ENFIELD WIND-POWER

EXHIBITION

Prae Wood, St. Albans

June, 1953

ENFIELD CABLES LIMITED

Progress Report No. 2

"You cannot drive a windmill with a pair of bellows."

OLD SCOTTISH SAYING

Windmills

It is not the driving fury of the gale that men would harness to their own uses, but rather the gentler breezes that blow more constantly on headland, hill and coast, and across the empty spaces of Arctic waste or tropical desert. Seen in its wider perspective the wind is still one of the inexhaustible sources of energy that mankind has found no effective way of taming. In this it takes its place alongside the tides, the waves, the direct rays of the sun, the internal heat of the earth in any of its various forms, and the atom nucleus itself.

There are many who aver that there is no useful purpose in seeking to find new ways of harnessing the winds that blow. They stress that others throughout the centuries have seldom garnered more than the equivalent of a very few kilowatts indeed, five or ten at the most, from each plant installed, whether it be to grind corn or pump water or generate electricity; they question the wisdom of spending further thought and money on a proposition so doubtful. They point disparaging fingers at the Chinese and the Persians of old, or at the countries which border the North Sea today, all of whom are the proud possessors of derelict or near-derelict windmills.

There is another train of thought coming to the front in many countries, which holds that the harnessing of the power of the wind is a task to which new thought should be applied, using the new techniques gained in other fields, because it is apparent that the benefits to be gained are considerable. Those who share this view consider that no major source of energy, and in particular no major source that does not involve the use of the thermal cycle, is too insignificant to be ignored.

It is in this spirit that *Enfield* has embarked upon this experiment. There is a job to be done and it is no idle speculation to seek ways of doing it. The *British Electricity Authority* have taken the initiative in this and, as their main contractor in the project, *Enfield* gratefully acknowledges the help received, whilst underlining that the *Authority* are in no way responsible for the Exhibition itself nor do they necessarily support the possibilities expressed in it.

Enthusiastic and practical help has been given to the venture at all times by the *Electrical Research Association*, whose knowledge of the basic technical requirements to be fulfilled is now probably unequalled anywhere in the world. The *Ministry of Fuel and Power* and the *Department of Scientific and Industrial Research* have both been consistent in their support.

Enfield believes that progress has been made towards the immediate target, the construction of a machine capable of generating 100 kW in a wind of 30 m.p.h. Lessons have also been learned, negative as well as positive; both will add to knowledge in a little explored field. *Enfield* gladly acknowledges the essential parts that its two principal sub-contractors, *de Havilland Propellers Ltd.* and *The English Electric Company Ltd.*, have played in helping to attain anything that has been achieved so far.

*"Blow, blow, thou winter wind,
Thou are not so unkind
As man's ingratitude."*

WILLIAM SHAKESPEARE

The Enfield Anemo-Electric Plant The *Enfield* wind-driven generator has been designed and built for the *British Electricity Authority* in the hope that it will prove to be a major contribution towards the evolution of a range of machines capable of converting some of the free and unpredictable forces of the wind into useful electrical or mechanical energy, controlled by the will of man, on a scale not hitherto possible.

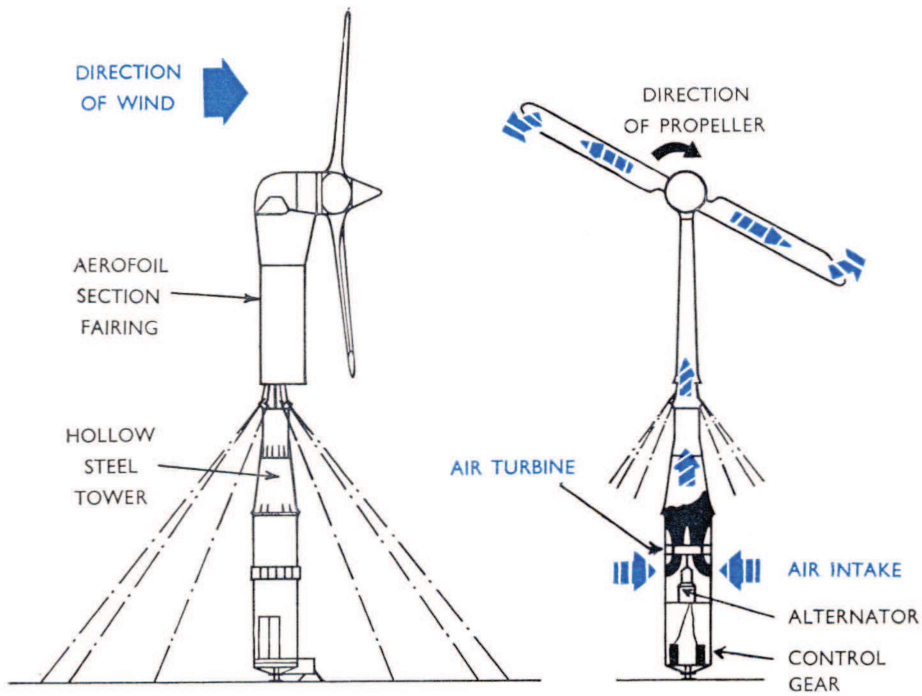
It must be stressed that the primary interest of the *B.E.A.* is to find out whether there is any possibility of achieving this target, because energy so obtained could be fed in parallel into the British Grid at almost any point in the country, the vagaries of the wind being smoothed out by the greater availability of thermally-generated electricity in the system. It is apparent that a network of wind-driven generating stations at different locations, up and down the country, would operate diversely, in accord with the diverse availability of wind at different points; it might in fact be found that during the greater part of the year a minimum of firm kilowatts could be relied on from the country as a whole, assuming such a diverse range of wind-driven stations. Equally, each kilowatt made available from the wind will not have involved the combustion of coal or of any other fuel, although capital costs per kilowatt installed will manifestly be a matter of major moment.

On the other hand, it has to be underlined that *Enfield*, as the potential manufacturer of these plants, must at the same time (in order to obtain a constant and worthwhile output of machines at an economic cost per kilowatt) explore the possibility of selling the machines for use in markets and at points where no existing or proposed grid system is available. With this in mind the present Exhibition has been arranged, with the help—gratefully acknowledged by *Enfield*—of many distinguished firms who have lent their products for display.

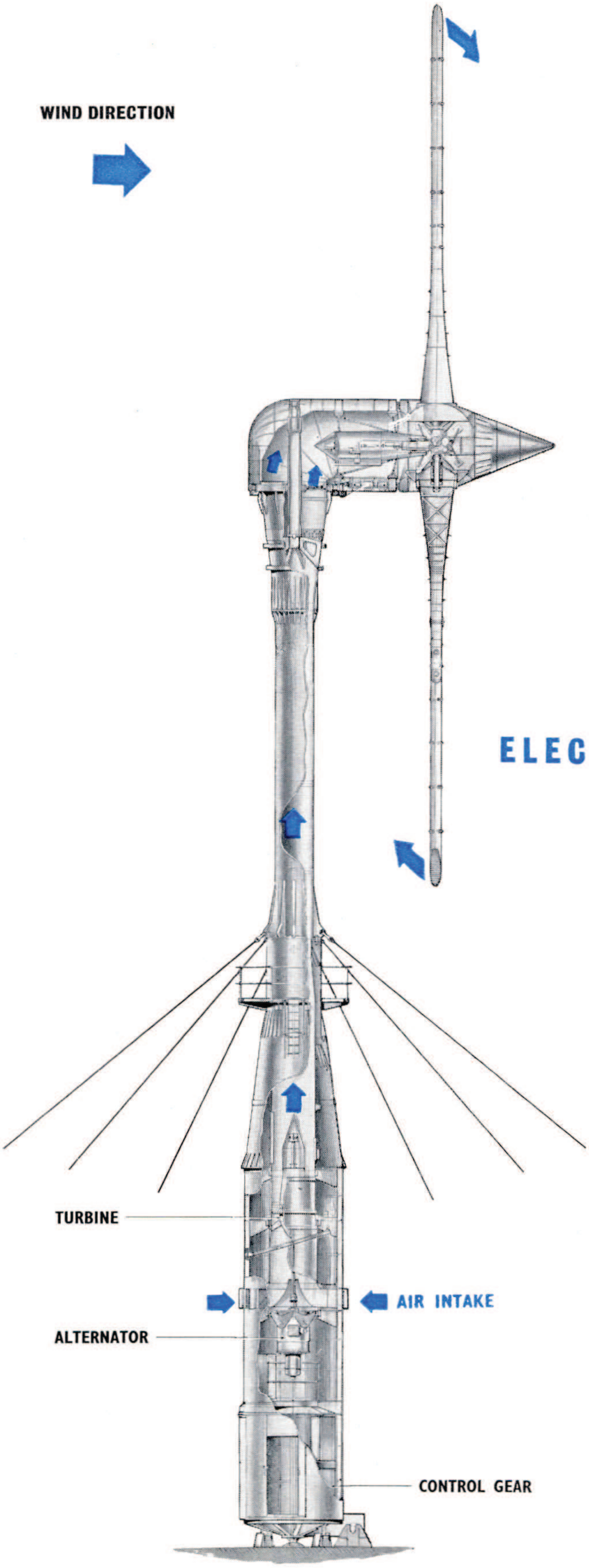
In designing a plant of the size required by the *B.E.A.*, namely a plant with a capacity of 100 kW at a wind-speed likely to be met reasonably often, there was little past experience on which future requirements might be based. The analogy of small direct-current machines generating up to 5 kW was not relevant. Considerable knowledge was available from Denmark of a series of plants built there in recent years, with the propeller geared to the generator at the top of a tower and with capacities up to some 80 kW. Much information had been gained in the United States of America from a 1,250 kW machine, of similar design, which had, however, sustained a mechanical failure after only a few hours of operation at full load and had then been abandoned. In many of the countries of Europe there were available the ideas of a host of inventors, who proposed machines surprisingly varied in form and function but generally unproven, uncosted, and confined to two-dimensional existence on the drawing-board or in patent applications.

In association with its two main sub-contractors, *Enfield* decided at the time, in 1949, that the disadvantages of the orthodox type of machine, with the generator geared to the propeller, were too great to justify the hope that they could be satisfactorily overcome even in a 100 kW plant, let alone in the larger machines that were expected to follow. It was agreed that the "depression" principle should be studied, then being tested on a small scale by Monsieur J. Andreau in France. It was found in theory that this system could produce electrical energy with a conversion efficiency only slightly lower than that obtained from orthodox plants of equal size, and that the cost of development would be higher. At the same time the mechanical advantages were considerable, even in a plant of 100 kW capacity, the most important of them being that the generator could be mounted at ground level and that there need be no gearing between it and the propeller.

The schematic operation of this depression system is shown in the accompanying diagram:



The *B.E.A.* machine installed at St. Albans, for trial before erection on a permanent and more exposed site, is the outcome of four years work by the designers, following the 1949 decision to adopt and develop the depression principle. In France several smaller machines, up to 10 kW, have been built, using the same principle; in Britain a far more basic study has been made of the factors involved in building a machine of this type, the design of a machine to generate 100 kW being in no sense a pantographic projection of the smaller machine to generate 10 kW at the same wind speed. The larger machine has, in fact, been designed from first principles by a team of engineers on the staff of *de Havilland Propellers Ltd.*, working full-time for *Enfield* during the past four years. The appearance of the machine as built is portrayed in the dissected drawing overleaf. Its essential characteristics are set out in what follows :



ENFIELD 100kW WIND-DRIVEN ELECTRIC GENERATOR

As built

approximate scale
$\frac{1}{16}''$ = one foot

CABLES, ELECTRIC, paper, cambric and rubber insulated.

CABLES, SUPPORTING, twelve of galvanised steel, equally spaced, inclined 50° and pre-loaded to 6 tons to reduce fatigue.

ELECTRICAL EQUIPMENT, one 100 kW, 415 volt, 3 phase, synchronous induction generator, with exciter, which is started from rest as an induction motor. When synchronous speed is approached, direct current is fed into the field thus causing the generator to operate as a synchronous motor running under 'no load' conditions. Air is then admitted to the turbine which in turn drives the 'motor' in synchronism with the connected system. Fully automatic control gear is connected to the generator by flexible armoured cables.

ERECTION, by removable equipment comprising two 65 ft. derricks, two 6-ton hand winches, pulleys and steel ropes.

FOUNDATIONS, central base, of reinforced concrete, and twelve anchors, on a pitch circle diameter of 96 ft.

HUB STRUCTURE, fabricated aluminium alloy structure faired with aluminium sheet and enclosing feathering mechanism and oil-immersed main bearings. The hub structure is mounted on roller bearings and rotates about the axis of the tower as the propeller orients into wind.

OUTPUT, increases from zero at wind speed of 17 m.p.h. (7.6 meters per second) up to 100 kW at 30 m.p.h. (13.4 m.p.s.) and remains constant thereafter until the wind speed reaches 65 m.p.h. (29.1 m.p.s.) when the plant shuts down.

PROPELLER, two blades of aluminium alloy, hinged for coning and maintained by torsion bar springs at a mean coning angle of 5°. The pitch is adjusted automatically by a hydraulic system so that the rotational speed is maintained constant when the wind speed is in excess of 30 m.p.h. and not more than 65 m.p.h. Each blade is made in two sections—inboard of circular section at the root changing to aero-foil; outboard of constant chord, 5.75 ft (1.75 m.), and thickness, terminating at the trailing edge with an exit port for extraction of air by centrifugal force. Diameter of swept circle 80 ft. (24.4 m.). The propeller operates down wind of the tower. Orientation is power-assisted and controlled.

SPEED OF ROTATION, propeller 95 r.p.m. at rated output; generator and turbine 1,000 r.p.m.

TOWER, 100 ft. (30.5 m.) from top surface of foundation to axis of propeller. Of stressed steel plate and girder construction, circular in section and decreasing in diameter from 9 ft. (2.74 m.) at the base to 3 ft. 6 in. (1.07 m.) where it enters the hub structure. The control gear is housed in the base.

TURBINE, axial flow, vertical axis, single stage, 48 in. (1.2 m.) diameter wheel, handling 50,000 cu. ft. or approximately 1.75 tons of air per minute (23 cubic meters per second).

WEIGHT, complete installation 40.50 tons (41,148 kg.). Propeller, 4.25 tons (4,318 kg.).

The machine will by implication require to be erected on exposed sites, having to face the most severe climatic conditions. It has throughout been appreciated that the risks of metallic corrosion will be severe, and suitable precautions to prevent it have been taken, notably the metallising of the outside and much of the inside surface of the tower with sprayed aluminium metal, and in addition the painting of all steelwork, whether sprayed or not, to specifications based on the combined experience of the British Admiralty and leading civilian authorities.

The ultimate success or failure of the project will be determined by the cost at which machines can be produced and sold, in series or in quantity production. The cost of the prototype has been substantial; it includes much development work and a number of refinements, which may be found to be unjustified in actual operation. Assuming that the machine operates successfully, and that orders are forthcoming to make series production possible, it is hoped to be able to build plants at a capital cost which will make wind power competitive with other sources of energy.

In this connection the *Electrical Research Association* have pointed out that there are two main factors which enter into the economy of large-scale wind-power generation, namely, the annual output of energy generated and the annual capital charges for interest, depreciation and maintenance, these being proportional to the capital cost of the plant. The cost per unit is obtained by dividing the annual charges by the number of units generated.

The *E.R.A.* have suggested that suitable sites for wind-driven generators are those which are windy enough to produce a minimum of 4,000 kWh of energy per annum from each kilowatt of capacity installed; a considerable number of such sites have already been found and investigated in the British Isles. The *E.R.A.* have further suggested that suitable automatically operating plant could be built at a cost of £50 per kilowatt; with capital charges at 8 per cent, the generation cost would be ·25d. per kilowatt-hour, which compares favourably with the fuel component of generating cost in a steam power station, at present about ·4d. per kilowatt-hour. It is impossible to forecast at this stage whether these figures can be achieved; it can with certainty be claimed that as fuel costs and the securing of fuel for steam generation must present problems of increasing difficulty in Britain, a method of generating even a small part of the national requirement of electrical energy by any other means is not to be ignored. Overseas, the costs of fuel and of electric energy per unit vary so greatly that there will be some markets where wind-power may be interesting even at a capital cost twice or three times as great as would be attractive in Great Britian.

The visitor to the *Enfield* Exhibition at St. Albans is asked to judge the machine as it stands there, on its own merits and for itself. It is now a reality and no longer a project. Its designers have sought to make it capable of performing the duty asked for by the customer, and at the same time to make it simple in outline and comely in form. It has indeed been designed to do its job, without frills or trappings, whether mounted on an exposed coastline or on a hill-top set amidst distinguished scenery. There is no evidence whatever that it will emit the banshee wailings that some of its decriers have already attributed to it, basing their charges on guesswork and not even on drawings or a study of the machine itself. Full tests of the machine will now follow, and its value must be assessed by the results.

"Puff not against the wind."
OLD ENGLISH PROVERB

The EXHIBITION

Against the background of the completed machine, now ready for testing, the Exhibition sets out some of the wider aspects of the use of wind-power, in terms of its history, its possible applications, and the thought behind the present development.

The exhibits are placed in numerical order, assuming a clockwise tour starting from the Observation Room.

PAST AND PRESENT

The origins of the use of wind-power for the propulsion of ships and to supplement manual labour on land are lost in antiquity. The techniques of ship propulsion developed exceedingly, whilst "windmill" design for long remained localised, individual and primitive.

It is interesting to try to account for this; amongst many reasons, two appear to stand out. The first is the inescapable cube law, by which the energy available in the wind increases as the cube of the wind-speed. The effect of this is that a wind plant must be placed where there is an average wind of appreciable velocity, if it is to work economically. Ships, moving on the unsheltered sea, caught this energy. Windmills were stationary and, because man had as yet no knowledge of energy transmission in the form of electricity, had to be placed on sites where they were comparatively ineffective.

The second reason for the more rapid development of sailing ships as against windmills was that the former were needed for the safety and wellbeing of mankind, whilst the advantages of harnessing the wind for pumping or grinding were not yet understood.

This Exhibition is possible only because transmission technique is to hand and a determined effort is being made to seek out and make available first-class sites, in Britain and elsewhere. Governments, in many parts of the world, are investigating wind-power as a supplementary source of energy.

10 **British Electricity Authority.** The customer for the 80 foot anemo-electric plant.

In the year ending March, 1952, *the Authority generated* 59,250 *million units of electricity; supplied* 13½ *million consumers; and received an average price of* 1.220*d. per unit for electricity supplied. Installed generating capacity was* 15,768,779 *kilowatts.*

WIND AND WATER

High-level hydro-electric schemes have storage capacity which enables them to give an output equal to the installed capacity of plant whenever there is water in the reservoir. In many countries it has been necessary to erect thermal power stations to bridge the gaps when water at high level is not available.

The availability of electric power generated by the wind will reduce the need for such thermal stations. Alternatively, wind-generated electricity can be used to pump water from the tail-race or from some other source up to the headstocks of a high-level hydro-electric plant, for use as required.

12 **Model of Loch Sloy Hydro-Electric Station,** Dunbartonshire, Scotland (installed capacity 120 megawatts),
lent by **The English Electric Co., Ltd., London.**

15 **Model of Diesel-Electric Power Station** (installed capacity 5 megawatts),
lent by **The English Electric Co., Ltd., London.**

WIND AND THE DESERT

How to keep the pumps moving? This is the constant anxiety of communities which have adopted deep-well irrigation in arid areas. Each well that is bored becomes a consumer of energy which is nearly always derived from oil-fuelled generating plant. Each new oil engine demands fuel continuously and fuel may require transport and foreign currency, which might in turn have bought the extra food that irrigation ought to produce. This is a vicious circle which the availability of cheap wind-power may help to break.

The progressive reclamation of the desert fringe, the turning of the flint-stone into a springing well, the harnessing of wind to make fertile the land and not to erode it, these are all applications where an intermittent source of electrical energy may change the physiography of the earth's surface.

13 **Deep-well Pump,** electric motor driven, 0.5 horse-power,
lent by **Sumo Pumps, Ltd., Birmingham.**

14 **Model of Tropical "Absorption" Irrigation Scheme,** scale $\frac{3}{8}$ inch to 1 foot,
planned by **Sumo Pumps, Ltd., Birmingham,**
built by **Enfield Cables, Ltd., Contracts Department.**

16 **Diesel-Electric Standby Generating Plant,** 8 kilowatt,
lent by **R. A. Lister & Co., Ltd., Dursley.**

WIND AND ISOLATED LIVING

In the polar regions, and in other areas where transport is difficult and fuel scarce, there is often a regular availability of wind. This can be harnessed, as a main source of energy with a diesel or steam engine as a standby, or as a standby to save the carriage and cost of fuel to feed a steam or diesel engine.

From Arctic Canada to the Falkland Islands, on Kerguelen and on St. Helena, electric power may be required for light and heat, and for the transmission of messages by new techniques of radio. Oil supplies cannot be guaranteed; the use of wind-power can make each cargo, each load of solid or liquid fuel last longer.

The feeding of intermittently generated electric energy into an electrode boiler to generate steam, and then the passage of the steam to a steam-accumulator, whence it may be taken to generate electricity again in a steam-electric plant, might even be regarded as a relatively efficient process in places where communications are poor and costly. The steam could be used, too, for space-heating, water-heating and cooking.

17 **Electrode Boiler,** "Autolec" 30-kilowatt totally enclosed type,
lent by **G.W.B. Electric Furnaces, Ltd., Dudley.**

18 **Steam Accumulator,** 150 p.s.i., vertical type,
lent by **The Steam Storage Co., Ltd., Leeds.**

19 **Steam Engine,** "Live on the Land" prime mover, 2½ h.p., lent by the **National Research Development Corporation, London.**

34 **Accumulators,** alkaline, for power and radio, lent by **Nife Batteries, Ltd., London.**

WIND AND THE ELECTROLYSIS OF WATER

One of the most attractive methods of storing the intermittently available energy of the wind is to use the output of the generator for the electrolysis of water. The resultant hydrogen can be bottled or stored, the oxygen probably allowed to go to waste. The methods of achieving this electrolysis are relatively simple and are well known.

The hydrogen may be used for cooking; it may be burned in gas engines; it may be put to drive a tractor or other tool. Each of these applications gives energy when required, at the turn of a valve, in the still periods when no wind blows.

21 **Rectifiers, Selenium-Metal,** three units to give 500 amps direct current at 24 volts with a three-phase alternating current input, lent by **Electric Construction Co., Ltd., Wolverhampton.**

20 **Electrolysers, Low-pressure.** Battery of 12 Knowles cells to give 96 cubic feet of hydrogen per hour, lent by **The International Electrolytic Plant Co., Ltd., Chester.**

22 **Gas Container for Hydrogen,** 50 cubic feet, sheet metal, water sealed, lent by the **Department of Scientific and Industrial Research, Fuel Research Station, Greenwich.**

23 **Gas Cooker,** "New World Eighty-four," modified to burn hydrogen, lent by **Radiation, Ltd., Luton.**

24 **Electric Lighting Plant,** hydrogen-fuelled, 2½ h.p./1 kilowatt, lent by **R. A. Lister & Co., Ltd., Dursley;** research and modifications by **Ricardo & Co., Engineers (1927), Ltd., Shoreham-by-Sea.**

25 **Earth-moving Plant, Tractor and Scraper,** "hydrogen-fuelled" Vickers tractor, powered with 180 b.h.p. Rolls-Royce engine and towing a 13-yard scraper,
lent by **Jack Olding, Ltd., Hatfield,** in co-operation with **Onions & Sons (Levellers), Ltd., Bilston.**

WIND AND THERMAL STORAGE

The isolated wind-driven generator, serving as the main source of energy to a homestead or small community, must depend for its usefulness on the existence of various methods of thermal storage, to bridge the gaps between wind and calm.

In the house the electric cooker can be built to operate on heat-storage principles; space-heating can be undertaken by cabinet heaters, which radiate warmth long after the supply of electricity to them has been cut off. Latent heat-storage equipment, weighing ounces rather than pounds, is now a possible method of space-heating.

On the farm and in the dairy the sterilisation of vessels by means of thermal-storage sterilisers is already a widely used technique in Britain, flash steam being produced by the spilling of cold water on a block of iron or other material, heated by means of small internal elements, the whole being heavily lagged. The storage of meat and produce in refrigerators, again suitably lagged, may be possible for long periods without a continuous supply of electricity, if the lagging is properly arranged and if access is not too frequent during the periods when no wind is blowing.

Even more interesting is the use of the floors of buildings as thermal accumulators, heated by elements embedded in or under them. They can be radiating warmth long after the wind has ceased to blow. The energy produced by a wind-driven generator has not been through the thermal cycle, and may be used to operate a heat pump with a reasonable degree of efficiency, and to make a larder or cold store its source of heat and to use the heat obtained for warming water in a thermal storage cylinder.

In the garden the capacity of good soil to store heat may be used in a similar way. Glasshouses, frames and lights, cloches, and even open-air beds, may have their soil (just above sub-soil level) heated by means of buried wires so as to provide warmth at the roots of the plants without heating the air above them. The ability of the earth to store heat, even without compost or mulch, is such that considerable periods between winds could be bridged without detriment to growth.

26 **Space Heating,** electric floor storage with elements buried in concrete, under development by the **Electrical Research Association.**

27 **Space Heater,** thermal storage, 1½-kilowatt "Thermodare," lent by **Aberdare Electric Co., Ltd., Dublin, Eire.**

28 **Space Heating,** electric latent heat-storage in chemical salts under development by the **Electrical Research Association.**

30 **Cooker, Thermal Storage,** electric, type SM2, supplied by **K. Pettersens Sønner A.S., Sarpsborg, Norway.**

31 **Heat Pump,** domestic. A new approach to domestic cooling and heating. By using the larder as a source of low-grade heat and the hot-water tank as a sink for high-grade heat, a refrigerator and boiler might be dispensed with. Under development by the **Electrical Research Association.**

29 **Water Heater,** thermal storage, 50-gallon off-peak "Sadia," lent by **Aidas Electric, Ltd., Greenford.**

33 **Refrigerator,** domestic, electric, 6 cubic feet sealed compressor unit lent by **The English Electric Co., Ltd., London.**

32 **Sterilising Plant,** steam/electric, 2-kilowatt thermal storage, for dairy use, lent by **J. W. Woolley & Co., Tamworth.**

36 **Soil-heating Demonstration;** flowers and vegetables in the open and under glass, by **Enfield Cables and Rolling Mills Fruit Garden, St. Albans.**

37 **Soil-heating Equipment,** transformers and control panels, lent by **Electrocult, Ltd., Harpenden.**

38 **Time Switch,** synchronous motor-driven, 20-ampere, lent by **Sangamo Weston, Ltd., Enfield.**
The time switch is set to energise the above soil-heating equipment automatically and intermittently, according to the typical 24-hour wind-regime of a chosen wind-power site in Britain.

THE FUTURE

39 The purpose of the Exhibition is summed up in the last feature of the display.

The shadow of a giant windmill revolves across a clouded sky, wind-swept. Below, a pump lifts water to the reservoir near the top of a mountain, whence it falls again to turn a reaction turbine. This is the *electro-motive* application of an intermittent source of energy.

A model electrode-boiler and a steam accumulator stand beside a model steam engine, the *electro-thermal* application that seeks to give continuous running from an intermittent source.

A model electrolytic plant and its gas-holder stand beside a horizontal stationary gas engine. Here is the *electro-chemical* employment of an unreliable source of electric energy, which again can give continuous working from a seemingly haphazard supply.

These are but the first beginnings. There will still be fresh fields to conquer.

WE PROFFER OUR THANKS ESPECIALLY TO:

Ove Arup & Partners, Consulting Engineers, whose work lies buried in the foundations of the 80-foot plant.

Architects' Co-operative Partnership, for the design of the exhibition buildings and overall layout.

Glanvill, Enthoven & Co., Ltd., for arranging the insurances, not only of the exhibition, but of the wind-plants themselves.

8 **The Pyrene Co., Ltd.,** for fire-protection.

9 **Evershed & Vignoles, Ltd.,** for the loan of the Meggers and other instruments for maintaining the many complicated exhibits in sound electrical condition.

Electrocult, Ltd., for the loan of the steel furniture in the Observation Room.

The many friends, customers, potential customers, sub-contractors and critics, who have encouraged and helped us to make this exhibition possible.

"*Except wind stands as never it stood,*
It is an ill wind turns none to good."

from "DESCRIPTION OF THE PROPERTIES OF WINDS," by THOMAS TUSSER, 16th CENTURY POET-FARMER.

AN

Enfield

ENTERPRISE

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