DOMINION WATER POWER BRANCH
DEPARTMENT OF THE INTERIOR
OTTAWA, CANADA.

WATER RESOURCES PAPER No. 12.

SMALL WATER POWERS

BY
A. M. BEALE, B.Sc.,
Engineer.

Prepared under the direction of the Superintendent of Water Power

Appendix No. 13, Part VIII, Annual Report 1914

OTTAWA
GOVERNMENT PRINTING BUREAU
1915

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REPORT

ON

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OTTAWA, March 31, 1914.

J. B. CHALLIES, Esq.,
Superintendent, Water Power Branch,
Ottawa.

SIR,—I have the honour to submit a Report on Small Water Powers compiled by the undersigned as a result of investigations carried on in the field during the past fiscal year.

I have the honour to be, sir,
Your obedient servant,

A. M. BEALE.

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REPORT ON SMALL WATER-POWERS.

The water-power studies were made during an inspection trip which I made during the last three months of 1913, and the study of other small powers—oil, gasoline, etc.—has been made since my return to Ottawa. For convenience it has seemed advisable to divide my subject into two parts, the first deals with the inspections made in the West, while in the second part the problem of "power for the farm" has been dealt with. It cannot be claimed that any definite solution of this problem has been reached, the various alternatives have been considered fully—perhaps too fully—with the idea of submitting all the available evidence for those interested to make their own deductions.

It should be remembered that cost figures for small powers are extremely hard to obtain with any accuracy; original cost figures are but seldom available, and actual annual cost data never. Manufacturers supply figures of the latter founded on certain percentage allowances for overhead charges, and upon figures for fuel consumption founded on test; actually these charges must vary through very wide limits, depending on the requirements and skill of the purchaser.

PART I.

Disregarding the chronological order of inspection I will deal first with the actual plants visited, namely:—

Canadian Pacific Railway plant at Lake Louise, Alta.
" " Glacier, B.C.
Mount Stephen Mines Plant near Field, B.C.
Municipal Plant, Armstrong, B.C.
Private Plant at Spences Bridge, B.C.
Small Saw-mill at Louis Creek, North Thompson River, B.C.

LAKE LOUISE, ALTA.

This plant is situated about one-half mile from the chalet, and supplies current for lighting the chalet and the station at Laggan. This is practically a new development, for very little of the old remains. A concrete bridge, recently constructed at the mouth of the lake, was designed with spillway sections between the bridge piers; only a small degree of regulation is desirable as this lake is situated in the Rocky Mountains park, and anything detrimental to the scenery must be avoided.

Water is brought from lake Louise in a 20-inch wood stave pipe 2,800 feet to the power-house. The actual fall in this distance is 140 feet, a portion of this, however, is wasted in pipe friction. The pipe line is designed for 100 horse-power, and should more power be required another pipe would be necessary.

The turbine is a 24-inch Morgan-Smith wheel running at 600 r.p.m. and rated at 100 h.p., it is belted to a 75-k.w., 3-phase generator, with a separate exciter on the same shaft, these running at 1,200 r.p.m. Current is transmitted at 2,500 volts, being transformed to 125 volts at the chalet and at Laggan station.

This plant would probably compare favourably as to cost with any rival source of power, though data on this point were not available. In any case, cost is of secondary importance here, and ordinary considerations of dollars per horse-power do not apply; electricity available without noise, smoke, or unsightly buildings, is a great asset to a tourist resort, where the transient population can and does spend freely, and where every convenience has a bearing on the general attractiveness of the resort.

The demand for power is heavy only during the summer tourist season, and it is possible that, even with the small degree of regulation available on lake Louise, a larger amount of power could be developed at this season if required.

In the development of tourist centres in the Dominion parks, and in locating new resorts, the existence or otherwise of a suitable small water-power should be taken into account.

GLACIER, B.C.

This objective for tourists is situated on the western slope of the Selkirks, the main attraction being the famous Illecillewaet glacier. The Canadian Pacific Railway has a station and comfortable hotel, and it is for lighting these buildings that a small power-plant has been installed on the creek flowing from the glacier.

Owing to the deep snow, I was unable to make as thorough an examination as was desired, and the weather prevented the taking of good photographs. The following particulars have been courteously supplied by Mr. McQuarrie, the resident engineer of the Canadian Pacific Railway at Revelstoke.

A 12-foot concrete dam has been constructed across the Glacier creek and forms a forebay, the intake is a 24-inch pipe reduced just below the dam to 18-inch, and a wooden stave pipe of this diameter 1,000 feet long carries the water to the power-house.

The power-house is a 17-foot by 21-foot frame building, 10 feet to ceiling, constructed on a solid rock foundation levelled up with concrete.

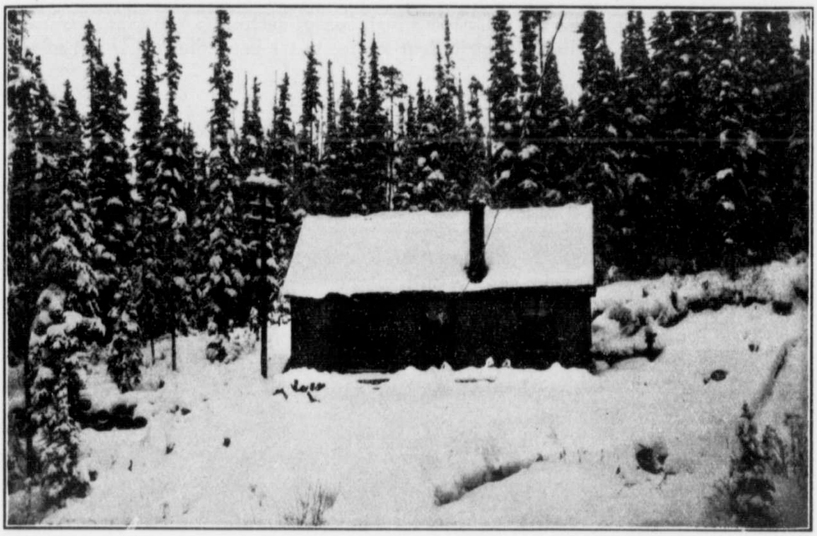
The water wheel is a Morgan-Smith turbine running at 900 r.p.m., it has a 24-inch intake, 2⅜-inch shaft with two 18-foot pulleys driving two dynamos; these are 25 k.w., 125 volts, shunt-wound, bi-polar machines running at 1,050 r.p.m.

The transmission line consists of two No. 00 solid wires on 25 foot poles, with double cross-arms and strain insulators at each end, the line being 1,800 feet long.

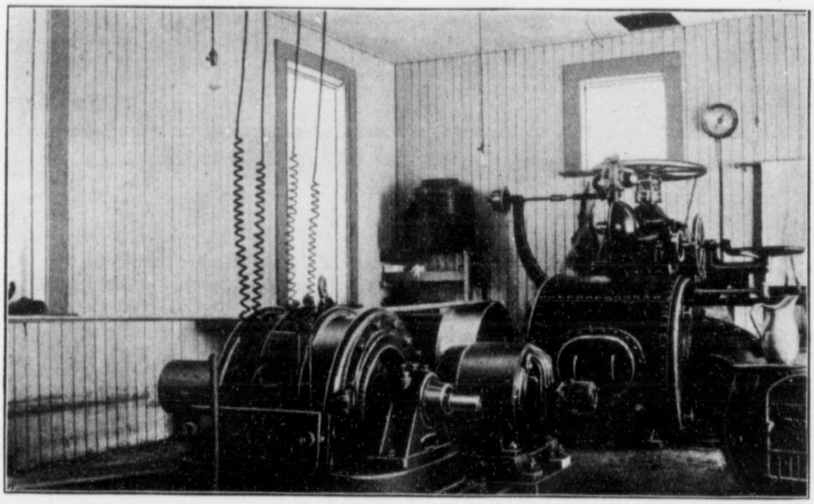
The water supply is very irregular, but sufficient to run the plant all the year round. Heavy freshets occur during the hot season. The working head is 90 feet.

Cost.

Two dynamos at $600	$ 1,200 00
Turbine (about)	500 00
Switchboard complete	250 00
Belting and cost of installing in power-house	200 00
Cost of pole line (including construction)	500 00
Cost of dam	4,500 00
Cost of power-house and foundations	1,000 00
	$8,150 00



Small Water Power. Lake Louise Development. Power House.



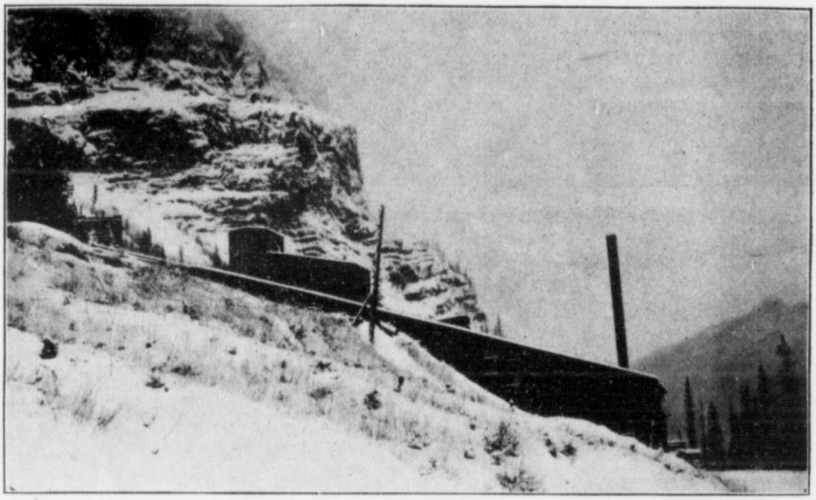
Small Water Power. Lake Louise Development. Interior of Power House.

This cost may be considered a trifle high, which would be chiefly due to the inaccessibility of the plant, and the consequent high cost of getting in material; when we consider the value of a reliable electric light service to the hotel the cost is not excessive.

MOUNT STEPHEN MINES, B.C.

Ore mined on Mount Stephen is brought down by an aerial tramway to the mill, which is situated about 3 miles east of Field and just above the Canadian Pacific Railway track.

The power for the mill is obtained from Cathedral creek in the summer, but a 100 h.p. steam engine is used when the mill is operated during the winter; last winter it was closed down.



Small Water Power. Mount Stephen Mines, Field, B.C. Concentration Plant operated by water power.

Here, as at Glacier, weather conditions and the depth of snow rendered out of door measurements impracticable, and the following figures are merely approximate.

Cathedral creek is fed by the glacier between Mount Stephen and Cathedral mountain; on this creek a 9-foot dam has been constructed to form an intake, and a 12-inch wood stave pipe conducts the water 1,500 to 1,700 feet to the mill, where it drives a 100 h.p. Pelton wheel under a head of some 300 feet.

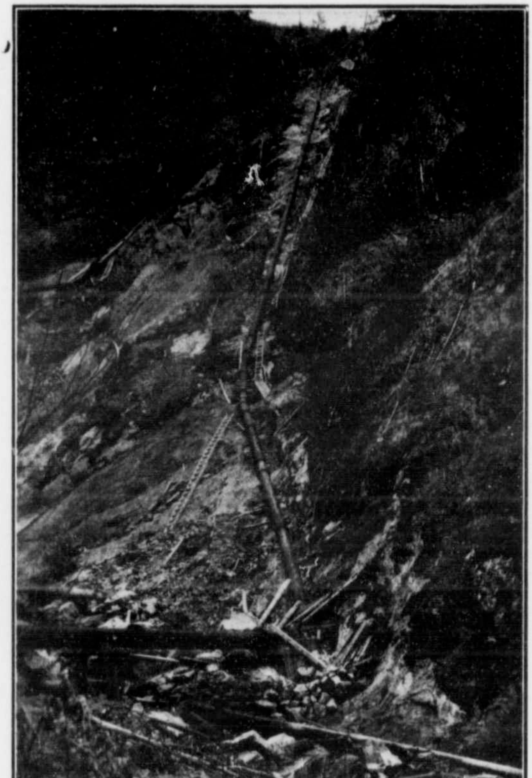
The wheel is securely set upon a concrete foundation, and the driving pulley, 3 feet diameter, is belted to the main shafting, from which all the machinery in the mill is driven.

The head could be increased considerably by placing the machinery lower down the mountain side, but for the purpose for which it is required it would be inconvenient to do so. The stream is being studied by the British Columbia Hydrographic Survey, and present information leads to the belief that there is practically no winter flow, the water-power being available only during June, July, August, and September.

Mr. John A. Thompson, manager of the Mount Stephen mines stated that the development cost approximately as follows:—

1,700 feet pipe line	$1,500 installed.
Dam	600
Pelton wheel (100 b.h.p.)	1,800
	$3,900

He further stated that, in four months' steady operation, the saving on the steam plant would amount to $4,000 or practically the capital invested.



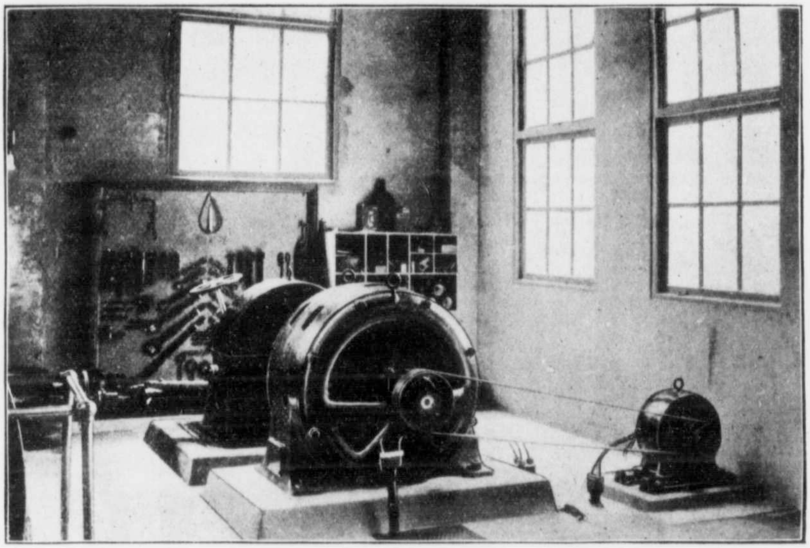
Small Water Power. Municipal Plant, Armstrong, B.C.
Pipe line.

ARMSTRONG, B.C.

This city has a thoroughly up-to-date municipal plant on Fortune's creek, 3 miles from the city. For nine months of the year the water-power of this creek supplies all demands, during the balance of the year a Diesel engine auxiliary set supplies any deficiencies, and also acts as an emergency plant at all seasons. This plant is particularly interesting for, to quote the *Electrical News* of November 1, 1913: 'The revenue from the electric plant for the last year was approximately eleven thousand dollars, or over seven dollars per capita. A very considerable portion of this is due to the general use of fans and heating appliances. The system is entirely self-sustaining, and is being extended to all agricultural districts within a radius of five miles, the ranches being quick to seize the opportunity of improving their property and rendering home life more attractive to the younger generation.

The water-power plant was purchased from the Armstrong Light and Power Company, and completely remodelled. A new power-house has been built, the greater portion of the wooden stave pipe line has been replaced by a steel pipe, and a new Pelton wheel purchased.

The water-power section of the plant is as follows: A small timber dam on Fortune's creek about three-quarters of a mile above the power-house forms an intake; a wood stave pipe leads the water nearly one-quarter of a mile to the edge of a steep cliff, where the new 10-inch steel pipe begins. The water reaches the power-house



Small Water Power. Municipal Plant, Armstrong, B.C. Pelton Wheel and Dynamo.

under a head of 550 feet, and drives a 150 h.p. Pelton wheel direct coupled to a 100-k.w. Canadian General Electric generator running at 900 r.p.m. The auxiliary set consists of a 200 b.h.p. Carel-Diesel engine direct connected to a 125-k.w. Swedish General Electric generator. Both generators are three phase, 60 cycle, 2,500 volt machines and can be operated singly or in parallel. The switchboard consists of one feeder and two generator panels.

The costs of this plant have been supplied through the courtesy of the municipal authorities. The plant, as it now stands, has cost in the neighbourhood of $92,300, of which $68,300 is for new equipment and engineering, the balance being the purchase price.

The following are the principal items of cost:—

Purchase price of old plant	$24,000
New steel pipe line	21,000
New power-house (reinforced concrete)	28,800
Diesel oil engine (200 b.h.p.)	11,850
Oil tanks	934
Pelton water-wheel (150 h.-p.)	845
Governor	780
Generator (156·5 k.v.a.)	3,090
Switchboard	997
Total	$92,296

The monthly costs are given as—

Interest and sinking fund	$425 40
Wages	310 00
	$735 40

That is, $8,824.80 per annum.

Such a plant as the above is difficult to criticise, especially as it is hardly a completed commercial proposition. Undoubtedly, an efficient electric light and power service is a large factor in the development of a city, and an indirect revenue producer. Whether the plant taken over from the Light & Power Company was actually worth $24,000, in view of the large proportion of it that was replaced, does not appear If we add the cost of the new water-power equipment to the purchase price, and allow only $3,375 for a power-house sufficient to house the wheel and dynamo (the oil-engine set takes up much the greater space in the $28,800 power-house), we obtain the result that a 150 h.p. water-power development cost $50,000. This, while not necessary uneconomical, must be considered expensive.

The monthly costs as given indicate that the interest and sinking fund on $92,296 is roughly 5½ per cent, no allowance is made, apparently, for repairs or depreciation; the running cost is given as $310 per month for wages—when the Diesel engine is running the costs will be much higher. It would appear therefore that the annual costs will be considerably more than $8,824.80. The writer has not been able to thoroughly investigate the costs in every detail.

SPENCES BRIDGE, B.C.

This plant is situated about three-quarters of a mile from the Canadian Pacific Railway station at Spences bridge, and near the mouth of Murray creek which flows into the Thompson river.

About a quarter of a mile from the mouth of this creek, there is a fall of over two hundred feet, at the crest of which a very small timber dam has been constructed, forming a pool a few square yards in area. A tunnel 200 feet long has been driven through the rock, and delivers water from this pool to a 10-inch pipe which carries it to a concrete power-house below.

The power-house is 34 feet by 24 feet inside and substantially built. Water is delivered to a 48-inch wood mounted Pelton wheel running at 250 r.p.m., which is supplied with a 10-inch standard gate and double nozzle. The speed is regulated by means of 3-inch stream deflectors controlled by a standard Pelton governor. This wheel is belted to a 75 k.w., 6 pole single-phase alternator running at 200 r.p.m.; the exciter is a 125 volt, 20 ampere machine, running at 1,800 r.p.m. Power for lighting is transmitted to Spences Bridge at 7,500 volts and is there transformed to 110 volts.

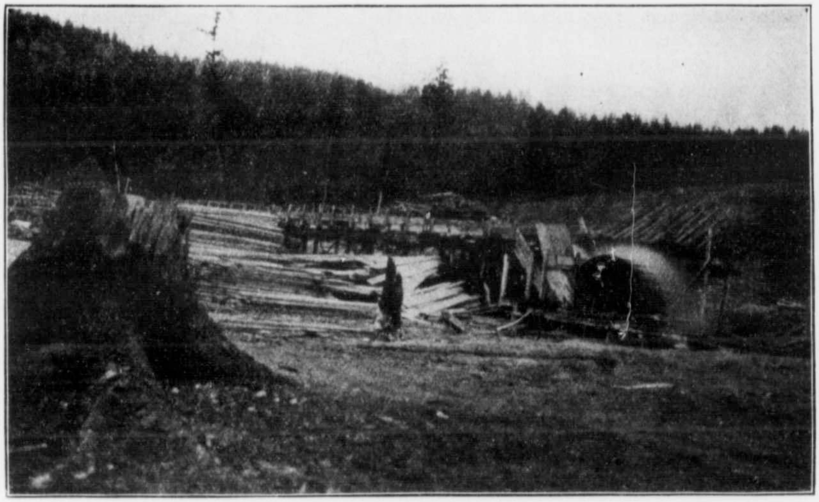
Water supply.—The B. C. Hydrographic survey has established a station on this creek, and records are available from May to December, 1912 (inclusive). The lowest daily flow during this period was 6 c.f.s., and the discharge will probably be even lower during the succeeding three months. With a head of 255 feet and efficiency of 80 per cent (allowing also for pipe friction), the flow necessary to give 75 k.w. would be about

5 c.f.s. There are irrigation and water supply diversions from this creek, the former occurs when there is ample supply and the effect of the latter on the supply for power is negligible.

This plant was installed as a private undertaking by Mr. Clemens who stated that the total cost was approximately $12,500; $2,500 of this represented replacements, etc. which initial errors in design and construction rendered necessary.

At present the only demand for power is for lighting in Spences Bridge; probably this does not exceed 10 h.p. for a short part of the day, consequently the plant is actually run at a loss as, making no allowance for depreciation, interest on capital, etc., the revenue does not pay the attendant's wages.

Mr. Clemes hopes that, when the Canadian Northern Pacific railway is completed, he will sell power for lighting the new station and possibly for other railroad purposes, he also hopes that it will cause the town to grow and thereby increase his general business.



Small Water Power, Louis Creek, B.C. Wooden Undershot Wheel driving Sawmill.

LOUIS CREEK.

This is about 36 miles from Kamloops up the north Thompson river, and is an example of a primitive application of water-power.

A flume of 15 second-feet capacity, about one-quarter to one-half mile long, brings water to a rough-timber undershot wheel (formerly an overshot wheel). The wheel is about 12 feet in diameter, and operates under a head of approximately 14 feet. The wheel is about 5 to 6 feet wide, and the large driving pulley is belted to a countershaft from which the saw-mill machinery is operated. (*See* plates.) The probable efficiency would be in the neighbourhood of 50 per cent. This wheel has served its purpose for a number of years but it will, it is expected, fall into disuse when the Canadian Northern Railway is completed, as the up-to-date Kamloops mills will probably be able to deliver lumber at a rate cheaper than the owner could offer.

Mr E. M. Dann, of Kamloops, division engineer British Columbia Hydrographic Survey, has supplied a series of photographs (with notes), of two primitive developments in his district and these are here reproduced.

KINCOLITH PACKING COMPANY.

Mr. Henry Doyle, the managing director of this company, kindly supplied information concerning the water-power plant at Mill bay, Naas River, British Columbia.

The hydrographic layout is as follows: Lake No. 3 with an area of 1,500,000 square feet is at an altitude of 1,360 feet and drains by a small creek into Lake No. 1. Lake No. 2 has an area of 1,700,000 square feet and is drained into Lake No. 1 by a creek 600 feet long. Lake No. 1, area 900,000 square feet at an altitude of 360 feet drains into a bay at sea-level.

The rainfall in this district is considerable, but runs off very rapidly so that, except during the rainy season, the natural discharge is small; the actual quantity of water available is not known but, so far, has proved sufficient to supply the power required to run the cannery, i.e., lighting, freezing, and canning machinery—during the season.

The outlet of each lake is narrow, good rock foundation is available, so that it is a comparatively simple operation to convert the lakes into storage basins. At the outlet of Lake No. 1, a 10-foot dam has been constructed; while on the creek between Lakes 1 and 2 an 18-foot dam has been built with a 12-inch gate valve. It has been found that the small lake is drawn down 2 inches per working day, so when the water is only 4 feet above the intake, the 12-inch gate valve is opened and the lake is raised 2 feet, sufficient to run the plant for twelve days. It is proposed to construct a 10-foot dam at the outlet of Lake No. 3, and store the water from that drainage area also

A 2,000-foot 8-inch wood stave pipe line brings the water to the cannery, where there are, three 18-inch and one 36-inch Pelton wheels, all of which are not used simultaneously. If the size and length of the pipe-line are correctly given, the maximum power available, allowing an 85 per cent efficiency for the wheels, would be about 90 h.p.; 120 feet of the 360 feet (i.e., one-third of the head), being wasted in pipe friction, without undue friction loss from 50 to 65 h.p. could be obtained.

If the wheels are designed for 350-foot head, their combined horse power would be 190, which would necessitate a pipe 12 inches to 14 inches internal diameter, and would draw down the lake 6.6 inches per twenty-four hours' operation. If the wheels are designed for 300-foot head, their combined horse-power would be 150 h.p., drawing down the lake 6 inches per twenty-four hours, and requiring a new 8-inch pipe. These remarks, however, are by the way.

The cost of the plant was approximately:—

Engineer	$ 100
First dam	400
Pipeline	1,400
Valve	50
36-inch wheel (installed)	500
3 18-inch wheels	450
	$3,650

Mr. Doyle states that the plant is operated approximately 200 days per annum, and that if coal were used the consumption would be 5 tons per day; coal being worth $8.50 per ton here, the cost would be $42.50 per day or $8,500 per annum for coal alone.

This is a case where a small water-power is extraordinarily valuable, and I was informed that this plant is not an isolated instance of the use of water-power in connection with the canning industry. The fishing industry lends itself to the construction of a power plant at a reasonable cost, as it is not necessary to transport a force of men a long distance for a few week's work. The men who are to be engaged in the cannery during the season can be taken up sufficiently early to do all the necessary work, such as building dams, laying pipe, etc., before the fish begin to run.

A sufficient number of varied examples has been given here to indicate the possibilities of water-power in mountainous districts, there are probably an immense number of sites available which will be capable of economical development when the power demand permits.

The power available being proportional to the product of quantity of water and the head, it is evident that a high-head development requires proportionately less water than one of low-head. The comparatively small quantity of water necessary for a high-head power assists the economy of development, for the dam is, as a rule, small, being constructed merely to form an intake; turbines of the same power are smaller and cheaper for high than low heads.

The pipeline is a feature not met with in low-head construction, its cost will generally be more than covered by the saving in other directions, for the gradient is nearly always steep and the length, therefore, not excessive.

PRAIRIE SECTION.

It will be well to state at once that the prairie country is, as a whole, unsuited to the development of small water-powers. In the spring time, there being no shelter nor shade, the snow rapidly melts, and in two weeks or so the bulk of from four to six months' precipitation runs off, producing high stream-discharge which any dams or head works must be constructed to cope with. The flood having passed, the flow drops to normal, and as the rainfall is comparatively light, the natural gradient of the ground slight, and the soil absorbent and unsheltered, comparatively little water is available to swell the run-off.

As winter comes on, the springs begin to freeze solid, and during the severe weather, the flow of all, except the larger streams, is suspended. Thus a stream which may have a flood discharge of 500 second feet has practically no winter flow. In other words, a structure must be able to withstand a big flow carrying probably, logs, ice, etc.; while, as a power producer, it will probably be inoperative for at least four months of the year.

Surface rock is seldom available, the banks of the creek are alluvial, making for instability of dams or requiring extra cost to make them secure. The banks as a rule are not steep, so that the length of the dam increases rapidly with the height.

As a rule there are no falls; a few rapids may be caused by gravel bars but, in general, to obtain a head of 10 feet it will be necessary to construct a dam possibly 15 feet high (from the impervious clay foundation—if it is to be found—to the crest), and timber suitable for construction work is not available.

It is obvious, therefore, that unless the power is only required temporarily, for a special summer industry, the fact that the power is not available during the winter will be a great drawback. It practically puts it out of the running as a source of electric power for the farm.

A water-power will only be useful where a farmer or settler in a remote district has sufficient skill to build a dam and wheel in his spare time. The investment would be slight and the power could be profitably used to cut lumber, saw up firewood, chop and grind feed, etc., in sufficient quantities during the open season to last the whole year.

A site on the Medicine river was inspected, and was one of the very few prairie sites which could be considered economically feasible; even here the country is not real prairie for there is some timber, this location being on the borders of the foot-hill country. At this site the settler, Mr. Fritz Kinna, has built a power-house, and has constructed from wood and sheet-metal a 5-foot inward flow, vertical turbine, with draft tube, cylinder gate, etc. This settler, a Norwegian, has had experience of these developments in Norway, and has built his turbine from patterns obtained from there; the workmanship was excellent, and the wheel will probably prove quite as efficient as a home-made overshot wheel. Exclusive of his own time Mr. Kinna has expended $160 in all, for lumber, bearings, shafting and bevel gears for the wheel and driving shaft; it is probable that, another two hundred dollars will complete the dam, and that for an outlay of $350—$400 he will have from 16 to 20 horse-power for six months of the year.

The other sites inspected in the prairie region have been already reported upon in dealing with the individual cases, one or two of these might, in the hands of a settler such as Mr. Kinna, prove worth developing; the remainder were quite unfeasible. In any case where no technical skill can be anticipated, and where conditions of insecure foundations, pervious banks, heavy spring flood with floating ice are likely to be met with, it will not be wise to encourage the development of water-power.

Small Water Power. La Plonge River, Sask. Operated for some years by R. C. Mission.

NORTH OF THE PRAIRIE.

Here the prairie conditions are modified in several important particulars, the run-off is better regulated, large lakes, muskegs and swamps equalize the flow to a considerable extent, and the country is timbered. Rapids and falls become more frequent, the rainfall is greater and materials for construction are close at hand. The population of this area is inconsiderable and scattered, until recently the Indian and fur-trader were in undisputed possession. Settlers are gradually moving northward, and some of the small power-sites will doubtless be used at some future time.

In 1909 and 1910 I travelled extensively in northern Saskatchewan and Alberta, and saw many sites where a small power could be developed; there was also one where the water had been successfully harnessed. At the Roman Catholic mission, where the La Plonge river enters the Beaver river in Saskatchewan, a saw mill has been in operation for some years, driven by the waters of the La Plonge river, (see photographs). This saw mill supplies all the lumber used around the mission, and has rendered the whip-saw obsolete in the large area bordering on the waters of Ile à la

Crosse, Buffalo, Clear, and Island lakes. Indians and settlers obtaining their lumber from the mission.

A lengthy discussion of the small power situation in the country north of the prairies would be out of place here, sufficient has been said, however, to draw attention to the fact that there are possibilities which may be further considered when the probable demand is less remote.

RECOMMENDATIONS.

Knowledge of the discharge is essential in dealing with any water-power, large or small, and in the case of small streams, information in this regard is usually conspicuous by its absence. The average untrained individual, acting in perfectly good faith, makes most absurd statements regarding the flow of the stream in which he is interested. During the open season, in estimating the flow, he will get the cross-section reasonably accurate, perhaps, but will estimate the flow at the swiftest place, and assume it to be uniform across the section and, more often than not, will overestimate the velocity 100 per cent or more. The winter flow is an unknown quantity, but if there is a stream under two or three feet of ice, and the water rises to the surface when a hole is cut in the ice, he will say " the stream runs all winter, just about as much as before freeze-up," when in reality it is, perhaps, only one-tenth of the fall flow.

I would suggest that the possibility of small water-power developments be brought to the notice of hydrographers, so that they may make estimates, at different seasons, of creeks which may, in their opinion, be utilized in the future. It is not expected that any extensive work be done along these lines, as the expenditure of time and money would not be justified; it is thought nevertheless that opportunities arise from time to time which might well be utilized.

I would further repeat my recommendation, that no small water-power development be authorized, without inspection of the site by a qualified technical officer of the department. Apart from the question of flow, are those of head, area flooded, material for dam, stability, etc., all of which have serious bearing on the economic aspects of a site, and regarding which the applicant has frequently very erroneous ideas; it will be seen, therefore, that considerable individual hardship may be avoided if the inspection is insisted upon.

Part II of this report deals with power for the farm, discussing different sources of energy. It is suggested that this branch endeavour to keep abreast of future developments, so that up-to-date information will be available, enabling the officer in charge to give definite advice to an applicant, as to the comparative value of his proposed water-power plant.

PART II.

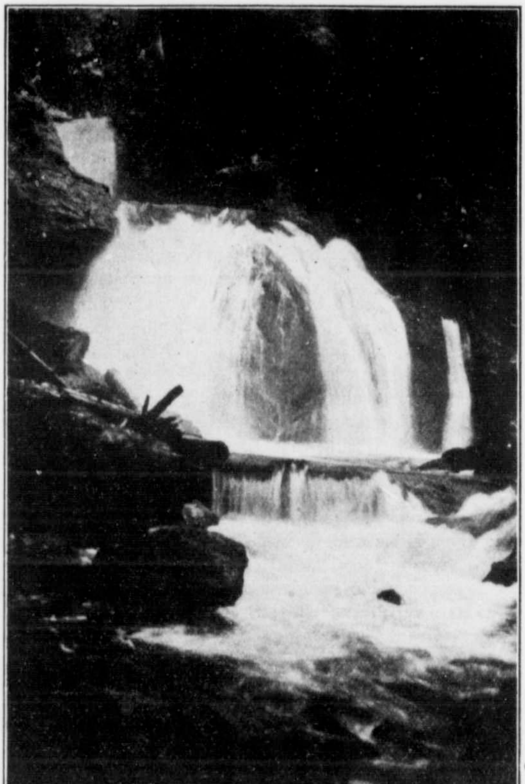
POWER ON THE FARM.

The use of power on the farm has recently been attracting much attention; the benefit of having mechanical devices, which will not only reduce the number of hired men required, but which will be available at any hour of the day or night, is being widely advertised. In almost every case electrical energy is the kind dealt with, several books and pamphlets on the subject have been published, and the technical press is constantly referring to one phase or another, of the supply of current to the farm.

Mr. David R. Cooper, of the Conservation Commission of the state of New York brought out, in 1911, a pamphlet on the use of water-power for the farm and country home, the Ontario Hydro-electric Commission has done much pioneer work on the farms of western Ontario, and Messrs. Purcell and Espenschied, of the technical staff, recently gave valuable evidence before the committee of the Dominion House of Commons on Colonization and Agriculture. The sixth annual report of the Hydro-electric

Commission contains a wealth of valuable information. Possibly the subject of agricultural electricity is most fully treated by Koester in his book "Electricity for the Farm and Home," in this work he deals with the general advantages of the power, generation, distribution and utilization of the electricity, going quite fully into costs and demonstrates very convincingly the numerous and diverse applications to which electricity may be put.

The remarks that follow must be largely a compilation from the above and other sources. Some of the more specific information has been tabulated elsewhere.



Small Water Power. Crazy Creek, near Taft, B. C. Overflow, Oct. 25, 1913. A small portion of power used by Forest Mills, Ltd.

Agriculture, the oldest industry in the world, is the most ancient in its methods. Until quite recently the horse-drawn single plough had not been improved upon, it is but the other day that the first effort was made to use steam-power to do some of the work hitherto done by man or beast. In Germany the steam plough first came into extensive use about fifteen years ago and, ever since, that country has led in the field of agricultural technology; at the present time much ploughing is done by electricity, which method, it is claimed, is faster, cheaper, leaves less unutilized area in the field than other methods, and is applicable to rough ground. Koester states that "by a proper rotation and selection of crops, and by the time saved between the harvest of one crop and the sowing of the next, largely effected by the speediness of the electric plough, the German farmer reaps with its aid two crops a year on much of his land, harvesting on an average 2,600 acres of crops from 1,600 acres of land." The use of this plough is, owing to its high initial cost, confined to the large farms, except where the owner rents it out or the outfit is purchased by a group of small farmers. The long-suffering agriculturist was for generations the butt of the citizen, many opprobrious terms were coined at his expense, but his inertia is being overcome, and he is taking his rightful place near the top of the economic ladder.

Probably the chief cause of the comparative mechanical inefficiency of the farm has been the intermittent nature of agricultural tasks. Ploughing, seeding, reaping, threshing, and other seasonal operations each lasting but a small portion of the year; the daily operations being numerous but brief. One of the greatest aids to invention has been the existence of a continuous monotonous task, *i.e.,* "mechanical," for which a machine is soon found. The farmer's day, though monotonous according to some critics, contained so many varied duties that it probably never occurred to him to find a machine for an operation, unless it was particularly irksome, or required greater power than a team of horses could give him. Other reasons might be multiplied—absence of capital—his isolation, which has made a mutual understanding with engineers difficult; the fact, however, remains that the average farmer, particularly in Canada, needs waking up to the greater possibilities of his land.

It is not an easy task to reach and influence a farmer; he is isolated in position works longer hours than most men, and has little time to study. The inhabitants of his house work just as hard, so that the only method of attack is by missionary work, coupled with articles in the farm journals. Recently, especially where electric power is available, electric appliance salesmen have commenced work in this field.

At the convention in Toronto of the Electrical Association, one speaker attacked the advertising matter used, stating that the farmer did not expect his women folk to be able to sit around, therefore the picture of a lady in neat attire, reading a magazine whilst the washer worked by itself, did not appeal to him at all. The real argument according to this speaker was to show the farmer where he could increase his earning power. This is being done in Eastern Canada, and it is the object of this paper to draw the western farmers' attention to what is being done, so that they will take advantage of central station service as soon as such is available for them. It is also hoped that the data on private station costs will be of use.

SOURCES OF POWER AVAILABLE IN THE WEST.

WATER-POWER.

Large Central Station Service.

Power in Western Canada is at present an expensive commodity, as compared with costs in Europe, the United States and Eastern Canada. The Ontario Hydro-electric Commission purchases power in bulk at Niagara for $9 per h.p. year, and transmits it long distances; transmission lines are expensive, but when a line is being tapped every few miles to supply a city, town or municipality, the line is revenue-earning along its whole length, and can pay interest on the investment, without making the cost excessive to the various consumers. The wide distribution of the load, and the multiplicity of purposes to which the power is put, improves the load-factor thus cheapening the production.

The Hydro-electric Commission has a contract for up to 100,000 h.p. with the Ontario Power Company and obtains the power at 13,000 volts at the figure already stated of $9 per h.p. The voltage is stepped-up to 110,000 volts for distribution to the main stations such as Dundas, Hamilton, Toronto, etc.; a pressure as high as this requires expensive equipment, so that it is stepped-down at the larger stations to 13,200 or some other convenient secondary voltage, for transmission to the smaller towns or villages, where it is again transformed for still further distribution, the voltage finally being lowered to 110 volts for lighting and to 550, 220 or 110 volts for motors.

The price of power naturally varies with the distance from Niagara; in Hamilton, the price is now $15 per h.p. year, in St. Thomas, $28, and at distant Seaforth, $40. The cost of rural electric service in these localities will bear a fixed relation to that of city supply.

The farmer is charged in two amounts, one a "service charge," to cover the annual fixed charges on the capital expended in the township by the Hydro-Electric Commission and by the township, and varies with the number of users in the township; the other a "power charge," for the actual current used. The former charge is $3 per month when there are three consumers to the mile, $2.50 with four, and $2 with five. The "power charge" varies of course with the locality: In West Oxford, the total cost per h.p. year on the farm is for 1 h.p., $66, and for 2 h.p., $96; in the neighbourhood of Chatham, the respective figures would be $76, and $116, assuming a service charge of $3 per month and a power charge of $40 per h.p. year. In the neighbourhood of Dundas, the charges would be roughly $52 and $78 for 1 h.p. and 2 h.p. respectively.

Further detail is not desirable here, any one interested will find full particulars in the evidence given before the Select Standing Committee on Agriculture and Colonization of the Dominion House of Commons, session 1914, by Messrs. G. C. Wilson, M.P., F. F. Espenschied, and J. W. Purcell, this evidence is reprinted under title "Hydro-Electric power as applicable to the farm."

Travelling farther west, the next large centre for hydro-electric power is Winnipeg. Power is received here from the Winnipeg river, where the city of Winnipeg has a plant of which the present capacity is 15,000 k.w. at normal load, the power-house as at present constructed can house machines for a further 9,000 k.w. and is designed for extension to an ultimate capacity of 48,000 k.w. At present, however, the indications are that, without storage, the minimum river flow will only provide 34,000 k.w.

The Winnipeg Electric railway has a station on the Pinawa channel capable of giving some 20,000 k.w. at 50 per cent overload; this power is not capable of any considerable extensions, and is fully loaded. The same interests are about to develop the site at Little du Bonnet falls, where, under present flow conditions with 56 foot head and 75 per cent efficiency, 43,000 k.w. is available.

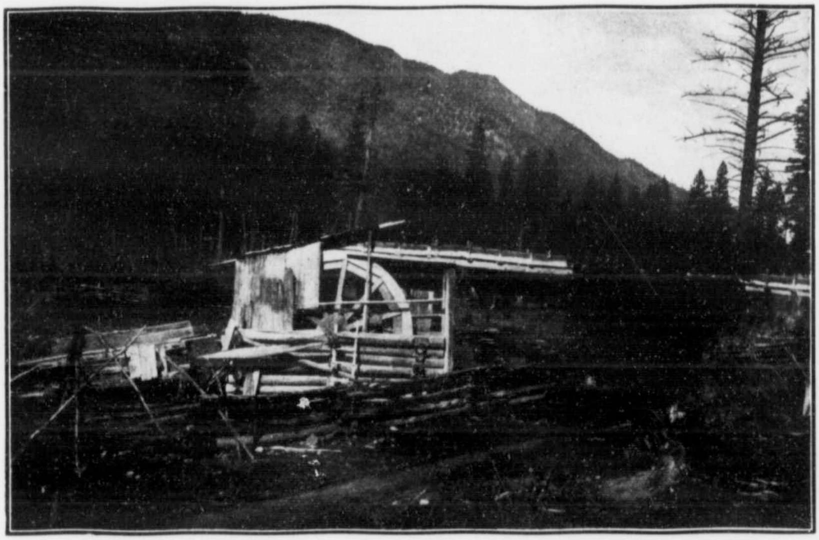
The Winnipeg river has within transmission distance, sites where some 226,000 k.w. is capable of development at a reasonable cost; of this some 35,000 k.w. is already developed. It would seem that the Manitoba farmer might hope for a small share of this vast supply at rates profitable to him, yet H. A. Robson, K.C., Public Utilities Commissioner, in his report on "projected Hydro-electric system for the province of Manitoba," shows that the cost of any system similar to that of the Ontario Hydro-electric Commission, would be excessive, and says:—

> "Until such time as the development of the province will warrant building long transmission lines, it seems that the cheapest power for farmers obtainable must come from small gasolene installation, unless it is desired to promote the industrial development of the province by carrying a heavy deficit for a considerable period of years. It is clear that a general hydro-electric undertaking for the provision of electric service, merely for the use of the agriculturist, could not be accomplished on any satisfactory financial basis,

and that such a scheme would depend on the growth of towns and villages, which would make such demand for power as to give a foundation for the enterprise."

The same report shows that the cost of power to towns and villages would amount to 16·2 cents per k.w.h., and to 19·27 cents to individual consumers.

It must be remembered however that, as Judge Robson says, no report of this nature can be considered final; it will be modified by the increase of population, and by the progress of hydraulic development and electrical transmission. As time progresses, these different influences may bring the schemes within the economic limits, outside of which it now lies.



Small Water Power. Fadear Creek, near Cahilty, B. C. Typical overshot wheel for farm power.

The above mentioned report contains a preliminary report by W. E. Skinner, Limited, Consulting Engineers, which deals in detail with the costs of transmission, etc., and contains also tables giving the comparative cost of purchasing power and of generating it in small quantities by steam or gasoline; these tables contain useful information, and will be reproduced in this report under their respective headings.

The first of these is that on purchased power.

	Cost of Electric Power.			
Size of plant in horse-power	2	6	10	20
	$ cts.	$ cts.	$ cts.	$ cts.
Cost of motor installed	125 00	150 00	300 00	450 00
Cost of electricity, 3,000 hours	409 40	858 75	1,028 95	2,023 00
Attendance per year	20 00	30 00	50 00	50 00
Interest, 5 per cent	6 25	7 50	15 00	22 50
Depreciation, 10 per cent	12 50	15 00	30 00	45 00
Repairs, 5 per cent	6 25	7 50	15 00	22 50
Supplies, 1 per cent	1 25	1 50	3 00	4 50
Insurance, 2 per cent	2 50	3 00	6 00	9 00
Taxes, 1 per cent	1 25	1 50	3 00	4 50
Total cost per annum	459 40	924 75	1,150 95	2,181 00
Cost of 1 horse-power per annum of 10 hour basis	229 65	154 15	115 09	109 05
Cost of 1 horse-power per hour	·07655	·05138	·03836	·03635

(*See below—Base price, Discount, and method of obtaining total cost.*)

Base Price for cost of Electric Power—10 cents per k.w. hour—Discount on Monthly Bills:

$ 5 00 10 per cent.	$100 00 to $125 00 40 per cent.
10 00 to $ 20 00 15 per cent.	125 00 to 150 00 45 per cent.
20 00 to 25 00 20 per cent.	150 00 to 175 00 50 per cent.
25 00 to 50 00 25 per cent.	175 00 to 200 00 55 per cent.
50 00 to 75 00 30 per cent.	200 00 to 500 00 60 per cent.
75 00 to 100 00 35 per cent.	500 00 and ov 65 per cent

COST PER ANNUM.

2 Horse-power Plant.

$$\frac{3,000 \text{ hours} \times 2 \text{ horse-power} \times \cdot 746}{82 \text{ per cent efficiency.}} = 5,458\cdot 53 \text{ k.w. hours.}$$

5,458·5 k.w. hours x 10c. = $545 85 annual cost without discount.

$$\frac{\$545\ 85}{12} = \$45\ 49 \text{ monthly bill-discount, 25 per cent.}$$

75 per cent of $545 85 or $409 40, *annual cost.*

6 Horse-power Plant.

$$\frac{3,000 \times 6 \times \cdot 746 \times 10 \times 55 \text{ per cent}}{86} = \$858\ 75.$$

Monthly bill, $130=Discount 45 per cent.

10 horse-power Plant.

$$\frac{40 \text{ per cent of } 3,000 \times 10 \times \cdot 746 \times 10c}{87} = \$1,028\ 95.$$

Monthly bill, $214 36=Discount 60 per cent.

20 Horse-power Plant.

$$\frac{40 \text{ per cent of } 3,000 \times 10 \times 20 \times \cdot 746}{88\cdot 5} = \$2,023$$

Monthly bill $421. =Discount 60 per cent

The costs for purchased power depend on: A basic rate of 10 cents per k.w. hour, a discount proportional to the monthly bill, the use of all the power for 3,000 hours per annum. On another page in Judge Robson's report, the cost in Manitoba is figured at 19·27 cents for generation and distribution, and makes no allowance for any discounts; this would appear to show that the above costs do not apply. The outlay for apparatus necessary to use full power for 3,000 hours per annum will be far beyond the means of the average farmer.

The next big centre with a large supply of water-power is Calgary. The Dominion Water Power Branch has made extensive surveys on the Bow river, and the following particulars are taken from the report of Mr. M. C. Hendry, B.A.Sc., on this work.

The Calgary Power Company has so far developed an aggregate of 28,000 h.p. at Kananaskis falls and Horshoe falls. There remain four undeveloped sites to develop, which would cost in all some $3,800,000 delivered in Calgary, giving a further 24,000 horse-power, these figures including a pro-rata charge for the cost of storage; this storage has been thoroughly investigated, and a portion of the work completed, it is designed to regulate the flow of the river and benefit all the power developments. Mr. Hendry estimates that this power will cost delivered in Calgary from 0·49 to 0·60 cent, per k.w.h. at a 50 per cent load factor, or roughly from $49 to $53 per horse-power year.

The rates at present in force in Calgary are, for lighting 7½ cents per k.w.h., and for power:—

Motor Rating.	Charge per Horse-Power year.
1— 3	$41·89
4— 9	37·71
10—18	33·52
19—54	27·23
55 and over	23·04

The "load factor" of a plant during a given period is the ratio of the average load to the full load capacity of the plant while running. The capacity of any plant will be governed by the "peak," i.e., the maximum load, and it is accepted that any increase in the load factor makes for the economy of the plant. Any power user, who refrains from using power when the demand on the central station is high, restricting his use of energy to the hours when the load is light, is entitled to and obtains a cheaper rate than that quoted to the unrestricted consumer. It is easily possible for a farmer to confine his use of electricity to "off-peak" hours, and take advantage of the cheaper rate.

At the present time there cannot be said to be any other centres in Manitoba, Saskatchewan or Alberta, except the Edmonton and Prince Albert districts, where water-power is an active contender in the power market, and there is no indication of any immediate development of sites other than those already mentioned.

Sites on the Athabaska, Saskatchewan, Nelson, Churchill, and other rivers have been investigated in a preliminary way, but as these are all remote from the present centres of population, their economic value is prospective and a discussion thereon would be out of place here.

British Columbia has many water-powers, large and small. The Kootenays have much power, there being extensive developments at Bonnington falls near Nelson. Vancouver is well supplied from the Burrard Inlet and Stave River sites, where a total of 150,000 h.p. is available. Vancouver Island, too, is well supplied.

Passing to other sources of power for large central stations, the questions of cost are problematic and vary so much with local conditions that a long and careful study on the ground, such as I have had no opportunity to make, would be necessary to develop reliable figures as to the cost of production in any given locality.

Actual figures from municipalities are frequently misleading, in many cases power is sold more cheaply than the cost of production would justify, in order to induce industries to locate within the municipality. Fair allowance for interest, sinking fund, depreciation and repairs is not always made, and some plants show a profit where in reality, proper accounting would reveal a loss. Actual expert estimates for power plants in one locality cannot be adapted for another locality, where the conditions are apparently only slightly different.

The Department of Mines has been studying the production of power from various fuels in a most comprehensive manner, and has already issued a report upon the utilization of peat fuel for the production of power. A new report is already in the press, dealing with producer gas in general, and deals in considerable detail with central stations in Germany and the use of electricity on farms; this being the case it is unnecessary here to go further into the subject, except to state that a well-designed producer plant using peat, lignite or bituminous coal, with complete installation for the recovery of by-products can, under favourable conditions, produce power at a very cheap rate.

In 1912-13 an investigation was made for the Dominion Water Power Branch by Mr. H. E. M. Kensit, concerning the best method of producing power for the necessary pumping for the supply of water to the cities of southern Saskatchewan.

In this report, Mr. Kensit states that a well-designed steam plant of from 3,000 to 5,000 k.w. capacity, having a load factor of 35 per cent can be operated for 0·921 cents per k.w.h. (0·518 cents being the cost of coal at $3.50 per ton), and total cost of 1·524 cents.

In Edmonton (see *Electrical News*, June 1, 1914) the rates are:—

> "Domestic Lighting—7½ cents for the first 100 k.w.h.; 101 to 400 k.w.h., 7 cents; 401 to 1,000 k.w.h., 6½ cents; 1,001 to 2,200 k.w.h. 6 cents; 2,200 k.w.h. and over, 5½ cents. Minimum charge per month to be 75 cents. Discount of 5 per cent, if paid within ten days from date of bill. No discounts allowed on accounts of less than $1.
>
> "Power—6 cents per k.w.h. for the first 150 k.w.h.; 150 to 300 k.w.h., 5 cents; 301 to 5,000 k.w.h., 3 cents; 5,001 and up 2 cents per k.w.h. Minimum charge on motors up to 15 h.p., 75 cents per h.p. per month on total connected load. Minimum charge on motors above 15 h.p., 50 cents per h.p. per month on total connected load. Ten per cent discount allowed on all accounts exceeding $1. No bill issued for less than the following amounts: Single-phase connections 75 cents per month; three-phase connections, $2.25 per month."

The existing rates in Calgary have already been given. In a report made to that city by a prominent engineer, it was stated that a steam, coal fired plant with a 50 per cent load factor, would give power at the generator terminals at a price falling from 0.85 to 0.74 cents per kilowatt hour, as the size of the plant varied from 5,000 to 45,000 horse-power.

The Moosejaw electric railway uses Mirrless-Diesel oil-engines for power, the present capacity is 900 b.h.p., but is being increased. This plant has given great satisfaction, and with fuel oil at 14 cents per gallon, and an average load factor of 47.23 per cent the operating cost per k.w.h. delivered at the switch board last December was 1.76 cents.

Mr. Kensit prepared a table for cost of pumping at the Elbow, Saskatchewan; this table includes transmission of power or haulage of fuel to this site and also the cost of pumping machinery, the power is given in w.h.p. or water horse-power, and means the power actually used in elevating the water.

Type.	Cost per W.H.P. Year.[1]		Remarks.
	Initial Inst.	Final Inst.	
	$ cts.	$ cts.	
High duty pumping engines	100 00	66 50	Crowsnest coal at $5.85 per ton, Cost of fuel = 32·8 per cent and 47·3 per cent respectively.
Steam turbines and centrif. pumps (coal).	90 00	66 00	Same fuel cost being 52 per cent and 67·6 per cent respectively.
Steam turbines and centrif. pumps (nat. gas).	85 20	63 50	Natural gas at 25 cents per 1,000 cubic feet. Fuel cost 50 per cent. and 66·7 per cent respectively.
Water-power no steam res	110 00	27 60	
Water-power with steam res	121 00	35 00	
Producer gas with electric transmission.	187 00 (48·60 = cost of gen. at mine)	57 00 (15·00 = cost of gen. at mine.)	$1.00 per ton at mine. Cost of fuel 18·87 per cent and 30·50 per cent respectively.
Purchased power	83 00	66 00	Based on an offer of $33.75 per E.H.P. per year of 300 days i.e. $38.80 per whole year, delivered.
Diesel oil engines	129 00	93 50	Fuel oil at 15 cents. Cost of fuel 51·75 and 63·48 resp. 10 per cent change in cost of oil changes cost of power 5·2 per cent and 6·3 per cent respectively.

[1] Initial installation, 1,375 w.h.p.
Final installation, 6,875 w.h.p.

If the above figures were corrected for cost of pumping, the cost for power alone might be considerably less; also any change in locality that brought the plant nearer some source of power would bring about a great reduction in power cost; the figures, however, give one an idea of power costs in the west.

PRIVATE STATIONS.

Water-Power.

Messrs. Koester & Cooper, in the works already referred to, devote considerable space to actual small water-power plants and their cost, the following are examples:—

(1) An Illinois farmer has a 15 h.p. water-wheel which generates power for lighting and general farm machinery, the plant cost $1,200 and is operated for $10 per year.

(2) An Ohio plant which cost $1,022 will furnish current for 100 16 c.p. lamps or their equivalent.

(3) In New York state there is a 17 h.p. plant which is estimated to have cost $1,800.

(4) In the same state a 3 k.w. generator plant cost $518.

In most of the above cases the farmer did much of the work himself, and the value of his time is not included.

Briefly stated, some of the principal considerations for cheap production of reliable water-power are: (1) That an actual fall be available; (2) that a convenient and safe site be located near to the place where the power will be used; (3) that the flow be adequate at all seasons of the year, and that there be no excessive floods to endanger the structure or complicate the design.

Part I of this report has dealt, at sufficient length, with the prospects for small water-powers in the West, I will merely recapitulate to this extent.

In the mountainous districts the first two conditions are frequently fulfilled, the third being doubtful. In the prairies all the conditions are difficult of fulfilment, whilst north of the prairies it is thought that, when a demand arises, many available sites will be found.

OTHER SMALL POWER POSSIBILITIES.

This opens up many alternatives each of which will have advocates. Conditions both of fuel supply and power demand will vary so that, where one small power plant will meet one set of conditions, a slight change in these will render a rival form of development more suitable.

Most of the literature on private electric plants is of the trade variety, either from catalogues or trade journals; reasonably enough, therefore, each writer cries his own wares and the unbiased reader must bear this in mind, nevertheless a judicious study of the publications of reliable firms, will enable one to form a fair idea as to what outfit will prove most suitable for a given set of conditions.

The accuracy of any of the following statements and figures is not guaranteed, considerable care has been exercised in their preparation, however, and their object is to give an approximate idea of the principal features to be examined into by the prospective owner of a small plant.

The prime-movers which may be enumerated are engines driven by steam, gasolene, coal-oil or gas; electric accumulators can also be considered in conjunction with any of these.

Steam Engines.

Steam engines for farm power cannot be very favourably considered. The small engine is thermally inefficient, and the necessity of a boiler increases the first cost of the plant, space charges will also be increased. Attendance will cost more, and where power is wanted at short notice or for short periods the use of fuel consumed for keeping up or raising steam will be very wasteful.

Even close to a coal-mine where coal can be obtained cheaply, handling of coal, ashes, &c. will prove expensive. Wood is usually out of the question owing to the expense of cutting and hauling, though a saw-mill might well be driven by steam, the waste material being used for fuel. Oil or gas will generally prove more convenient used directly in an engine of the explosion type.

The following table is taken from the report of W. E. Skinner, to which reference has already been made:—

Cost of Steam Power.

Size of plant	6 H.P.	10 H.P.	20 H.P.
	$ cts.	$ cts.	$ cts.
Cost of plant per H.P.	220 00	150 00	100 00
Interest, 5 per cent	11.00	7 50	5 00
Depreciation, 5 per cent	11.00	7 50	5 00
Insurance, 2 per cent	4 40	3 00	2 00
Taxes, 1 per cent	2 20	1 50	1 00
Repairs, 10 per cent	22 00	15 00	10 00
Oil, waste, and supplies, 5 per cent	11 00	7 50	5 00
	61 60	42 00	28 00
Coal per horse-power, per hour, in pounds	20	15	12
Cost per horse-power at $6.50 per ton for 3,000 hours	195 00	146 25	117 00
Attendance per horse-power for 3,000 hours	75 00	50 00	30 00
Incidentals per horse-power (as above)	61 60	42 00	28 00
Cost of 1 horse-power per annum, 10-hour basis	331 60	238 25	175 00
Cost of 1 horse-power per hour	0·1105	0·0794	0·0583

This table contains details of cost, from which a revised table has been prepared more closely applicable to farm conditions.

The 20-h.p. engine, which is too large for anything but silo-filling or threshing on the average farm, especially in the West, has been omitted. In any case, the threshing outfit will probably burn wood when travelling and straw when threshing so that the above figures will not apply.

In considering the 6-h.p. and 10-h.p. engines, 500 hours per year has been assumed as the average service, and it is thought that unless the engine is used in conjunction with a storage battery for lighting, this time will be ample to do all the necessary wood-cutting, hay-baling, feed-grinding, etc.

Interest, depreciation, insurance, taxes, and repairs are all combined at 20 per cent.

Size of plant	6 H.P.	10 H.P.
	$ cts.	$ cts.
Cost of plant	1,320 00	1,500 00
Interest, etc. (20 per cent)	264 00	300 00
Oil, waste, etc., (2 per cent)	26 40	30 00
	290 40	330 00
Coal per H.P. per hour, pounds	20	15
Cost at $6.50 per ton for 500 hours	195 00	243 75
Attendance	75 00	75 00
Incidentals (above)	290 40	330 00
Cost per annum	560 40	648 75
Cost per H.P. hour	0·1868	0·12975

Thus, assuming the accuracy of Mr. Skinner's figures, and that the modifications are reasonable, we obtain the result that a 6-h.p. steam plant will cost for 500 hours' service per year 18.68 cents per horse-power hour and a 10-h.p. plant approximately 13 cents per horse-power hour.

It will be shown that the figures can be cut down considerably by using gasolene or oil engines, justifying the statement previously made that steam plants for farm use are not economical.

Coming to the explosion-type of engine we have gas, gasolene and oil.

Gas engines.—The field for these is restricted for agricultural use, for though a gas-producer plant using peat or coal is a possibility it cannot be looked on at all favourably at this stage. Future improvements may make the gas engine and gas-producer combination an active contender in the field of small farm power plants: the suction gas-producer is already receiving attention in England for country house lighting. Town-gas is generally not obtainable and in cases where it is, electric power from a central station is probably also available. The gas engine on the farm will probably be confined to one or two isolated cases where a farmer has sunk a well for, and obtained, a supply of natural gas.

Gasolene and Oil Engines.—The manufacturers of gasolene engines are well to the fore in laying their wares before the agriculturist. It is no uncommon thing to hear an 'exhaust' when driving across the western prairies, and the use of engines seems to be increasing.

Mr. Skinner, whose report to H. A. Robson, K.C., on the proposed Manitoba Hydro-Electric system has already been referred to, gives the following figures:—

Cost of Gasolene Power.

Size of plant in H.P.	2	6	10	20
Price installed	$ 200 00	$ 433 00	$ 666 00	$ 1,000 00
Gasolene per B.H.P. hour, in gallons	$\frac{1}{3}$	$\frac{1}{4}$	$\frac{1}{6}$	$\frac{1}{8}$
Cost per gallon	20c.	20c.	20c.	20c.
Cost per 3,000 hours	400 00	900 00	1,000 00	1,500 00
Attendance at $1 per day	300 00	300 00	300 00	300 00
Interest, 5 per cent	10 00	21 65	33 30	50 00
Depreciation, 5 per cent	10 00	21 65	33 30	50 00
Repairs, 10 per cent	20 00	43 30	66 60	100 00
Supplies, 20 per cent	40 00	86 60	133 20	200 00
Insurance, 2 per cent	4 00	8 65	13 30	20 00
Taxes, 1 per cent	2 00	4 35	86 65	10 00
Power cost	$ 786 00	$ 1,386 20	1,666 35	$ 2,230 00

Size of plant in H.P.	2	6	10	15
Value of space occupied	$ 100 00	150 00	200 00	300 00
Interest, 5 per cent	5 00	7 50	10 00	15 00
Repairs, 2 per cent	2 00	3 00	4 00	6 00
Insurance, 1 per cent	1 00	1 50	2 00	3 00
Taxes, 1 per cent	1 00	1 50	2 00	3 00
	9 00	13 50	18 00	27 00
Power cost	786 00	1,386 20	1,666 35	2,230 00
Total cost per annum	$ 795 00	1,399 70	1,684 35	2,257 00
Cost of 1 H.P. per annum–10 hour basis	$ 397 50	233 28	168 45	112 85
Cost per 1 H.P. per hour	$ ·1325	·0778	·0561	·0376

On the same basis as that assumed when dealing with the steam plant—

Size of plant in H.P.	2	6	10	20
Price installed	$ 200 00	433 00	666 00	1,000 00
Gasolene per B.H.P. hour, gallons	$\frac{1}{3}$	$\frac{1}{4}$	$\frac{1}{6}$	$\frac{1}{8}$
Cost per gallon	20c.	20c.	20c.	20c.
Cost per 500 hours	$ 66 67	150 00	166 67	250 00
Attendance	50 00	50 00	50 00	50 00
Interest, etc. (20 per cent)	40 00	86 60	133 20	200 00
Supplies, (20 per cent)	40 00	86 60	133 20	200 00
Space charges	9 00	13 50	18 00	27 00
	205 67	386 70	501 07	727 00
Cost per B.H.P. hour	0·2057	0·1289	0·1002	0·0727

If we compare the 6-h.p. size we find the cost per h.p. gasolene and steam to be 13 cents and 19 cents respectively while for the 10-h.p. size the ratio is 10 cents to 13 cents.

Reliable figures as to gasolene consumption per h.p. hour are hard to obtain, my own estimates farther on in this report have been based on a consumption of one-eighth of an imperial gallon per h.p. hour, assuming full load conditions and efficient attendance. The foregoing table, however, shows a widely varying consumption, also it does not state whether the imperial or United States gallon is intended, the latter being five-sixths of the former. The above table probably deals with engines designed for rough usage for direct drive, in which case the consumption of gasolene would be higher than for the better class engines considered later, which have been designed for the more exacting duty of driving electric machinery, and which require very much more accurate regulation. In Bulletin No. 25, "Electric Power on the Farm," by Adolph Shane, issued by the Iowa State College, is the following: "The sizes of gasolene engines referred to in these pages (2 to 10 h.p.), will operate on between a sixth and an eighth of a gallon of fuel an hour for each horse-power when running under full load. At a third load these figures will about double." Those interested in the question of farm power would do well to study this bulletin, also "Lighting Country Homes by Private Electric Plants," by T. H. Amrine, issued by the University of Illinois.

The following cost data have all been worked out on the consumption basis already stated, namely, one-eighth imperial gallon per h.p. hour at full load, and the cost is taken as 30 cents per imperial gallon—a fair average price in the West.

The first table is adapted from a detailed statement of the costs of a 15 k.w. gasolene-electric set. This information was supplied by the Sturtevant Co., of Hyde Park, Mass., who manufacture six and four-cylinder sets particularly designed for this class of service. The weight and cost of the smaller sets were also supplied by this firm. In drawing up the following statement 50 per cent has been added to the capital cost as stated by the Sturtevant Co. for freight and duty, and the interest on capital and cost of gasolene are as shown, being corrected to conform more closely with western conditions.

Size of set	5 k.w.	10 k.w.	15 k.w.
Weight, pounds	1,400	2,600	3,175
(1) Cost of complete set	$ 1,370 00	$ 1,925 00	$ 2,430 00
(2) Foundations	20 00	25 00	30 00
(3) Total generating plant	1,390 00	1,950 00	2,460 00
(4) Depreciation (8 per cent)	111 20	156 00	196 80
(5) Repairs (3 per cent)	41 70	58 50	73 80
(6) Interest (8 per cent)	111 20	156 00	196 80
(7) Total fixed charge	264 10	370 50	467 40
(8) Gasolene per k.w. hour ($\frac{1}{8}$ per horse-power hour) imp. gals.	$\frac{1}{6}$	$\frac{1}{6}$	$\frac{1}{6}$
(9) Cost of gasoline per 10-hr. day at full load at 30 cents per gal	2 50	5 00	7 50
(10) Attendance per day	15	15	15
(11) Oil waste and supplies	35	45	55
(12) Total daily expense	3 00	5 60	8 20
(13) Yearly running expense (300 days)	900 00	1,680 00	2,460 00
(14) Total yearly expense (items 7 and 13)	1,164 00	2,050 00	2,927 00
(15) Total k.w. hours per year	15,000 00	30,000 00	45,000 00
(16) Cost per k.w. hour, cents	$7\frac{3}{4}$	$6\frac{7}{8}$	$6\frac{1}{2}$
(17) Cost per horse-power hour, cents	$5\frac{13}{16}$	$5\frac{5}{32}$	$4\frac{7}{8}$

It must be borne in mind that the above figures can only be approximate and that the cost per k.w. hour represents, merely, that of manufacture; switching apparatus, wiring, motors, lamps, machinery, etc., is absolutely excluded.

These "gasolene-electric" sets are, according to the makers, intended to be used in direct connection with lighting and power circuits and not through a storage battery, though a storage battery can be used if desired. This, of course, means a particularly efficient governor control to insure a constant voltage through wide variations of load, if the sets are to be run without constant attention.

The oil engine has had a wide application for many years in Great Britain as well as the continent of Europe, many 1 to 2 h.p. engines being in use for pumping domestic water for country houses and farms. The coast defence stations were, many of them, equipped with 15 h.p. oil-engines which drove the dynamos supplying the current for search-lights, these being but examples of a wide application. These engines were generally regulated by a "hit and miss" governor, the fuel valve is opened at the beginning of every admission stroke, or left closed, according as the speed is below, or above, normal; this method of regulation did not admit of such refinement as does the throttling governor which is now more generally used on all but the smallest sizes.

Prices cannot be given accurately: trade discounts, freight, and many other considerations enter largely into their determination, not to mention the commercial rating of the individual customer, and his accessibility. The only way of obtaining an actual net price would be by submitting an actual proposition and furnishing the necessary references. It is thought, however, that the costs given below will be found to represent approximately the cost to the Westerner. Where eastern prices were obtained a rough allowance has been made for freight

The cost of gasolene engines in the East of from 3 to 10 h.p. varies from $70 to $50 per horse-power, according to manufacture and size, the bigger machines being, naturally, cheaper per horse-power. The following table gives figures for gasolene and coal-oil electric sets, and has been worked out from data courteously supplied by the Canadian General Electric Company.

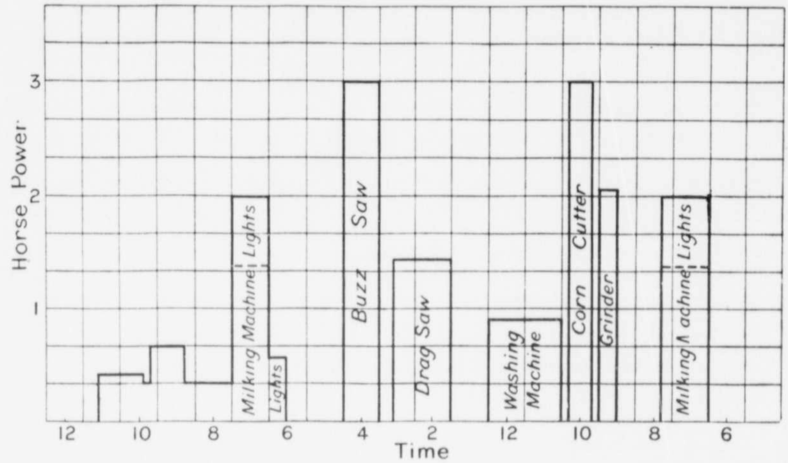
—	Gasoline.		Coal Oil.
(1) Size of engine....h.p.	4	6	6
(2) Size of dynamo....k.w	3	4·5	4·5
(3) Estimated cost erected in Calgary....	$ 520 00	720 00	730 00
(4) Depreciation, repairs and interest (20 per cent)....	106 00	144 00	146 00
(5) Gallons of fuel per horse-power hour....	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{5}$
(6) Cost of fuel per 10-hour day....	1 50	2 25	1 80
(7) Attendance, oil, waste and supplies....	40	50	50
(8) Daily expense....	1 90	2 75	2 30
(9) Yearly running expense (300 days)....	570 00	825 00	690 00
(10) Total yearly expense (4 and 9)....	676 00	969 00	836 00
(11) Total horse-power years....	12,000 00	18,000 00	18,000 00
(12) Cost per horse-power hour....cents.	$5\frac{2}{3}$	$5\frac{1}{3}$	$4\frac{2}{3}$
(13) Cost per k.w. hour....cents.	$7\frac{1}{2}$	$7\frac{1}{5}$	$6\frac{1}{5}$

These costs work out a trifle cheaper than those for the Sturtevant sets, for gasolene, and more than one per cent per h.p. hour cheaper for coal-oil. It must be remembered, however, that this outfit is a cheaper one and, not being particularly designed for variable loads, could not fairly be expected to be as uniform, in its action, under extreme variations of load, as the more expensive set.

The above analyses of cost assume a constant load for 10 hours a day, 300 days in the year. On a farm, energy may be required at any hour between 5 a.m. and midnight, and the load may vary from one-half h.p. to the maximum capacity of the plant, anything approaching full load will be the exception, rather than the rule. According to a diagram, given in Messrs. Sturtevant's catalogue, the quantity of gasolene required per k.w. hour at one-quarter load is three times that used at full load—this for a 10-k.w. gasolene electric set. The fuel efficiency of any other set under light load would hardly be any greater. Probably the most satisfactory method of attacking the problem, is to consider the power requirements of the average farmer. Here again we have to make many assumptions based on comparatively little positive information.

The Electric Power Co., Limited, of Belleville, has developed an extensive rural business and have furnished the following notes: "Farms in different localities vary as to class of farming and the methods of using electric current vary accordingly. For instance, in localities where fruit-growing predominates, the farms should not be looked upon as being able to use electricity to as good advantage as mixed farming, on farms of from 150 to 200 acres. The fact that electricity appears most attractive in stock-raising and dairying sections seems to be fairly well established." This company further states that occupants of farms varying from 150 to 200 acres are usually able to use from 2 to 4 h.p. to good advantage.

The Ontario Hydro-electric Power Commission's reports for 1912 and 1913 furnish valuable information, and on page 161 of the 1912 report a typical farm load diagram is given. This diagram shows energy used in water and air heaters which, though desirable when power is furnished at a flat monthly rate and is available at all times, cannot be looked upon favourably when the electricity has to be privately generated.



TYPICAL FARM LOAD DIAGRAM

{Adapted from Diagram on p. 161 of Fifth Annual Report of the Ontario Hydro-electric Commission}

The diagram given here is the same as the one just mentioned with the exception of the omission of the heaters, and it is proposed to use it as representing the power problem to be solved. An analysis of the diagram shows that there is a lighting load for 6½ hours of less than 1 h.p. while milking and other machines require power for 8¼ hours in all.

There are almost innumerable ways of handling this load suited to varying purses.

(1.) Electricity might be eliminated altogether and a portable 3-h.p. gasolene or oil engine might be used to operate the saws, cutters, grinders, etc.

(2.) The lighting might be done by an automatic lighting set, the milking and washing by hand and the balance of the work as in (1) or the same engine could be arranged for lighting and power.

(3.) The lighting set might be made a trifle larger, it would then drive the washing machine and might be arranged to work the milking machines and do any necessary pumping (an automatic set being able to handle any small uniform load). The other machinery being handled by the same engine through a line shaft or by a separate engine.

(4.) A gasolene-electric set could be purchased and run all the time, coal oil lamps being used to save expense at very light loads.

(5.) A gasolene-electric set in conjunction with a well equipped storage battery could be arranged so that the running time of the engine could be reduced and the load upon it kept as high as possible.

POWER COST.

CASE I.—3-h.p. gasolene engine would cost with belting, etc., about $250, this engine would work about 3½ hours per day using approximately 1⅓ gallons or 40 cents worth of gasolene per day, allowing 50 cents per day, in all we have:—

Capital invested	$250
Interest depreciation, and repairs (20 per cent)	$ 50
Running expenses, 50 cents per day for 300 days	$150
Total annual cost for power	$200

CASE II.—Messrs. R. A. Lister and Company, Limited, have kindly supplied information concerning automatic plants of their manufacture, and state that for farm use some of their customers prefer the following non-automatic outfit: A 5-h.p. engine with a one-half k.w. generator and a small storage battery of say twenty-four ampere-hours capacity, the battery being used when only a small amount of lighting has to be done and when no motors, electric irons, etc., are in use. The only additional attention required is that of starting up the engine to charge the battery in the day time. There is an automatic charging switch which cuts out the battery when it is fully charged.

This outfit would cost about $820 f.o.b. Winnipeg, and consists of:—

1 5 h.p. engine with necessary accessories complete.
1 ½ k.w. generator (57 volts) on sliding bed-plate connected to engine by leather belt.
1 switchboard with necessary instruments, switches and fuses.
1 storage battery of 27 glass cells of 24 amp. hour capacity capable of lighting 11 to 15 watt lamps for 8 hours, 17 for 5 hours or 22 for 3 hours.

CASE III.—The same firm have furnished particulars of a combination similar to that above except that the same is automatic: the dynamo in this case would be of 1.5 k.w., and the battery would consist of twenty-seven or fifty-four cells of the thirty-six or twenty-four ampere-hour capacity respectively at the 8-hour rate. This outfit would cost in the neighbourhood of $1,200, and the following running costs are given:

Running cost (6 hours per day except Sundays)	$100 00
Interest at 5 per cent	60 00
Depreciation and repairs, 10 per cent	120 00
	$280 00

If the above allowances are sufficient, the costs would be very attractive, but if we allow, as in outfit *B* Case V (see below) about $300 for gasolene and 20 per cent for fixed charges we have:—

Running cost	$300
Depreciation, interest and repairs (20 per cent)	240
	$540

still a very reasonable proposition.

CASE V.—This presupposes that every operation shown in the diagram is performed by electricity, but account is also taken of the fact that the battery and dynamo may be used in parallel to supply excessive power demands for silo filling and threshing; thus a 3-h.p. engine is in use the battery will probably give 2 h.p. if required, enabling us to drive a 5-h.p. motor. Thus it will be seen that such a set can look after maximum demands more readily than any other, for instance, suppose, 8 h.p. must be supplied on occasion; without a storage battery the engine itself would have to give this power or a special engine would have to be installed; with a storage battery a 5-h.p. engine will be sufficient for all purposes.

Also, for very light loads, the power can be given by the battery which works more efficiently at low discharge rates, the engine only being used at or near its rated capacity.

Two outfits are considered here and should be studied in conjunction with the load diagram given above.

Outfit A.—This is a 4-h.p. gasolene engine driving a 3-h.p. generator used in conjunction with a 62 chloride accumulator battery as listed by the Electric Storage Battery Company as No. 5663.

This battery discharging at 110 volts will give:—

20 amps. for $2\frac{3}{4}$ hours = 2·20 k.w. or 2·93 h.-p.
14 " $4\frac{3}{4}$ " = 1·54 " 2·05 "

It will require to charge it at 161 volts:—

14 amps. = 2·254 k.w. = 3 h.-p. (maximum charging rate).
10 " = 1·61 " = 2·14 " (normal rate).

If the cells are arranged for charging in parallel, a different voltage, but an equivalent quantity of power, will be required. The following table indicates the use of this outfit in handling the load:—

Time.	Farm Load.	Engine.	Charge.	Discharge.
a.m.				
6.30— 8.00	Milking machine and lights	Running	None	None.
8.00— 9.00	None	"	14 amps, 14 amp-hours	"
9.00—10.15	Grinder and cutter	"	None	"
10.30—12.30	Washing machine	"	10 amps, 20 amp-hours	"
p.m.				
12.30— 1.30	None	Stopped	None	"
1.30— 3.00	Drag saw	Running	"	"
3.00— 3.30	None	Stopped	"	"
3.30— 4.30	Buzz saw	Running	"	"
6.00— 6.30	Lights	Stopped	"	(4 amps, 2 amp-hours.
6.30— 7.30	Milking machine and lights	"	"	14 amps, 14 amp-hours.
7.30—11.00	Lights	"		4 amps, 14 amp-hours.
			34 amp-hours	30 amp-hours.

Engine runs $8\frac{1}{2}$ hours.

Thus a 4-h.p. engine, in conjunction with a 3-k.w. dynamo and battery will, by running $8\frac{1}{2}$ hours, handle the normal daily load and give a total amount of 6·93 electrical horse-power for $2\frac{3}{4}$ hours, or 6·05 for $4\frac{3}{4}$, without overloading engine, battery, or dynamo, less any line or motor losses.

The following costs have been worked out for this outfit:—

4-h.p. gasolene engine and 3-k.w. dynamo erected Calgary	$ 520	
Battery and switchboard delivered and installed	1,430	
Capital cost of plant (exclusive of wiring, motors, etc.)	$1,950	
Depreciation, interest and repairs, 20 per cent	390	
Gasolene per h.p. hour—$\frac{1}{8}$ gal. at 30 cents per gal.—Cost of gasolene per day of $8\frac{1}{2}$ hours		1.275
Attendance, oil, waste and supplies		.40
Daily cost		1.675
Yearly running expense (300 days)	$502 50	
Total annual cost	892 50	

Outfit B.—This consists of a 6-h.p. gasolene or coal oil engine, a 4½-k.w. generator and a battery listed as No. 5664.

This battery discharging at 110 volts will give:—

30 amps. for 2¾ hours = 3.30 k.w. or 4.4 h.p.
21 " 4¾ " = 2.31 " 3.08 h.p.

Charging at 161 volts the power required is:—

21 amps. = 3·38 k.w. = 5 h.p.
15 " = 2·41 " = 3¼ h.p.

Considering the same loading conditions as before, we have:—

Time.	Farm Load.	Engine.	Charge.	Discharge.
a.m. 6.30— 8.00	Milking machine and lights	Running	18 amps., 27 amp.-hours	None.
8.00— 9.00	None	"	21 amps., 21 amp.-hours.	"
9.00—10.15	Grinder and cutter.	Stopped	None	18 amps., 22·5 amp.-hours.
10.30— 12.30	Washing machine	Running	21 amps., 42 amp.-hours.	None.
p.m. 1.30— 3	Drag saw	Stopped	None	10 amps., 15·0 amp.-hours.
3.30— 4.30	Buzz saw	"	"	21 amps., 21·0 amp.-hours.
6.00—6.30	Lights	"	"	4 amps., 2·0 amp.-hours.
6.30—7.30	Milking machine and lights	"	"	14 amps., 14·0 amp.-hours.
7.30—11.00	Lights	"	"	4 amps., 14·0 amp.-hours.

Engine runs 4½ hours. Chge. 90 amp.-hours. Disch. 88·5 amp.-hours.

In this case a 6-h.p. engine, either gasolene or oil, in conjunction with a 4½ k.w. and battery will carry the farm load by working 4½ hours per day and will, if required, combine with the battery to give 10 h.p. for 2¾ hours or 9 h.p. for 4¾ hours at the generator terminals.

The following costs have been worked out for this outfit (1) for gasolene and (2) for coal oil:—

(1) 6 h.p. gasolene engine, 4½ k.w. dynamo erected at Calgary	$ 720 00
Battery and switchboard delivered and installed	1,800 00
Capital cost of plant (exclusive of wiring, motors, etc.)	2,520 00
Interest, repairs and depreciation (20 per cent)	504 00
Gasolene per horse-power, hour = ⅛ gal. at 30 cents. Cost of gasolene per 4½-hour day	1 01
Attendance, oil, waste, and supplies	0 39
Daily running cost	1 40
Yearly running expense (300 days)	420 00
Total annual cost	924 00

This is practically the same as for the smaller outfit; the capital costs are larger, but the running expenses are smaller, and we have a largely increased maximum capacity of plant.

(2) 6 h.p. coal oil engine, etc.	$ 730 00
Battery, switchboard, etc., as before	1,800 00
Capital cost of plant (exclusive of wiring, motors, etc.)	2,530 00
Interest, repairs and depreciation (20 per cent)	506 00
Coal oil per h.p. hour = ⅛ gal. at 15 cents. Cost of coal oil per day (4½ hours)	0 81
Attendance, oil, waste and supplies	0 39
Daily running cost	1 20
Yearly running expense (300 days)	360 00
Total annual cost	866 00

This is a saving of about $60 per year on the gasolene plant of the same size, the cost per k.w. hour is somewhat misleading as the load-factor of the 4 h.p. and 6-h.p. plants are different. The actual work done during the day, shown in the diagram is 18-h.p. hours, so that the load-factor for the 4-h.p. plant working 8½ hours is 18 ÷ 34 or 53 per cent; while for the 6-h.p. plant working for 4½ hours it is 18 ÷ 27, or 67 per cent. The fairest way is to consider the actual work done, in which case this is 18 h.p. hours, or 13½ k.w. hours per day, and 4,050 k.w. hours per year, whence we have:—

Cost per k.w. hour for 4-h.p. gasolene engine and storage battery = 22 cents.
" " " 6-h.p. " " " " = 22·8 cents.
" " " 6-h.p. oil " " " = 21·4 cents.

With the outfits outlined above, an increase in use of current will reduce the cost per k.w. hour, as the overhead charges will not vary a great deal; while any decrease in power used will have a contrary effect.

The load diagram upon which the above estimates are founded gives, I imagine, a greater load than the average; in the summer the lighting will be less; the milking load will be fairly constant all the year round but, in the season when work is being done in the fields, the use of saws, grinders, etc., will be materially reduced.

The estimates given above are for the bare power-producing equipment: building for housing the plant, all wiring, motors and electrical devices, being absolutely excluded; these will increase the costs very materially.

The Electric Power Company, Limited, of Belleville, states that "The cost of an installation covering a 3 h.p. contract varies considerably, depending largely on the extent to which the party wishes to use the current. A holder of the above-mentioned amount may use, at different intervals, the following: 2,000 watt electric range, toaster, electric iron, radiator (not water heater), vacuum cleaner, pressure pumping installation, a general utility motor (¼ h.p.) which can be used to operate the washing machine, churn, buffing machine, etc.; while at the barn, a 3-h.p. motor can be connected to a countershaft and operate straw cutter, root pulper, milking machine, cream separator and wood saw. Together with the necessary wiring, this installation might cost $550. At the present time, it cannot be termed a representative installation as the usual investment will be approximately $250."

The question of the power necessary for silo-filling and threshing is not quite settled. Mr. Purcell, of the Ontario Hydro-electric Commission, has stated that a 5-h.p. motor will drive a small thresher or silo-filler, and that these will operate quite satisfactorily; whether these smaller machines will ever become popular remains to be seen. The Electric Power Company, already referred to, state that "should small threshing outfits, which may be used at opportune time, and the carrier ensilage cutter replace the equipment most used now, it is our opinion that 5 h.p. will be quite adequate."

The writer perfectly realizes that the above estimates may well be wide of the mark, the assumption as to load is entirely arbitrary; until a large number of diagrams for many farms, extending over long periods have been taken, a fair estimate of power demand cannot be made. The prices are, except where otherwise stated, given for plant erected near Calgary, long road hauls will affect these costs considerably, and as was stated previously the prices given can only be taken as fair approximations.

The figure for overhead charges (20 per cent) will have to be verified or revised by experience.[1] The use of batteries, too, may prove unsatisfactory in the hands of the average farmer; as a general rule a storage battery requires reasonably careful handling to give its best results. Attention was perhaps not sufficiently directed to the fact that the loss in charging and discharging a battery is about 40 per cent.

The cost and consumption of fuel are believed to be reasonably correct, these items are variable in any case and difference will affect daily and annual costs in a very marked degree.

The advantages to be gained by using electricity on a farm have been enumerated again and again, in technical papers and trade publications. Special stress has been laid upon the convenience and cleanliness of a house and farm completely equipped electrically, and it is here taken for granted that the proposition has been sufficiently demonstrated as to convenience. With regard to economy, it can but be obvious that any device that increases the efficiency of the hired man 300 per cent or more, or reduces the number of men required, is a great saving when one considers the costliness and difficulty of obtaining and keeping farm help.

The General Electric Company has issued a well arranged, illustrated bulletin '*Electricity on the Farm*' which treats very fully of the applications of electricity, and some of the data in this publication are incorporated in the appendix. I have not, therefore, elaborated on the uses of electricity, but have confined these notes to the sources of power available to the Western farmer, and it is hoped that these together with the appendices and some photographic illustrations will be of interest to the agriculturist and not prove misleading.

CONCLUSIONS.

It may be thought that some of the outfits elaborated on have proved unworthy of the space devoted to their discussion; I have thought it well, however, to treat the matter fully, so that those interested may study all the alternatives and select the outfit best suited to their needs and resources. I do not feel called upon to make any recommendations, on what is, largely, a theoretical study of the question.

It is not claimed that every alternative has been looked into, nor that the figures given are accurate. The assumptions have, of necessity, been somewhat arbitrary. The data given have been collected with great care from all available sources and, it is thought, are free from any gross errors.

An appendix is given containing a bibliography, and a collection of information as to power consumption on the farm.

I have the honour to be, Sir,

Your obedient servant,

A. M. BEALE,

Engineer.

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[1] Recent figures supplied me by manufacturers place depreciation of batteries at 10 per cent, and gasolene-electric sets at from 5 to 10 per cent according to hours of service. If continuous service, of say 18 hours, is required, if no battery is used, the engine will be running long hours and the depreciation will be high and the gasolene consumption, owing to the high proportion of light load, will be inefficient.

If a large storage battery is used the engine depreciation will be low; but the increased gasolene efficiency will be counterbalanced by the electrical inefficiency of the battery, also the 10 per cent depreciation on the expensive battery will amount to a considerable sum.

The automatic set, it is claimed, avoids the above disadvantages, the engine does not operate for very light loads, while the battery is cheap and is only used to supply a small portion of the energy used. So we have greater gasolene efficiency and lower depreciation charges.

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Report on Projected Hydro-Electric System for Manitoba, by H. A. Robson, K.C.
Bulletin No. 25, Iowa State College, Ames, Iowa. "Electric Power on the Farm," by Adolph Shane.
Bulletin No. 25, University of Illinois, Urbana, Ill. "Lighting Country Homes by Private Electric Plants." T. H. Amrine.
Bulletin No. 146, United States Department of Agriculture, Washington, D.C. "Current Wheels—their use for lifting water for Irrigation."
Bulletin No. 529, University of Wisconsin, Madison, Wis. "Theory and Test of an Overshot Water Wheel." C. R. Weidner, C.E.
"Electricity for the Farm and Home." By Frank Koester.
"Water Power for the Farm and Country Home. David R. Cooper, State Water Supply Commission, New York.

Frequent reference is to be found in technical journals such as the *Electrical News* and the *Transactions of Electrical Societies.* Many reputable manufacturing firms have issued catalogues, pamphlets, bulletins or other advertising matter, which contains much interesting information on one phase or another of the small power question.

APPENDIX.

AMOUNT OF POWER CONSUMED BY FARM MACHINERY.

Mr. Purcell, Assistant Engineer Ontario Hydro-Electric Power Commission

½ h.p. Will light fifteen 20 c.p., nine 32 c.p. or six 48 c.p. Tungsten lights. It will supply energy for a pump of average lift, electric iron, washing machine, coffee percolater, toaster, cream-separator, churn, buttermaker, grindstone, cider-mill, fanning mill, etc., some cases more than one at a time.

1 h.p. The above, also small stove of fireless cooker type; some milking machines, some circular saws, water heater for night load.

2 h.p. All above, any milking machine, most types of cutting box, 6-inch or 8-inch choppers of 10 bushels capacity per hour suitable for horses or cattle, or 6 bushels for pigs.

5 h.p. Can do almost any operation required on the farm.

"*Small Water-power for the Farm and Country Home.*"—David R. Cooper.

1 h.p. Will pump all water from a well of ordinary depth for ordinary farm-house and building requirements.

3 h.p. Converts 6,000 pounds milk per day into cheese.

5 h.p. Grinds 25 to 40 bushels feed per hour, grinds 10 to 12 bushels ear-corn per hour, drives 30-inch circular saw cutting 50 to 75 cords stovewood from hard oak in ten hours.

6 h.p. Will drive grain separator and thresh 2,500 bushels of oats in ten hours, will run a feed-mill grinding 20 bushels corn an hour, runs heavy apple grater, grinding and pressing 200 to 250 bushels per hour, saws all the wood four men can pile in cords.

7 h.p. Drives an 18-inch separator, burr-mill and corn and cob crusher and corn sheller grinding from 12 to 15 bushels of feed per hour and 5 to 8 bushels of good fine meal.

10 h.p. Will run 16-inch ensilage cutter and blower[1] and elevate the ensilage into a silo 30 feet high at the rate of 7 tons per hour.

12 h.p. Will drive a 50-inch circular saw, sawing 4,000 feet of oak or 5,000 feet of poplar a day.

"*Electricity for the Farm and Home.*"—Frank Koester.

All costs are figured for power at 5 cents per k.w.h. Machinery prices are for United States, and to these must be added freight and duty. Power required for farm machinery (pp. 103-104):—

Thresher	5 h.-p.
Cow milker	½ h.-p.
Grindstone	¼ h.-p.
Grist-mill	15 to 30 h.-p.
Refrigerator	5 to 25 h.-p.
Pump	½ to 25 h.-p.

*Mr. Purcell considers blower outfits prodigal of power, and recommends elevator.

Hay press (120-pound bales)—

14-inch	by	18-inch	bale chamber;	capacity	12	tons	per day,	3	h.-p.
16	"	18	"	"	14	"	"	4	"
17	"	22	"	"	16	"	"	6	"
14	"	18	"	"	10	"	"	2	"
16	"	18	"	"	10	"	"	2	"
17	"	22	"	"	12	"	"	3	"

Feed grinder—

8-inch	large or small;	capacity	8	bushels	per hour,	4 h.p.
16	"	"	36	"	"	10 "
10	"	"	15	"	"	6 "
10	"	"	50	"	"	15 "

Husker—

6 roll;	capacity,	all that one man can carry	15 h.-p.
Two 6 "	"	300 to 400 bushels per hour	12 "
4 "	"	175 to 250 " "	8 "
2 "	"	100 to 200 " "	4 "

Combination churn and buttermaker—

Capacity, 50 gallons	1 h.-p.
100 "	1 "
200 "	2 "
300 "	2 "

Pasteurizer—

600 gallons	2 h.-p.

Cream separator—

350 gallons of milk per hour	½ h.-p.
450 " " "	½ "
650 " " "	½ "
850 " " "	1 "
1,000 " " "	1 "

Pumping 1,000 gallons per day elevated 35 feet, $18.25 for energy.

Threshing 80 to 200 bushels per 10 hours (threshing, cleaning and sacking) 3 to 5 k.w.; 160 to 240 bushels per 10 hours (threshing, cleaning and sacking) 5 to 7 k.w.; 300 to 800 bushels per 10 hours (threshing, cleaning and sacking) 10 to 20 k.w.

The energy required per 100 bushels is: rye, 25 k.w.h.; wheat, 22 k.w.h.; oats, 19 k.w.h.; barley, 21 k.w.h., or an average of 1·1 cents per bushel.

Fodder cutters, 1 to 2 h.p. use 1/80 k.w.h. per 100 pounds; 10 head of cattle consume 60,000 pounds of cut beet, etc., per annum, energy costing 50 cents per head.

Oil-cake breakers, ten head use 9,000 pounds per annum, energy costing 25 cents per head.

Grain crusher, ten head use 9,000 pounds per annum, energy costing 27 cents per head.

Cream separating and churning, ten cows give 30,000 quarts per year costing $1.50 for energy.

Vacuum cleaners, ¼ h.p. machine costs $125; one woman working 260 hours cleans 208,000 square feet costing $43.19 yer year (interest, depreciation, labour, energy); 3 h.p. machine costs $1,365, cleans 2,500 square feet in 1 hour 53 minutes, working 156 hours per annum cleans 260,000 square feet at 9½ cents per 100 square feet or $248 per year (interest, depreciation, labour, energy, etc.).

Washing machine, ¼ h.p., costs $165 complete, 260 hours per year, 780 washes, $35.41 in all.

Horse groomer, costs $75, 1 h.p. motor cleans four horses in 36 minutes, one man working 328½ hours per year can do 2,190 groomings at $72.93 or 3½ cents per grooming.

Separator and churn, 1½ h.p. motor, 183 hours per year, 237,900 pounds milk at $88, or 3·7 cents per 100 pounds; butter churn, 0·2 cents per pound.

Sausage machine grinder costs $71, capacity 750 pounds per hour, 4 h.p. motor costing $145. Eighty hours per year, 60,000 pounds at $60 or, 1 cent per pound.

Stuffer costs $229, 116 pounds per hour with two operators, 517 hours per year for 60,000 pounds, or 0·37 cents per pound.

Hay hoist, 10 h.p., $163; rigging, $105; 2,450 pounds placed in thirteen minutes, or 3½ cents per ton for power, and 10 cents for labour.

Root cutter, 6 tons turnips per hour costs $26.30; 2 h.p. motor, costing $86, in 52 hours cuts 300 tons beets and turnips at $35.94 or 11·9 cents per ton.

Milling, 25 h.p. motor works roller, rolls 40,000 bushels oats per year at 4/10 cents per bushel for power and labour. Same motor has power to run grist mill of capacity 70 bushels cracked corn per hour, and can run cracking machine for this.

Fodder cutter, capacity 3 tons dry fodder per hour, costs $128.10, and is operated by 10 h.p. motor ($118.50), in 88·70 hours per year cuts 180 tons at cost of $54.85, with one operator, at 30 cents per ton.

Electric ploughing, one motor 80 to 120 h.p. plough system cost $8,000; two motor system $11,000. Steam plough of same capacity $14,000 to $15,000. Disadvantage, not self-propelled to field. Advantages, all other points.

Cost of Electric Ploughing at 3 cents per k.w.h.

Depth of furrow inches	8¾	10¾	14½
Acres per hour	2.25	1.92	1.70
Minutes per acre	27	31	35
Kilowatt-hours per acre	19·2	23·2	33·6
Cost of electricity per acre in cents	57·6	69·6	100·8
Wages per acre for three men in cents	20	24·9	27·9
Total cost of ploughing per acre in cents	77·6	94·5	128·7

Average speed of 80 to 120 h.p. plough with four shares for 9 inch furrows, including time lost in tilting at end of furrows, is 315 feet per minute (about 3½ miles per hour).

Tree cutting, by hot wire (this wire is heated by the friction):—

Diameter of Scotch fir, inches	7·6	12	19·2	
Minutes for hand sawing	1·5	4	12	
" hot-wire cutting	0·7	1·8	4·5	
Diameter of beech, inches	7·6	12	19·2	30
Minutes for hand sawing	2·7	6·9	18·9	120
" hot-wire cutting	1·3	3·4	8·5	20·8

Steam saws may be even faster than hot wire on very big trees, but require four men and a team of horses, besides leaving a stump, whereas by the hot-wire method trees can be cut even below ground.

General Electric Company's Bulletin.

Household Uses.—One cent's worth of electricity at 10 cents per kilowatt-hour will operate:—

A 16 c.p. Tungsten lamp for five hours.
An electric washer, capacity 12 sheets, long enough to wash 20 sheets.
A toaster to produce 10 slices of toast.
A 12-inch fan for two hours.
A heating pad from two to four hours.
A chafing dish twelve minutes.

A water heater to bring 1 quart water to boil.
A griddle eight minutes.
A radiant grill for ten minutes.
A 4-inch disk stove for twelve minutes.
A 6-pound flat iron fifteen minutes.
A vacuum cleaner long enough to clean 450 square feet.
A pump to raise 100 gallons of water 100 feet.
A sewing machine for two hours.
A coffee percolator to produce 3 cups of coffee.
A domestic buffer and grinder for $1\frac{1}{4}$ hours.
A foot warmer $\frac{1}{2}$ hour.
A broiler six minutes.
An electric curling iron once a day for two weeks.

SIZE OF MOTORS.

Machine.	Horse-power of Motor.		
	Minimum.	Maximum.	Size most commonly used.
Sewing machine	....	........—	$\frac{1}{30}$
Buffer and grinder	$\frac{1}{30}$	$\frac{1}{30}$	$\frac{1}{30}$
Vacuum cleaner	$\frac{1}{8}$	5	$\frac{1}{8}$ to $\frac{1}{2}$
Ice cream freezer	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{8}$
Washing machine	$\frac{1}{8}$	2	$\frac{1}{8}$ to $1\frac{1}{2}$
Meat grinder	$\frac{1}{4}$	$\frac{3}{4}$	$\frac{1}{4}$
Water pump	$\frac{1}{4}$	1	$\frac{1}{2}$

Dairy uses.—One cent's worth of electricity at 10 cents per k.w. hour will separate 700 pounds milk, will churn 10 pounds butter, or milk five cows if machine is capable of milking sixteen cows at a time. This bulletin gives in all some twenty uses for electricity in the dairy, such as bottle-washing, pasteurizing, &c.

SIZE OF MOTORS.

Machine.	HORSE-POWER OF MOTOR.		
	Minimum.	Maximum.	Size most commonly used.
Water pump	$\frac{1}{2}$	5	3
Cream separator	$\frac{1}{10}$	$\frac{1}{4}$	$\frac{1}{8}$
Churn	$\frac{1}{8}$	3	$\frac{1}{4}$
Milking machine (vacuum system)	1	3	3
Refrigerator	$\frac{1}{2}$	10	5

General Farm Uses.—With current at 10 cents per k.w. hour, 0.7 cents will thresh a bushel of oats, 1 cent a bushel of barley, and 1.6 cents one of wheat; root-cutting will cost 1.6 cents a ton; $1.10 will pay for the current for a 60-egg incubator hatching and $1.60 for a 250-egg incubator. The following are the costs per bushel for grinding:—

Corn on the cob, 4.1 cents; oats, 3.7 cents; crushing oats, 0.45 cents; grinding shelled corn, 2.7 to 4.3 cents according as size of motor decreased from 15 to 5 h.p. Cracking corn, 0.86 cents.

Attention is called to the cost of hauling grain to the mill and back, which may be from 1 to 6 cents per bushel according to the grain and distance to mill (1 to 7 miles).

SIZE OF MOTORS.

Machine.	HORSE-POWER OF MOTOR.		
	Minimum.	Maximum.	Size most commonly used on average farms
Feed grinders (small)	3	10	5
Feed grinders (large)	10	30	15
Ensilage cutters	10	25	15 to 20
Shredders and huskers	10	20	15
Threshers, 19-inch cylinder	12	18	15
Threshers, 32-inch cylinder	30	50	40
Corn shellers, single hole	$\frac{3}{4}$	$1\frac{1}{2}$	1
Power shellers	10	15	15
Fanning mills	....	....	$\frac{1}{4}$
Grain graders	....	....	$\frac{1}{4}$
Grain elevators	15	5	3
Concrete mixers	2	10	5
Groomer, vacuum system	1	3	2
Groomer, revolving system	1	2	1
Hay hoists	3	15	5
Root cutters	1	5	2
Cord wood saws	3	10	5
Wood splitters	1	4	2
Hay balers	3	10	$7\frac{1}{2}$
Oat crushers	2	10	5

Many of the values given for minimum horse-power exceed 5 h.p.; probably, however, machines using not more than 5 h.p. can and will be built if there is a demand for them.

CLASSIFIED LISTS OF REPORTS

The Reports published by the Dominion Water Power Branch with the exception of the Annual Reports, have been called Water Resources Papers, and have been numbered 1, 2, etc.

Annual Reports previous to 1913 are included with the Annual Report of the Department of the Interior, and can be secured from the Secretary of the Department.

Annual Report for 1912-13, published 1914.

Annual Report for 1913-14, published 1915.

Annual Report for 1914-15. In Press.

WATER RESOURCES PAPER No. 1.—Report of the Railway Belt Hydrographic Survey for 1911-12, by P. A. Carson, B.A., D.L.S., Chief Engineer. Published 1914.

WATER RESOURCES PAPER No. 2.—Report of Bow River Power and Storage Investigations (Bow river west of Calgary,) by M. C. Hendry, B.A.Sc., Chief Engineer in charge of surveys. Published 1914.

WATER RESOURCES PAPER No. 3.—Report on Power and Storage Investigations, Winnipeg river, by J. T. Johnston, B.A.Sc., Hydraulic Engineer of Water Power Branch. In Press.

WATER RESOURCES PAPER No. 4.—Report of the Manitoba Hydrographic Survey to the year ending 1914, by M. C. Hendry, B.A.Sc., Chief Engineer. In Press.

WATER RESOURCES PAPER No. 5.—Preliminary Report on the Pasquia Reclamation Project, by T. H. Dunn, C.E., O.L.S., Chief Engineer in charge of Reclamation Survey. Published 1914.

WATER RESOURCES PAPER No. 6.—Report on cost of various sources of power for pumping in connection with the South Saskatchewan Water Supply Diversion Project, by H. E. M. Kensit, M.I.E.E. and Mem. Am. Inst. E. E. Mem. Can. Soc. C. E. Published 1914.

WATER RESOURCES PAPER No. 7.—Report on the Manitoba Water Powers, by D. L. McLean, S. S. Scovil, and J. T. Johnston, compiled for the Manitoba Public Utilities Commission. Published 1914.

WATER RESOURCES PAPER No. 8.—Report of the British Columbia Hydrographic Survey for 1913, by R. G. Swan, B.A.Sc., Chief Engineer. Published 1915.

WATER RESOURCES PAPER No. 9.—Report of Red River Navigation Surveys, by S. S. Scovil, B.Sc., Assistant Chief Engineer of Manitoba Hydrographic Survey. In course of preparation.

WATER RESOURCES PAPER No. 10.—General Guide for Compilation of Water Power Reports of Dominion Water Power Branch, prepared by J. T. Johnston, B.A.Sc., Hydraulic Engineer of Water Power Branch. Published 1915. Limited edition.

WATER RESOURCES PAPER No. 11.—Final Report on the Pasquia Reclamation Project, by T. H. Dunn, C.E., O.L.S., Chief Engineer in charge of Reclamation Survey. Published 1915.

WATER RESOURCES PAPER No. 12.—Report on Small Water Powers in Western Canada, and discussion of sources of power for the Farm by A. M. Beale, B.Sc. Published 1915.

WATER RESOURCES PAPER No. 13.—Report on the Coquitlam-Buntzen Hydro-Electric Development, by G. R. G. Conway, M. Inst. C.E., M. Can. Soc. C.E., Chief Engineer of the British Columbia Electric Railway Company, Limited. In press.

WATER RESOURCES PAPER No. 14.—Report of the British Columbia Hydrographic Survey for 1914 by R. G. Swan, B.A.Sc., Chief Engineer. Published 1915.

WATER RESOURCES PAPER No. 15.—Report on the Water Powers of Alberta and Saskatchewan by C. H. Attwood, O.L.S., Chief Engineer Alberta and Saskatchewan Power Surveys. In course of preparation.

WATER RESOURCES PAPER No. 16.—Water Powers of Canada. A series of five pamphlets in one volume covering the water power situation in Canada prepared for distribution at the Panama-Pacific Exposition, San Francisco, 1915, by G. R. G. Conway, Consulting Engineer to the Vancouver Power Co., Percival H. Mitchell, E.E., Consulting Engineer, Toronto, H. G. Acres, Hydraulic Engineer Hydro-Electric Commission Ontario, F. T. Kaelin, Asst. Chief Engineer Shawenegan Power Co., K. H. Smith, Engineer, Nova Scotia Water Power Commission. Published 1915.