GILKES

REPORT
upon the
HYDRO-ELECTRIC
and
OTHER POWER RESOURCES
in the
FALKLAND ISLANDS

WATER TURBINES AND GOVERNORS

10th June 1955

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KENDAL
WESTMORLAND
ENGLAND

OUR REF PNW/EH
YOUR REF

24th June, 1955

The Falkland Islands Company Ltd.,
120 Pall Mall,
London S. W. 1.

Dear Sirs,

HYDRO-ELECTRIC
and
OTHER POWER RESOURCES
in the
FALKLAND ISLANDS

Between 1946 and 1954 we received several enquiries for the supply of small hydro-electric sets for the Falkland Islands. It appeared that relatively little information was available regarding the flow conditions of the streams and rivers and this made it difficult for us to be certain that any plant which we recommended would meet satisfactorily the needs of the community.

The matter was discussed with your Chairman, Mr. L.W.H.Young, and after you had consulted other interested Companies it was agreed that we should send an engineer to the Falkland Islands to make a general brief survey.

This was carried out by our London Manager, Mr. J. H. Walker, who is fully experienced in the investigation of small hydro-electric schemes and has done many similar investigations in Great Britain, Ireland and overseas.

Mr. Walker has now completed his report, a copy of which is attached.

We are sorry that in some respects the result of the survey has been disappointing, but as will be seen from the report there are possibilities, all of which should be considered when the necessary records are available. It is also possible that conditions involving such factors as the availability of labour for peat cutting, the cost of oil fuel, etc. may change the situation in years to come and we would suggest that the report should be carefully filed so that it may be referred to in the future.

We should like to express our sincere thanks for the assistance and hospitality extended to Mr. Walker from the time of his departure until his return.

Yours faithfully,

For GILBERT GILKES & GORDON LTD.

Paul N. Wilson

(Paul N. Wilson)
M.A., M.I.C.E., M.I.Mech.E.
Chairman

DIRECTORS
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Dear Sirs,

REPORT
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HYDRO-ELECTRIC
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FALKLAND ISLANDS.

Following Mr. Walker's visit to the Falkland Islands, we have pleasure in submitting this report upon the power possibilities.

1. TERMS OF REFERENCE.

The primary object of the visit was to investigate possible hydro-electric development but it was agreed that being in close touch with modern wind power development and research he should also investigate the wind power possibilities.

In assessing the possibilities of either water power or wind power it is essential to consider actual potential in conjunction with many other factors such as the economy of the Islands, population, alternative means of power production and, in particular, the potential demand for power.

2. THE MAIN CONCLUSIONS.

(i) The Falkland Islands are neither so wet nor subject to such continuous winds as information made available before this visit had indicated.

ii) There are many sites in the Falkland Islands where small water power schemes would be possible, but few of these are deserving of consideration due to factors which are discussed in this report.

iii) Due to the lack of accurate information relating to the flow of streams, measuring weirs should be set up in those streams which might be harnessed and flow readings should be taken for a period of at least 12 months. These readings should be analysed in conjunction with the rainfall records and it can then be decided whether or not a hydro-electric set should be installed.

iv) The possibility of further development of wind power may be considered but here again more records should be obtained before any action is taken.

3. ITINERARY.

Mr. Walker left London on the 1st February 1955 flying to Montevideo and then taking passage in S.S. "Fitzroy" to Port Stanley, where he arrived on 11th February. He left on 16th April, returning by the same route, having been in the Falkland Islands for a period of 64 days.

In consultation with Mr. Barton a preliminary itinerary was worked out. This was subsequently followed with variations, as detailed below :-

Date.	Method of Travel.	Places Visited.
14th Feb. to 11th March.	S.S. "Fitzroy".	Fitzroy North Arm Fox Bay East and Fox Bay West Port Stephens Weddell Island Roy Cove Chartres West Point Hill Cove Saunders Ajax Bay San Carlos North Tyson Port Howard

Date.	Method of Travel.	Places Visited.
11th March.	Air	Douglas Station Darwin Stanley
16th March.	H.M.S. "Burghead Bay".	San Salvador Teal Inlet
22nd March.	Overland	Douglas Station San Carlos River Port San Carlos
23rd March.	Boat	San Carlos
26th March.	Overland	Darwin
29th March.	Air	Pebble Chartres Fox Bay Port Howard
1st April.	Overland	Warrah River Green Hills Chartres
4th April.	Overland	Hill Cove
7th April.	Overland	Roy Cove
9th April.	Overland	Hill Cove
10th April.	S.S. "Fitzroy"	Saunders San Carlos Stanley
15th April.	Air	Darwin Douglas Station North Camp Teal Inlet

While in Stanley discussions were held with a number of people respecting Stanley electric supply, meteorological conditions, etc., and a visit was made to the Murrell River in company with Mr. Weir, Mr. Livermore and Mr. Mathews.

The foregoing is a short outline of the main pattern of travel. Expeditions were made from the various settlements to examine the surrounding country and overland journeys deviated from the straight for the same purpose.

4. POWER REQUIREMENTS IN THE TERRITORY.

Apart from Port Stanley and Ajax Bay there are no large consumers of power in the Falkland Islands, nor does it appear likely that there will be. Should the demand for electricity increase it might become economical to transmit from sites at considerable distances, but with the existing requirements hydro-electric plants will need to be quite close to the consumer points in order to render them economical.

Most of the settlements, with the exception of Darwin and Goose Green, have a population of between 30 and 50 people, and the main requirements for power or fuel are as follows :-

a) Domestic heating, cooking and hot water.

b) Sheep shearing.

c) Small machines, i.e. lathes, drilling machines, etc.

d) Electricity for domestic convenience, i.e. lighting and such small domestic devices as irons, refrigerators, vacuum cleaners, radio, etc. not included under (a).

(a) Domestic Heating.

Large deposits of peat are available and this is generally used.

(b) Sheep Shearing.

This takes place for some 10 weeks in the year and for about 10 - 12 hours per day. About 0.5 B.H.P. per shearer is required, so that 10 - 12 B.H.P. would be adequate for the average settlement. The relatively high capital cost of a hydro-electric set would not be justified when the power for this short period could be provided by an internal combustion engine.

(c) Small Machine Tools, etc.

The power demand for the above would not justify the installation of hydro-electric plant but if the electricity is available the use of such small machines might increase.

(d) Domestic Convenience.

The advantages of a constant and cheap supply of electricity in the home are so well known that they require no emphasis. If domestic heating is cut out generating plant developing 5 - 10 kW should be adequate for the average settlement.

5. ALTERNATIVE FUELS AVAILABLE.

It had been hoped by some owners that alternative means, possibly electricity, could be used to provide domestic heating, cooking and hot water. From various sources it was learned that the average cost of peat, including the cost of winning it, transporting it, etc. is about 4/- per cubic yard or 32/- per ton delivered to the customer. At any rate this is believed to be a fair average. The actual price per yard may vary from 3/- to 5/-.

The efficiency of heat producing appliances varies at the different settlements, some being more modern than others, but a mean figure of 50% efficiency may be taken for comparing peat with other fuels.

Assuming heating values of 4,000 B.T.U. for peat, and 12,000 B.T.U. for coal, the price of coal delivered to the settlements would have to be less than £4. 16. 0. per ton to render it more economical. This is much less than we pay for it in England for domestic purposes.

In view of the very high price of coal in the Falkland Islands, clearly it cannot compete with peat on a cost basis.

Fuel oil is another possible alternative and has a thermal value of about 16,000 B.T.U. per pound, but with the same boiler efficiency it would have to be delivered to the consumer for £6. 8. 0. per ton to compare with coal or peat upon the above basis. Fuel oil now costs about £30 per ton in Port Stanley and considerably more in the camp.

In giving the above figures it is realised that modern oil burning equipment has a higher thermal efficiency than 50% but so have modern coal and peat burning appliances, so that the comparison will be reasonably correct.

When electricity is applied for heating purposes the usable heat from one unit of electricity is about equivalent to that from 1.7 lbs. of peat. As the average cost of peat is about 0.171 pence per lb., electricity would have to be delivered to the consumer at 0.29 pence per unit in order to make it an economical competitor.

In large installations power can often be generated, and indeed transmitted short distances, for lower figures than this but certainly in the Falkland Islands, owing to the special conditions which exist, electricity cannot be produced cheaply enough to compete with peat for heating purposes.

6. EXISTING SOURCES OF POWER FOR DOMESTIC USE.

A number of settlements have been equipped with automatic engine generating plants of the type which start up when the first light is switched on and stop when the last light is switched off. With these sets a considerable amount of servicing is necessary, and in the British Isles the purchaser often makes a service agreement with the manufacturer to ensure adequate maintenance. In the Falkland Islands such service is not available quickly and cheaply, and there is much to be said for a straightforward D.C. generating set charging a battery of the lead acid or nickel alkaline type. This system has been used successfully at Roy Cove and is less liable to breakdowns than the fully automatic installation.

Small wind generators have been fitted up for some houses and in the absence of any better electricity supply they operate quite satisfactorily. The question of using wind power is dealt with later.

7. POTENTIAL HYDRO-ELECTRIC SCHEMES FOR SMALL SETTLEMENTS.

In certain instances it may be possible after flow investigations are complete to use a small hydro-electric set to augment or replace the engine generating set for some of these installations, and wind power may similarly be used.

In those few cases where sufficient water power is available, the hydro-electric plant may be run continuously

24 hours a day, feeding electricity to the settlement without any intermediate storage battery.

The domestic consumption of electricity will be relatively small, thus weighing against the higher capital cost of the hydro-electric set, but the extreme simplicity and low maintenance costs of the latter should be given full consideration.

The following sites for small units should be further investigated with a view to possible hydro-electric development :-

Settlement.	Owner.	Remarks.
Port Howard	James Lovegrove Waldron Ltd.	Survey carried out and measuring notch installed.
Hill Cove	Holmstead & Blake.	Survey carried out. A small notch had already been installed, a more suitable one has been suggested.
Roy Cove	Bertrand & Felton	Survey carried out and measuring notch installed.
Chartres	Anson & Dexton	Survey carried out and arrangements made for installing measuring notch.
Port Stephens	Falkland Islands Company Ltd.	Very brief investigation but suggest installing measuring notch.

8. DARWIN AND GOOSE GREEN.

Total power requirements at these two settlements for domestic purposes is not at present known but it would be worth setting up a measuring weir at Camilla Creek and taking a set of levels up the stream in order to determine whether there is any possibility of using it and transmitting power to Darwin. The distance is estimated at 4 to 5 miles.

It is not considered that any other streams in the

Darwin area are worth investigating although Mr. Walker was unable to cover this district as fully as he would have liked. Certainly none of the streams to the south of Darwin in Lafonia would be of any use.

9. AJAX BAY.

As the freezer is the only power consuming industry of any size outside Port Stanley Mr. Walker considered the possibility of providing an alternative to the Diesel engines. There are two units, each of 196 kW, one being a standby to the other. For many months in the year the freezer is not in operation and one of these large engines is run continuously to provide for a small domestic load usually in the region of about 12 kW, rising to a peak of 25 kW. This method of operation is highly uneconomic in fuel consumption.

The freezer is at present closed down but should it come into operation again and be likely to continue doing so on a regular basis, then it would be worth while looking for a possible source of power in the head waters of the San Carlos River. The probable distance as the crow flies from Ajax Bay is about 10 miles.

The lower reaches of the river are very flat and there is no possibility of adequate economic hydro-electric power there. Mr. Walker examined the river for some miles upstream but was unable to visit the upper reaches. Inspection by air indicated that there are some falls and that one of the feeders to the river comes from a lake high up on Mount Usborne. Varying information was obtained, one gentleman stating that the stream flowing from this lake never dried up and that it dropped 500 or 600 feet in a comparatively short distance. Another informant stated that it dried up in dry weather.

The course of the San Carlos River as shown on the map is far from accurate, and this applies to many of the rivers in the Falkland Islands.

Although aerial inspection does indicate some fall at certain parts of the upper reaches of the San Carlos, a survey on the ground would be necessary to establish the amount of it, the flow and the possibilities of development.

10. PORT STANLEY.

The present electric supply to Port Stanley is from a modern diesel station and we are indebted to Mr. Gutteridge for some figures relating to this station. The peak load is about 230 kW, the normal evening load 225 - 230 kW, the day load in winter 180 - 200 kW, and the normal night load 40 kW.

It is understood that owing to the installation of various fairly high consuming devices the load is likely to increase substantially in the near future.

The total number of units sold in 1954 was 550,000 and the fuel consumption was such that the cost of the fuel component would be about 2.4 pence per kW.Hr. This figure allows for certain wastage due to drums not being full and is calculated at a fuel cost of £30 per ton. With the installation of the new storage tanks it is thought that the fuel cost may come down to the region of £24 per ton, in which case the equivalent fuel component would come to 1.9 pence per kW.Hr.

This is a very high figure compared with that which is achieved in some other small communities. One of the Channel Islands, for instance, with a smaller installation than that at Port Stanley achieves a fuel component of about 1.175 pence per kW.Hr.

It appears that the high cost of freight makes it unlikely that the fuel component at Port Stanley will drop appreciably in the near future below the 1.9 pence per kW.Hr. above stated. Hence it is well worth while to investigate the possibility of some power being obtained by other means, i.e. by water power or by wind power.

The wind power problem will be dealt with under a separate paragraph below. It may suffice in this paragraph to say that it is well worth further investigation.

A visit was made to the Murrell River in company with Mr. Weir and Mr. Livermore to investigate the possibility of water power for transmission to Port Stanley. The new filtration plant to be installed at the outlet from the Moody Brook to Stanley Harbour is at a distance of approximately $2\frac{1}{2}$ miles from the Stanley generating station and it is understood that a power line is to be carried from the generating station to feed it.

To the Murrell River at any point where power is likely to be developed is a further $5\frac{1}{2}$ miles beyond the filtration plant. If the voltage of the line to the filtration plant were stepped up it would be possible to use this line as part of the transmission system for feeding power back from the Murrell River to Stanley, taking in the filtration plant on the way.

The flow in the Murrell River was distinctly greater than Mr. Walker expected to find, being in the region of 50 cusecs, but to what extent weather in the preceding few days had affected this flow is not known. There was no time to make a detailed survey but it was clear that it would be worth while installing a measuring weir in the river, perhaps in the stretch of a mile or so below Murrell Bridge, and having readings taken every few days. The cost of doing this is not great but if it is done, records must be taken and later considered in conjunction with the rainfall figures at Port Stanley. Better still, a rain gauge in the region of Murrell Bridge could be read at the same time as the flow over the measuring weir.

The three survey sheets of which we have copies are to a small scale but indicate considerable fall on the Murrell River which it may be possible to utilise. From the 150 ft. contour there seems to be quite a steep fall down to the 100 ft. contour in a distance of only 430 yards. By taking in water somewhat upstream of the 150 ft. contour and going downstream below the 100 ft. contour a reasonably short distance might give a fall of anything up to 100 feet, but a larger scale survey of this stretch of river would be necessary before the cost of a scheme could be estimated.

For reasons stated later a large dam is not advisable, but it is thought that a small diversion dam might lead water into a contour channel, in turn feeding to a pressure penstock to convey water down to a turbine.

Approximate estimates of cost based on such information as is at present available indicate that, subject to water measurements being taken over a year or so, a small hydro-electric set might prove an economic proposition as an adjunct to the present Stanley supply.

If a measuring weir is installed, it is suggested that it should have a maximum capacity of about 50 cusecs. Anything greater than that will be in the nature of flood flow, and will not be of interest from the point of view of power production.

A hydro-electric installation as visualised at the Murrell River could be made automatic in the sense that its output would be automatically adjusted according to the available water to supply it. It could be so designed that a visit would only be necessary every few days and no continuous attendance would be required.

11. FACTORS AFFECTING THE LOW AVAILABILITY OF WATER POWER.

The runoff in rivers in any territory is of course closely related to the rainfall. The rainfall in the Falkland Islands is quite low. It is stated in the Colonial Report of 1952/53 that the average rainfall is 28" per year, which is rather more than London. A number of records kindly supplied by you seem to indicate that this statement is too optimistic. Good records have been kept at Port Stanley over a long period and a figure of 27" - 28" will be a reasonable estimate of the long term average for that town. You supplied records at other points from which the following have been dedmced :-

Darwin Harbour.	Mean	annual	rainfall	over	15 yrs.	17.13"
North Arm.	"	"	"	"	14 yrs.	19.45"
Fitzroy.	"	"	"	"	14 yrs.	16.30"
Fox Bay West.	"	"	"	"	11 yrs.	17.38"
Spring Point.	"	"	"	"	12 yrs.	15.43"
Port Stephens.	"	"	"	"	5 yrs.	25.48"

From other sources we obtained the rainfall of Port Howard over 5 years and the average is 27.50". We also know that the Port Stanley rainfall is in the region of 27" long term average.

An approximate long term average for the Islands based upon the above comes out at 20.83", being just a little higher for the 4 stations on West Falkland than it is for the 4 stations on East Falkland by about 1½" per annum.

By comparison the long term average rainfall for London is over 25", and the long term average for the British Isles is between 39" and 40", or nearly double that of the Falkland Islands.

From the above it will be clear that relatively low run-offs would be expected per square mile of catchment area.

No figures are available for evaporation in the Falkland Islands but it seems clear, and Mr. Howkins agrees with this, that the evaporation must be a high percentage of the total rainfall.

The Camp with certain exceptions, consists of a very thin layer of earth, sometimes only 4" or 6", overlaying virtually impervious clay or rock. The result is that a small amount of rain makes it sodden, any surplus runs off quickly in the streams, and the rest is evaporated. "Flashy" flows resulting from surface run-off during rain are useless for power production and it is certain that the streams in the Falkland Islands are very "flashy" indeed. For instance, at Port Howard with a measuring weir in the settlement stream the following figures were recorded on six consecutive days :-

48	cubic	feet	per	minute
236	"	"	"	"
56	"	"	"	"
236	"	"	"	"
2,660	"	"	"	"
360	"	"	"	"

The nature of foundation material in most streams in the Falkland Islands is such that the construction of dams of any size would be unwise both from the point of view of very high cost and unreliability. Hence it is not sound to consider dams which will store water for considerable periods, making use of rainfall in a wet period to supply power in a dry period.

Apart from cost and unreliability, the creation of large open water surfaces will lead to increased evaporation.

This statement may be supported by the fact that in many parts of the Falkland Islands large and small ponds exist which are basins of inland drainage and have practically no water flowing out of them. Water flowing in simply evaporates and the surface level rises and falls somewhat according to the rate of rainfall. A further factor against the development of water power upon any scale in the Falkland Islands is that, with few exceptions, the streams are very low lying and wind for miles with only a few feet of fall. This applies in particular to the larger rivers such as the Chartres, the Warrah, and the San Carlos, at any rate in the lower half of its length. Streams such as the Murrell, some streams at Port Howard, and others in the region of Hill Cove are exceptions.

There are streams running from the north and south slopes of the Wickham Heights which have a useful fall and which might also be developed, but for their being too far from any settlement.

12. SITE INVESTIGATION.

In those cases where no detailed survey has been made and it is worth while to obtain some actual figures, the following procedure is recommended.

A measuring weir should be installed at approximately the point where water would be taken into a pipeline or into an open race feeding to a pipeline. Readings should be taken at least every two or three days. The construction of such a weir will be described in detail in Appendix 'A'. It is important that the measuring weir should be built into a small concrete dam which should be securely based upon solid rock. Anything in the nature of an earth or clay dam is useful for single observations only, but will soon wash away.

The object of the solid foundation plus good penetration into each bank is to ensure that all the water in the stream will pass over the weir and will thus be included in the measurements.

At Port Howard a permanent concrete dam was constructed. It has the measuring weir built into it and also serves as the intake for the new house water supply. It is larger than will be needed in some other cases but as a guide the total cost of it, including all materials and labour, was roughly £35 to £40.

Photographs were taken of this dam and measuring weir and some of these are included in Appendix 'A'.

Weir measurements should be recorded carefully in a book together with rainfall measurements, and if rainfall measurements are already in existence they should be made available, after about a year's weir readings, for as many years as possible.

The profile of the stream may be taken with an engineer's level, a tape measure and a compass. The procedure for a preliminary survey is to drive a series of numbered pegs well in at a number of points up the banks of the stream. A spacing of about 100 feet is very suitable. Distances between these pegs should be carefully measured and recorded, at the same time recording compass bearings between them. Thus a rough plan of the course of the stream can be laid out.

With the engineer's level a transit should be made taking the approximate water level abreast of each peg, thus both plan and profile of the stream can be plotted on paper, and the best section of it selected for power development. A series of photographs taken at various points are particularly helpful in advising upon possible development.

The distance from the probable power house position to the nearest point of the settlement should be taken in order to consider the type and cost of transmission.

13. WIND POWER.

At the time of writing this report only one set of annual meteorological tables are available but others are on their way home from the Falkland Islands. However, in consultation with Mr. Howkins the writer learned that the average annual wind speed at the Port Stanley Meteorological Station anemometer is probably in the region of 16 - 17 miles per hour. The Stanley Meteorological Station anemometer is at an elevation of 163 feet above sea level, and is quite well sited for winds from all directions except south-west to north-west. High ground in this sector is certainly some miles away but may affect the readings to some extent. Three anemometers, two cup counters and one recorder have been installed on Sapper Hill at an elevation of 453 feet above sea level. There is higher ground between 2 - 3 miles to the west of them.

These anemometers on Sapper Hill seem to indicate, after only about a year's working, approximately a 20%

increase in mean annual wind speed above that at the Meteorological Station. The first year's readings are being tabulated and are to be sent home shortly to Mr. Golding of the Electrical Research Association.

Wind speeds of the order above stated are well worthy of consideration from the point of view of aero electric generation. The Sapper Hill site, for instance, is quite close to the Stanley generating station and an aero generator placed there could well be useful as a source of auxiliary supply to power to Port Stanley. The site is not ideal, having considerable rocky outcrops near to the summit, but it may be the best in the neighbourhood within reasonable reach for transmission.

Aero generators of suitable capacity for use at such a site as this are not at present available as production articles, but it is hoped that they will be in a year or two. It should be well worth while then continuing with the readings at Sapper Hill with a view to possible aero electric generation in two or three years time. The high fuel component for diesel electric generators at Port Stanley makes the use of aero electric power much more attractive than it would be in some other areas.

Apart from records at Port Stanley, not much is available which is useful in considering potential aero generation. Your Company installed two cup counters some time ago, one at North Arm and one at Darwin. We have before us two years records at North Arm which indicate for 1954 a total run of wind of 118,616 miles, being equivalent to a mean annual wind speed of 13.5 M.P.H.

The equivalent figures for 1953 were :-

Total run of wind	121,312 miles
Mean annual wind speed	13.85 M.P.H.

Apparently the anemometer operated at Darwin for only a little over a year, after which it blew down and was not replaced.

Comparing June 1st 1952 to May 31st 1953 we have for Darwin 120,850 miles of wind, mean annual wind speed

13.75 M.P.H., and for North Arm 110,786 miles of wind or 12.60 mean annual M.P.H.

It is understood that the Darwin anemometer was well sited in open ground. The North Arm anemometer is reasonably but not very well sited. It is on the lee side (in respect to the prevailing wind) of slightly sloping ground, and is further at the lee corner of a small building with another small building upwind of it. Some eddy effect is probably created but there is none the less reasonable agreement between Darwin and North Arm, showing considerably lower mean annual wind speed than that at Port Stanley Meteorological Station. Both North Arm and Darwin are in similar rather flat country and near to sea level.

Apparently no other anemometers exist in the Islands other than dial indicating instruments which are read once or twice a day or as requisite for reporting wind speed with a view to aircraft landing. The records of such wind indicators are of very little use for power investigations.

The dial indicating instrument at Fox Bay is on the leeside of higher ground. That at Darwin is reasonably well sited, except for the fact that it is in the centre of a settlement, and may be considerably affected by eddies. The one at West Point is really well screened from the prevailing wind by high ground. Data then are quite insufficient to deduce any average mean annual wind speed for the Islands but there seems to be some indication that the figure for relatively flat ground nearer to sea level, as for instance in Lafonia, may be substantially below the Port Stanley figures.

All figures available indicate, however, that it would be worth while for the low cost and trouble involved to install additional instruments and obtain records with the object in view of installing aero generators of perhaps 10 kW rated capacity at some of the settlements.

The various reports by the Electrical Research Association are available as a guide to the procedure, and in particular Technical Report C/T.108 entitled "The Selection and Characteristics of Wind Power Sites" would be found valuable.

The recommendation has been made that small and inexpensive cup counter instruments should be installed at various selected sites and two or three recording instruments should be installed also to establish the wind regime.

Verbal reports vary widely but it seems that there is generally rather less wind in winter than in summer, and the periods of calm are longer. One report said that calms of a week or even two weeks are frequent. This hardly seems to be supported by a perusal of those Stanley records which are available, but certainly calms in the winter should be studied by means of recording instruments at selected points, and from the results of these studies the amount of storage capacity can be calculated for a given installation.

14. TIDAL POWER.

Several people in the Falkland Islands enquired as to the possibility of developing power from certain tidal differences of level which occur in adjacent creeks. The general answer to the question of tidal power is that it has been closely investigated over a long period of years and technically it is well understood. Even in the most favourable cases, however, the capital cost per kW for a tidal installation is so high that it is uneconomic as a competitor with other methods of power production, even with those where fuel is consumed.

Certain pilot plants have been constructed for experimental purposes but no major scheme has been developed yet. By comparison with some other countries the tidal conditions in the Falkland Islands are far less favourable and it may be stated with certainty that the cost per kW of any tidal installation in the Falkland Islands would be far and away too high to warrant further consideration.

15. CONCLUSION.

From a perusal of the foregoing it will have been appreciated that some sites were examined in considerable detail, others were written off without detailed survey, and a few were not surveyed as thoroughly as Mr. Walker would have liked. Sufficient has been learned, however, and sufficient records taken for advice to be given upon any site which may come up for consideration in the future. A large number of photographs were taken and are being kept for record purposes.

Mr. Walker would like to conclude this report by expressing his most grateful thanks to all those people who made his visit a happy and an interesting one. He was shown the greatest hospitality wherever he went, and all possible facilities were arranged for his transport from point to point. Although rather disappointing in its results, this was one of the pleasantest overseas investigations that he has made.

Yours faithfully,

For GILBERT GILKES & GORDON LTD.

(J. H. Walker).
London Manager.

APPENDIX 'A'.

MEASUREMENT OF THE FLOW OF WATER.

At a time when the flow is reasonably normal, i.e. neither in dry nor in very wet weather, obtain an approximate measurement of rate of flow as follows :-

Choosing a part of the stream where the section is fairly regular, mark off a convenient distance along the bank and take several measurements of the time taken by a float to pass over its length. The average of the float velocities in feet per minute should then be reduced in a rough hill stream by 40% to obtain the average stream velocity throughout the section.

Now measure the depth in feet at a number of equidistant points across the stream. From these calculate the average depth and multiply by the width of the stream at water surface. The result is the approximate cross sectional area in square feet.

Multiply the cross sectional area by the average stream velocity and the result will be the approximate quantity flowing in cubic feet per minute.

For more exact readings to be taken over a period, a measuring weir must be set up. It will be described in more detail below but from the approximate figure for quantity above obtained the required size of it can be determined from Table I.

It is as well to make it large enough to pass about twice the normal quantity before water goes right over the top. Quantities of more than twice the normal will not usually be of interest for power development.

By way of example, assuming that by the rough method above a quantity of 100 cubic feet per minute has been obtained, a weir may be built to measure up to approximately 200 cubic feet per minute. Referring to Table I it will be seen that if the weir is made 2 ft. wide, it will pass

216 cubic feet of water per minute with a depth of 8" over the sill. The weir may be made, say, 9" from the sill to the top of the boards, and 2 feet in width.

The weir may be constructed either of steel plate or boards. It must be made accurately and the sides and sill should be bevelled at about 45° in a downstream direction, thus forming edges which are nearly sharp at the upstream face. To avoid chipping by stones and debris, the bevel should be such that about 1/16" of width is left at the edges, this thin strip being at right angles to the upstream face.

The measuring weir constructed at Port Howard is illustrated in Photographs 1, 2, 3 and 4. Part of the stream was selected where good solid rock was visible and water was by-passed from a fall upstream of it by means of two lengths of 9" Asbestos Cement pipe (Photograph No.1). Having placed the pipe in position a temporary dam was built at its upper end of sandbags two-thirds filled with earth and sods (Photograph 2, looking downstream, and Photograph 3, looking upstream).

This temporary dam was almost drop-tight and work proceeded in the dry (see Photograph 2, where the wooden weir is being constructed and all water is being by-passed beyond the point at which it will be placed).

The second Asbestos Cement pipe shown in Photographs 2, 3 and 4 was placed well below the level of the measuring weir to act as a wash-out pipe. A valve could be fitted to it, but in this case it was merely fitted with a wooden plug.

The dam was constructed (Photographs 2 and 3) with cement concrete in sandbags to form the outer walls of the dam and between them unbagged concrete was poured.

Photograph 3 shows most of the dam completed and immediately after it was taken the temporary earth dam was removed, allowing water to pass through the wash-out pipe below the weir, and the main by-pass pipe was taken away. The top of the dam was then completed towards the right bank (left-hand side of Photographs 3 and 4).

Before the temporary earth dam was removed, a knob of cement was placed upon a convenient rock and set absolutely level with the sill of the measuring weir. It was placed 6 feet upstream of the weir and close to the left bank. The purpose of this is to enable a rule to be placed on top of it to measure the depth from water surface. Being level with the sill of the measuring weir the depth measured by rule is the corrected head over the weir. An alternative method is to drive in a suitable stake and saw the top off level with the sill of the weir.

From a measurement taken by rule the water flowing in cubic feet per minute can be read from Table I, the figures in the columns being multiplied by the width of the weir in feet.

The small galvanised pipe beside the wash-out pipe in Photographs 3 and 4 has nothing to do with the measuring weir. It is a water supply to the settlement which was taken from the same dam.

As a general guide, the top width of such a dam should be about 18" to 2 feet, and the width at the base in an up and downstream direction should be about equal to the height of the dam plus 2 feet.

The upstream face of the dam may be as nearly vertical as possible and the downstream face may slope as shown in the photographs in order to obtain the dimensions above given.

Other important points to note are:-

1) It is absolutely essential that before placing any concrete the rock upon which the dam is to be built must be scrubbed clean of dirt and growths.

2) The abutments into which the measuring weir is built should be well clear of the vertical sides of the measuring weir both upstream and downstream (see Photographs 3 and 4).

3) The height from the concrete apron beneath the weir to the sill of the weir should be about equal to the height of the vertical sides of the weir.

4) The measuring point should be at least six feet upstream from the weir and set near to the bank for ease of measurement.

5) The sill of the weir must be most accurately levelled, and the measuring point accurately levelled in relation to it.

If the foregoing procedure is adopted quite accurate readings can be obtained of stream flow at any moment.

Should the weir be remote and difficult of access then a recording instrument can be obtained which can be set up to record the level on a chart over a period in the same way that a barograph records pressure.

APPENDIX 'A'.

TABLE I.

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Table of Discharge from each foot of width of Sill, in cubic feet per minute.				
Depth of Water at Measuring Point in Inches.	Fractions of an inch.			
	0	1/4	1/2	3/4
0	0	.596	1.69	3.1
1	4.78	6.66	8.83	11.1
2	13.5	16.1	18.9	21.7
3	24.8	28.0	31.2	34.6
4	38.2	41.7	45.2	48.9
5	53.4	57.4	61.4	65.4
6	69.4	74.1	78.8	83.6
7	85.4	93.3	98.2	103
8	108	113	118	123
9	129	134	139	145
10	151	156	162	168
11	174	180	186	192
12	198	204	210	217
13	224	230	236	243
14	250	256	263	270
15	277	284	291	298
16	305	312	319	326
17	334	341	348	356
18	364	371	379	387
19	395	403	411	419

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