30, 50, 60, 80, and even 120 feet below the surface. In every instance these were reported as roaring wells. There can be no possible doubt about the freezing of these pipes and but little doubt as to the cause.

Reports have come in from about twenty counties, distributed pretty evenly over the State, chiefly south of the Platte. The information is derived from landowners, farmers, well diggers, ministers, principals of schools, civil engineers, and students whose fathers own such wells, the only difference in the reports being that which arises from difference of observation. These accounts agree with personal observations. There are periods when these wells blow out for consecutive days and an equal period when they are reversed. This is tested with the flames of candles and by dropping paper, chaff, feathers, etc., into the casing to see it blown out with some force or drawn in. It is further stated that blowing often indicates high or low conditions of barometer, and that some wells blow most audibly when the wind is from the northwest, whereupon water rises to a higher level in the well than before; but when the conditions are reversed the air is drawn in, and in most reported wells the water is lowered. Many observers notice a reverse of the current according as it is morning or evening, and according as the temperature is high or low. During the progress of a low-barometer area over one of these regions the wind is expelled from blowing wells sometimes violently and with a noise distinctly audible for several rods. Consequent to the following of a high-barometer area the blowing becomes rapidly less until the current is reversed, when the high-barometer area is central over the region.

Steam or water vapor rises from the curbing, melting the frost or snow for several inches around it. Beyond this the well may be encircled by several feet of frost from the condensed vapor. Shortly after the current is reversed the thawed circle freezes again. Water vapor, coming from the stratum of invariable temperature, in winter is warmer when expelled than is the outside air. This may explain the fact that the pipes, if not too badly frozen, are often thawed out when the well blows. It is said that commonly inhalation (which carries the surface temperature to the bottom of the well, thus freezing the pipes), precedes the phenomenon of exhalation (which carries vapor at the average temperature of about 56°, and sometimes thaws the frozen pipes).

Experience has taught the people that the blowing of their wells is premonitory of an approaching storm; hence the name "weather" wells. This is an entirely reasonable and correct observation, for the falling barometer signifies a change of weather. The blowing means a low-barometer area, the sucking a high-barometer area. It is interesting, in this connection, to notice that the periods of most pronounced or unusual exhalation or inhalation are coincident, respectively, with periods of exceptionally low and exceptionally high barometer areas. The author has sent blanks to owners of blowing wells, requesting them to report the days and hours when their wells begin to blow, when the blowing is at its maximum, when the current is reversed, and when the indraft is at its maximum. After observations covering two or three months have been received comparison will be made with the barometric chart.

Professors Loveland and Swezey, of the Signal Service Station of the University of Nebraska, have made observations on such a well in Perkins County, the owners recording the hour when the blowing or sucking began. These, when compared with the records of the barometer, were exactly coincident. The citizens have elaborated many explanations, some of them as interesting as ingenious. Some reason that the blowing is plainly due to the liberation of natural gas; that natural gas is from petroleum; that petroleum is the natural distillation from great coal fields, and staking their fortune on this original reasoning have spent no small sum, besides valuable time, in prospecting for coal. A few, noticing a change of current every twelve hours—that is, morning and evening—think the blowing wells are due to tidal action of the sheet water, considering the sheet water as a great subterranean lake. They should recall that the effects of tides on the Great Lakes themselves is scarcely appreciable; what then could it be in the sheet water?

The phenomenon is most generally attributed to atmospheric pressure, which is probably the true but not necessarily the sole cause. The study of a representative section of wells in southeastern Nebraska is important and suggestive. Below 50 to 100 feet of soil and subsoil is a layer of dense, though thin, limestone about 4 inches in thickness. When this covering to the water-bearing gravel below is penetrated, water, under slight pressure, rises about 1 foot. The water-bearing layer is very porous and water is delivered through it readily. More or less air must always be inclosed in such, and especially between it and the roofing layer over the loose material.

It is plain that the air above and the air inclosed in the rock and gravel below are alike subject to the fluctuation of the barometer. If the surface air is rendered less dense by a low barometer, the air below will pass out by an opening, natural or artificial, until equilibrium between the rarer and the denser air is established, when they remain stationary. The reverse effect follows a high-barometer area. The author can not believe that this would account for the force displayed in the expulsion of air. Instead, the energy displayed seems due to the air forced out by the rising of the water below. Any force, barometric or otherwise, which would raise the water level in this layer would displace a certain amount of air. On the other hand, a lowering of the water table would admit a certain amount of air, but freedom of egress and ingress is retarded by the roofing layer of limestone, which is perforated here and there by an occasional well, and from such openings the air is expelled or drawn in. Confine this over a wide area, and it is apparent that a slight rise in water level would expel air from a well for several consecutive hours or even days. There is probably such close hydrostatic connection in the sheet water of the State that it is everywhere sensitive to differences of atmospheric pressure, and the difference is made sensible in certain localities by blowing or sucking wells. Awaiting the time when continued study shall have made exact explanation of this phenomenon possible, it is safe to attribute it to atmospheric pressure; but this is not the sole cause. The immediate effect is not so much the result of any one cause as of several. The observation is often repeated that wells blow and water rises appreciably when the wind is from the northwest. The wind is not so directly the cause as are the areas of low and high barometer, which travel ordinarily in this direction accompanied by more or less wind. The wind may, however, be the immediate cause in some cases, especially in those wells adjacent to Platte River, and an indirect cause in others. At times, when a strong wind from the northwest prevails for hours, its impact against the river water—that is, the friction of the wind—is sufficient to drive the shallow water of Platte River across its bed, leaving the irrigation ditches, the sand bars, and the interlacing channels on the north side dry, while those on the south side are flooded. That is, the waters are piled up here, as it were, and equilibrium is disturbed. To that extent there must be readjustment. This is rendered sensible in the immediate vicinity by water rising in wells, at a distance by a wave of transmitted energy, which can but affect to a certain extent every portion of the underflow of the Platte. This may show itself in an appreciable rise of water and consequent displacement of air from porous strata, and an appreciable rise over a wide area might expel a large volume of air. Tests show that it is air, not gas, that is expelled. While exact records have been kept respecting blowing wells as far west as Perkins County, those farther east in Jefferson County, probably the most numerous and best known in the State, have received no critical study as yet.

Mr. Cassius A. Fisher, assistant in the department of geology, was sent to visit this region December 16, 1896, just as a low-barometer area was central over this spot, and the blowing in all the wells of the neighborhood was most pronounced. This continued in a diminishing ratio during the night and until noon the following day. Then the current was slowly reversed consequent to an approaching high-pressure area. Mr. J. M. Rohrbaugh, a student in the department, reports a blowing well on the farm of his father, Mr. C. W. Rohrbaugh, as follows: The well is situated 4 miles southeast of Jansen, in Jefferson County, sec. 1, T. 2, R. 3 east of the sixth principal meridian. The well was bored to a depth of 130 feet; depth of water 120 feet. It blows out before storms, especially when the wind is from the northwest. It has frozen repeatedly to a depth of 120 feet, that is, to the water level. Water froze in the pipes down to this depth three times in one week during the winter of 1895, and the pipe had to be removed and thawed out each time. There are two such wells, one of which has been abandoned, and over the top of the casing has been fitted a keg with a hole so bored that it whistles when the current blows out. The well sucks in air during cold weather, and then it is that pipes freeze at unusual depths.

They are of such common occurrence in Jefferson County that little is thought of the phenomenon. Mr. Rohrbaugh has furnished the author with a map showing the blowing wells near Jansen. Mr. Cassius A. Fisher reports such a well, known to him from his childhood, on the farm of his father, Mr. M. C. Fisher, six miles east of Fremont, in Saunders County. The well was 60 feet deep, and on a hillside. They called it the "singing" well, because the sound exactly resembled the singing or simmering of a teakettle. The blowing often continued for three consecutive days; at the end of that time water stood several feet higher in the well, as they could tell by lowering the well bucket.

The "breathing" well of Joseph Henggler, of Columbus, Platte County, represents very nicely this type of wells. It has been reported in person by the owner and by at least six to eight different neighbors. They have long been familiar with the fact that the air was drawn in during certain seasons and blown out during others, and with the difficulty from the freezing of the pipes; the water escape has been lowered from 10 feet, where it was first placed, to 20 feet, then to 40, and finally to 50 feet, which was about on the water level, the well being 60 feet deep. The pipe was frozen at the depth of 50 feet. Mr. Henggler has kept a thermometer by his well, and has been able to make pretty close observations. "When the temperature stands at 32° a rise of 1° will cause a current to blow out and a fall of 1° to blow in." Finding that the well was freezing, he undertook to stop the ingoing current by banking up the well curbing with manure and straw from the barn. This was soon blown away. Then straw with a layer of earth was placed over the curbing. Finally the "imprisoned wind" blew around the curbing to such an extent that it hollowed out a considerable basin. After several years the well was abandoned and a second well dug, which has caused the owner, according to his account, almost as much trouble. In Franklin County exactly similar wells are reported. An assistant has visited and reported a well near Macon which has frozen in winter to a depth of 80 feet, because of the indraft of cold air. He also reports of the same well that when the wind is from the northwest the water is raised about 18 inches, and when in the opposite direction the water is lowered about 18 inches.

In Phelps County, 3 miles north of Phelps Center, there are blowing wells in which the current of air is out or in, according as the wind is from the north and northwest or from the south and southeast. Mr. J. F. O'Brien, engineer of the irrigation canal at Kearney, has seen these wells, and has told the author personally of them and of blowing wells found in Lincoln County. According to his account he has seen numerous wells of this type, and they are usually found in loose sand and gravel south of the Platte.

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1895.

Sixteenth Annual Report of the United States Geological Survey, 1894–95, Part II, Papers of an economic character, 1895; octavo, 598 pp.

Contains a paper on the public lands and their water supply, by F. H. Newell, illustrated by a large map showing the relative extent and location of the vacant public lands; also a report on the water resources of a portion of the Great Plains, by Robert Hay.

A geological reconnoissance of northwestern Wyoming, by George H. Eldridge, 1894; octavo, 72 pp. Bulletin No. 119 of the United States Geological Survey; price, 10 cents.

Contains a description of the geologic structure of portions of the Bighorn Range and Bighorn Basin, especially with reference to the coal fields, and remarks upon the water supply and agricultural possibilities.

Report of progress of the division of hydrography for the calendar years 1893 and 1894, by F. H. Newell, 1895; octavo, 176 pp. Bulletin No. 131 of the United States Geological Survey; price, 15 cents.

Contains results of stream measurements at various points, mainly within the arid region, and records of wells in a number of counties in western Nebraska, western Kansas, and eastern Colorado.

1896.

Seventeenth Annual Report of the United States Geological Survey, 1895–96, Part II, Economic geology and hydrography, 1896; octavo, 864 pp.

Contains papers on "The underground water of the Arkansas Valley in eastern Colorado," by G. K. Gilbert; "The water resources of Illinois," by Frank Leverett; and "Preliminary report on the artesian areas of a portion of the Dakotas," by N. H. Darton.

Artesian-well prospects in the Atlantic Coastal Plain region, by N. H. Darton, 1896; octavo, 230 pp., 19 plates. Bulletin No. 138 of the United States Geological Survey; price, 20 cents.

Gives a description of the geologic conditions of the coastal region from Long Island, N. Y., to Georgia, and contains data relating to many of the deep wells.

Report of progress of the division of hydrography for the calendar year 1895, by F. H. Newell, hydrographer in charge, 1896; octavo, 356 pp. Bulletin No. 140 of the United States Geological Survey; price, 25 cents.

Contains a description of the instruments and methods employed in measuring streams and the results of hydrographic investigations in various parts of the United States.

1897.

Eighteenth Annual Report of the United States Geological Survey, 1896–97, Part IV, Hydrography, 1897; octavo, 756 pp.

Contains a "Report of progress of stream measurements for the year 1896," by Arthur P. Davis; "The water resources of Indiana and Ohio," by Frank Leverett; "New developments in well boring and irrigation in South Dakota," by N. H. Darton; and "Reservoirs for irrigation," by J. D. Schuyler.

1898.

Nineteenth Annual Report of the United States Geological Survey, 1897–98, Part IV, Hydrography, 1899; octavo, 814 pp.

Contains a "Report of progress of stream measurements for the calendar year 1897," by F. H. Newell and others; "The rock waters of Ohio," by Edward Orton; and "Preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian," by N. H. Darton.

Water-Supply and Irrigation Papers, 1896–1899.

This series of papers is designed to present in pamphlet form the results of stream measurements and of special investigations. A list of these, with other information, is given on the outside (or fourth) page of this cover.

Survey bulletins can be obtained only by prepayment of cost, as noted above. Postage stamps, checks, and drafts can not be accepted. Money should be transmitted by postal money order or express order, made payable to the Director of the United States Geological Survey. Correspondence relating to the publications of the Survey should be addressed to **The Director, United States Geological Survey, Washington, D. C.**

WATER-SUPPLY AND IRRIGATION PAPERS.

1. Pumping water for irrigation, by Herbert M. Wilson, 1896.
2. Irrigation near Phœnix, Arizona, by Arthur P. Davis, 1897.
3. Sewage irrigation, by George W. Rafter, 1897.
4. A reconnoissance in southeastern Washington, by Israel C. Russell, 1897.
5. Irrigation practice on the Great Plains, by E. B. Cowgill, 1897.
6. Underground waters of southwestern Kansas, by Erasmus Haworth, 1897.
7. Seepage waters of northern Utah, by Samuel Fortier, 1897.
8. Windmills for irrigation, by E. C. Murphy, 1897.
9. Irrigation near Greeley, Colorado, by David Boyd, 1897.
10. Irrigation in Mesilla Valley, New Mexico, by F. C. Barker, 1898.
11. River heights for 1896, by Arthur P. Davis, 1897.
12. Water resources of southeastern Nebraska, by Nelson Horatio Darton, 1898.
13. Irrigation systems in Texas, by William Ferguson Hutson, 1898.
14. New tests of pumps and water lifts used in irrigation, by O. P. Hood, 1898.
15. Operations at river stations, 1897, Part I. 1898.
16. Operations at river stations, 1897, Part II, 1898.
17. Irrigation near Bakersfield, California, by C. E. Grunsky, 1898.
18. Irrigation near Fresno, California, by C. E. Grunsky, 1898.
19. Irrigation near Merced, California, by C. E. Grunsky, 1899.
20. Experiments with windmills, by Thomas O. Perry, 1899.
21. Wells of northern Indiana, by Frank Leverett, 1899.
22. Sewage irrigation, Part II, by George W. Rafter, 1899.
23. Water-right problems in the Bighorn Mountains, by Elwood Mead, 1899.
24. Water resources of the State of New York, Part I, by George W. Rafter, 1899.
25. Water resources of the State of New York, Part II, by George W. Rafter, 1899.
26. Wells of southern Indiana, by Frank Leverett, 1899.
27. Operations at river stations, 1898, Part I, 1899.
28. Operations at river stations, 1898, Part II, 1899.
29. Wells and windmills in Nebraska, by Erwin Hinckley Barbour, 1899.

In addition to the above, there are in various stages of preparation other papers relating to the measurement of streams, the storage of water, the amount available from underground sources, the efficiency of windmills, the cost of pumping, and other details relating to the methods of utilizing the water resources of the country. Provision has been made for printing these by the following clause in the sundry civil act making appropriations for the year 1896-97:

Provided, That hereafter the reports of the Geological Survey in relation to the gauging of streams and to the methods of utilizing the water resources may be printed in octavo form, not to exceed 100 pages in length and 5,000 copies in number; 1,000 copies of which shall be for the official use of the Geological Survey, 1,500 copies shall be delivered to the Senate, and 2,500 copies shall be delivered to the House of Representatives, for distribution. [Approved June 11, 1896; Stat. L., vol. 29, p. 453.]

The maximum number of copies available for the use of the Geological Survey is 1,000. This number falls far short of the demand, so that it is impossible to meets all requests. Attempts are made to send these pamphlets to persons who have rendered assistance in their preparation through replies to schedules or donation of data. Requests specifying a certain paper and stating a reason for desiring it are granted whenever practicable, but it is impossible to comply with general requests, such as to have all of the series sent indiscriminately.

Application for these papers should be made either to members of Congress or to

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