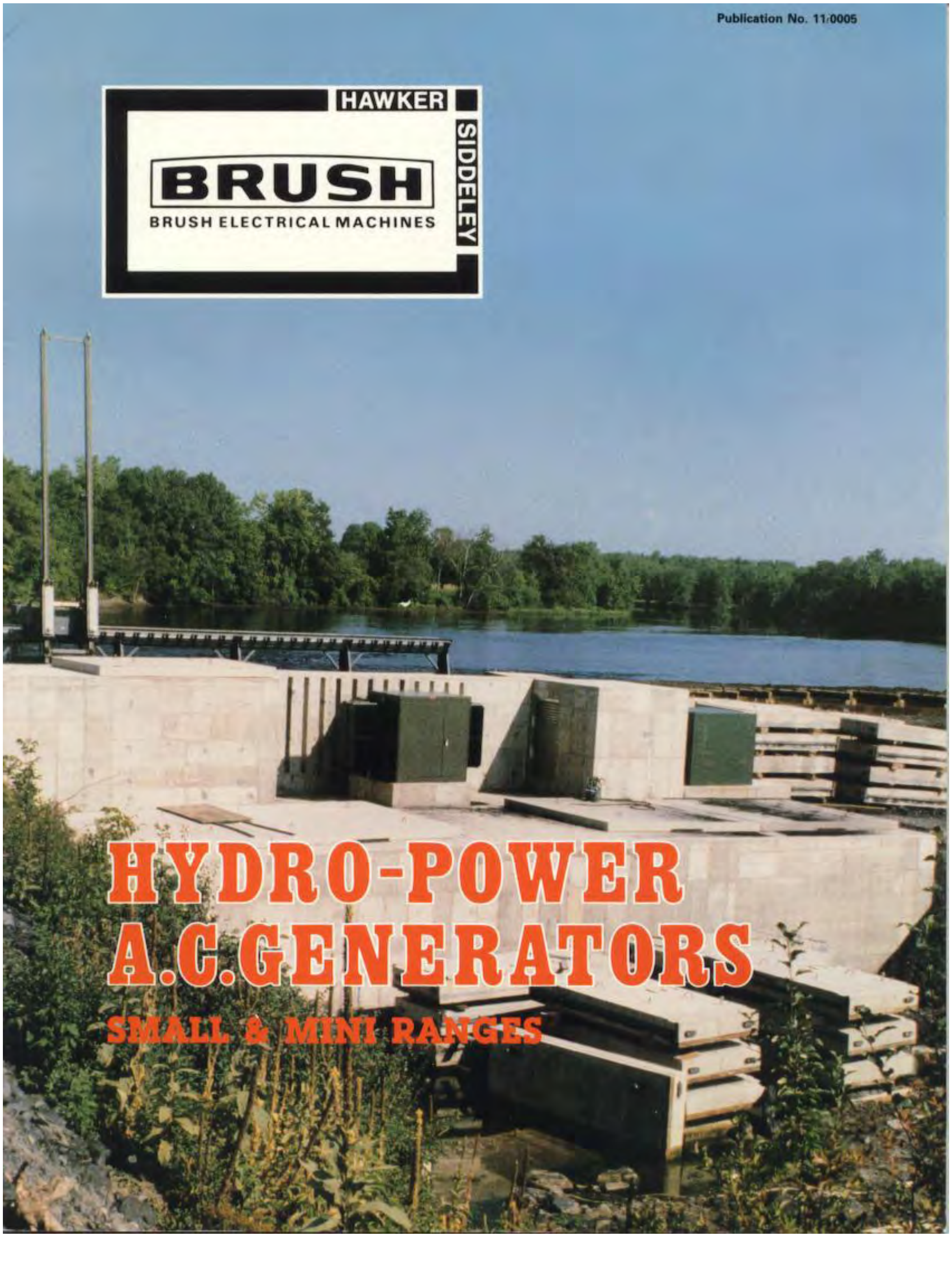
Publication No. 11/0005

HAWKER SIDDELEY

BRUSH

BRUSH ELECTRICAL MACHINES



HYDRO-POWER A.C.GENERATORS

SMALL & MINI RANGES

Generators for hydro-turbine drive

Figs. 1 & 2. One of the earliest hydro-electric generators built by Brush in 1894 with its Gunter turbine, showing the original generating house where it was installed at Hawkshead, Cumberland, U.K.

Brush Electrical Machines is a major subsidiary of the Hawker Siddeley Group and has been an important supplier to the power generation industry for over one hundred years.

In the field of diesel driven salient pole generators, Brush is a respected name in the eyes of engine manufacturers and specifying authorities throughout the world. It is against this background that the company has developed the present range of generators customized for the requirements of small and mini hydroelectric installations, horizontal or vertical mounting, synchronous or induction type.

With a unique facility at our Loughborough factory for total "in-house" production of all generator components, transformers, and switchgear, backed up by a versatile range of control equipment, and the engineering services of our Projects Division to provide total electrical power packages, Brush are fully equipped to meet the requirements of the industry.

Materials and manufacturing techniques meet the requirements of all applicable British and U.S. standards. Quality control procedures have been audited and approved by many of the world's multi-national organizations and by defence procurement authorities throughout the world.

Front Cover
Fort Miller Hydro-generation Project, N.Y., U.S.A., utilizes two Brush 2.9 MW Generators supplied through Kvaerner Hydro Power Inc.

Fig. 3. Up-river from the Logan River Project, Utah, where two Brush 3.375 MW, 720 rev/min (overspeed 1350 rev/min) 4160 V, 3 ph, 60 Hz, salient pole generators were supplied through Kvaerner Hydro Power Inc.

Fig. 4. Feed dam area of the Georgetown Irrigation Project, Utah, U.S.A. A' Brush 480 kW, 720 rev/min (overspeed 1382 rev/min) 480 V, 3 ph, 60 Hz, induction generator was supplied through Gilbert, Gilkes and Gordon.

Fig. 5. Sulby Hydro Power Station, Isle of Man, U.K., housing two Brush 600 kW, 750 rev/min. (overspeed 1350 rev/min). 415 V generators supplied through Gilbert, Gilkes and Gordon.

Fig. 6. Lower Camp Creek Hydro Project, Orville, California, 1.1 MW 450 rev/min (overspeed 900 rev/min) 4160 V, 3 ph, 60 Hz, Brush generator supplied through Kvaerner Hydro Power Inc.

Fig. 3

Fig. 4

Fig. 1

Fig. 2

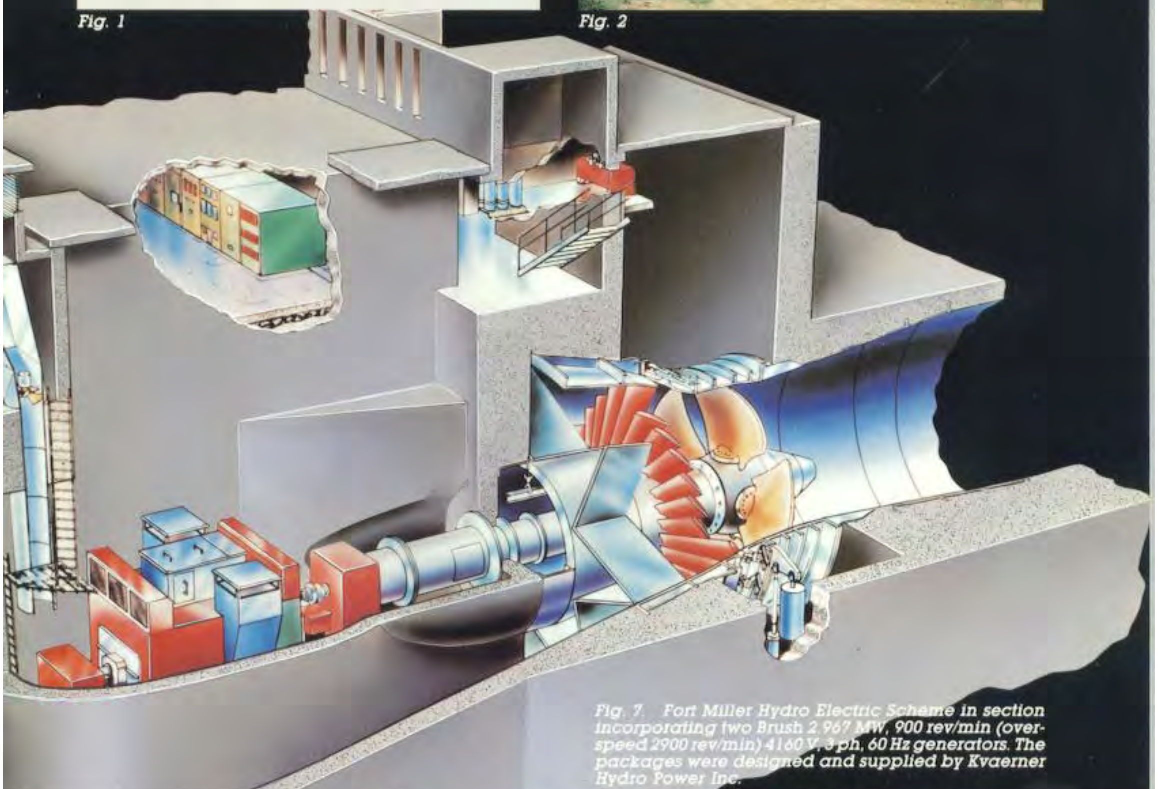


Fig. 7. Fort Miller Hydro Electric Scheme in section incorporating two Brush 2.967 MW, 900 rev/min (overspeed 2900 rev/min) 4160 V, 3 ph, 60 Hz generators. The packages were designed and supplied by Kvaerner Hydro Power Inc.

Fig. 5

Fig. 6

Some Factors in the Selection of Hydro Generators

Generators for hydro turbine drive differ from their counterparts in other applications. Due to the unique and sometimes widely varying nature of the power sources, and the necessity for utilising these resources in an economical manner with respect to both machinery and local civil works, special consideration has to be given to both electrical and mechanical aspects of the generator design in order to optimise compatibility with the types of hydro turbine employed, and the natural conditions of the site.

Overspeed

Type of turbine, and operating conditions can contribute to generator rotor overspeed of considerable magnitude and duration. To cater for these conditions the Brush range of hydro-electric generators features rotor designs suitable for overspeeds from 150% to over 300% of rated speed. An overspeed duration of 2 hours is catered for.

Inertia

In order to maintain system stability, hydro-electric generators are frequently required to provide an inertia many times greater than the natural value of the base electrical machine. In some cases sufficient WR^2 can be obtained by simply increasing the normal duty size of the machine or increasing peripheral weight. In other instances it is necessary to add inertia by the provision of a flywheel incorporated integrally or carried separately in its own bearings on the machine bedplate. Brush engineers are always available to offer advice and assistance in the early stages of design to cater for a wide variety of service conditions.

Fig. 8. Brush 1.9 MW, 720 rev/min (overspeed 1225 rev/min), 4160 V, 3 ph, 60 Hz, generator installed at the Bidwell Ditch Hydro Scheme, Redding, California, U.S.A. Machine supplied through Gilbert, Gilkes and Gordon and Mega Renewables.

Fig. 9. Brush 1.976 MW, 514 rev/min (overspeed 1000 rev/min), 4160 V, 3 ph, 60 Hz, generator installed at the Dillon Dam Hydro Site, Denver, Colorado, U.S.A. Machine supplied through Gilbert, Gilkes and Gordon, and Hawker Siddeley Power Engineering Inc.

Fig. 10. Valley Falls Hydro-electric installation New York, U.S.A. incorporating a 2.967 MW, 900 rev/min (overspeed 2900 rev/min), 4160 V, 3 ph, 60 Hz, Brush generator supplied through Kvaerner Hydro Power Inc.

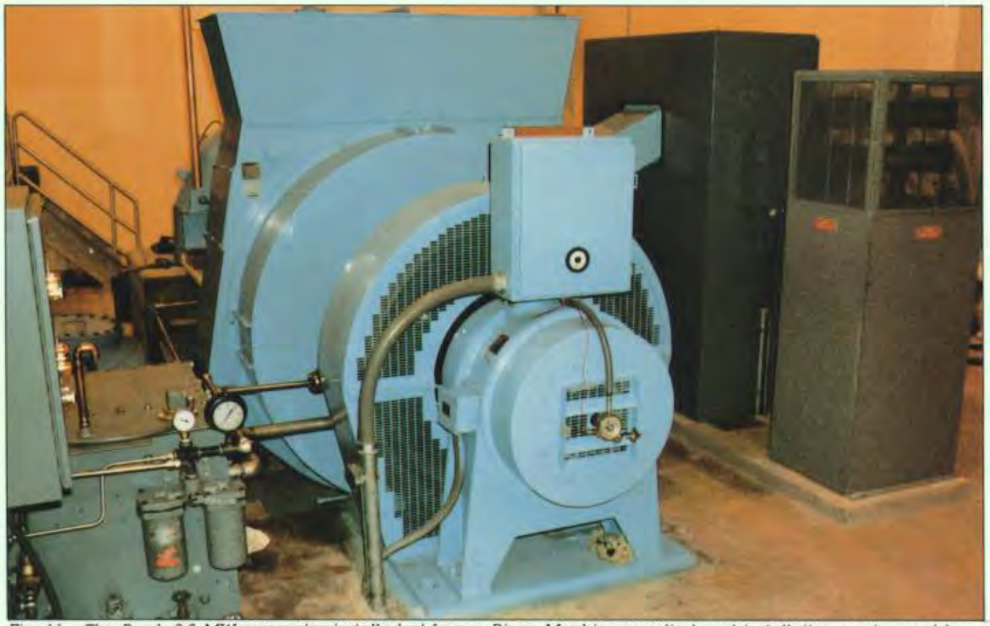


Fig. 11. The Brush 3.3 MW generator installed at Logan River. Machine supplied and installation engineered by Kvaerner Hydro Power Inc. The machine's lubrication module is also illustrated.

Thrust
Certain types of water driven turbines impose a very heavy axial thrust directly onto the generator rotor. To cater for this, special bearing and support systems are necessary. These bearing are usually specially designed by the manufacturer to a specification formulated by Brush engineers for each specific application and are described in more detail later in the publication.

Overhung Runners
In this case also, the extra radial loads imposed by the direct mounting of the turbine rotor on to the generator shaft need to be catered for in the design of the bearing and shaft system, in order to minimise shaft deflection and ensure smooth operation during all transient conditions.

Efficiency
With output per unit directly geared to revenue, the efficiency of a hydro-electric generator is of paramount importance. Brush generators, by careful design and utilization of low loss materials and systems, plus the benefits of a data bank from many thousand of installed machines throughout the world, offer consistently high efficiencies.

Fig. 12 One of the two Brush 600 kW, 750 rev/min (overspeed 1350 rev/min), 415 V, 3 ph, 50 Hz, generators installed in the Sulby Power Station, Isle of Man, U.K.

Fig. 13 The Weeks Falls Hydro Site, Washington, U.S.A. Another Kvaerner Hydro Power engineered site with Brush generation.

Construction

Stator frame and core

The stator frame is a substantial welded steel fabrication. The core is built up from laminations of low-loss, high permeability, high silicon content, electrical steel.

The stators have the core built up either on the core pack principle which is pre-wound and impregnated before being inserted and secured in the stator frame, or from laminations which are located by dovetail key bars, in the stator frame.

Stator windings

High tension coils are formed to shape from rectangular copper strips pre-insulated with polyester enamel, and a layer of film backed mica tape applied half lap.

The main insulation is provided by mica glass tapes applied as a number of half lapped layers. The coils are fitted into open slots in the stator core packs which are then closed with resin-bonded fabric slot wedges. The end windings are securely blocked and braced. Stator windings are impregnated using a resin rich or the vacuum pressure impregnation system.

After the impregnation and baking process, the whole structure forms a rigidly supported, fully consolidated, void free winding.

Low tension windings, similarly formed from rectangular copper strip, are of the bar type and are inserted into the slots before blocking, bracing and impregnating as above.

Rotor, Salient pole (Synchronous)

The rotor shaft is turned from a steel forging and ground on all fitting and journal surfaces. The attachment of the rotor poles to the hub is dependent upon the degree of overspeed and its duration. Methods employed range from the bolted-on-type to single or multiple inverted 'T' fitting. Fig 17.

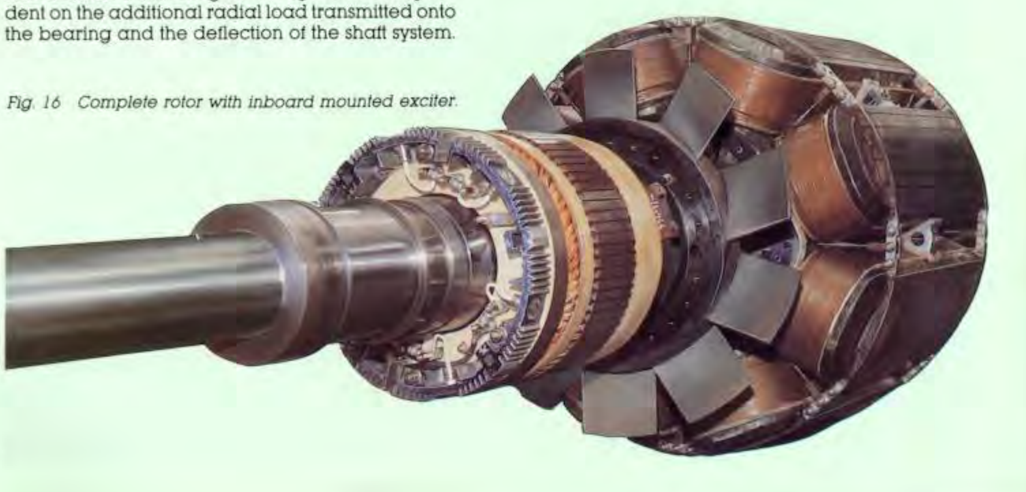
Flywheels

Flywheels can be either fabricated, cast, or forged depending on the degree of overspeed and inherent stresses. Positioning of the flywheel is dependent on the additional radial load transmitted onto the bearing and the deflection of the shaft system.

Fig. 14 Stator frame with completed winding. The frame also supports the magnet of the inboard mounted exciter.

Fig. 15 Typical wound high tension stator.

Fig. 16 Complete rotor with inboard mounted exciter.



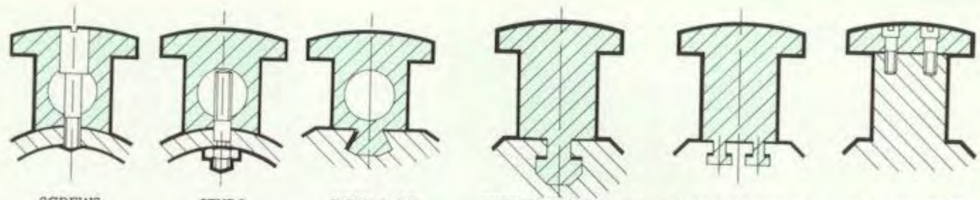


Fig. 17. Methods employed to attach the rotor poles to the hub.

Fig. 18. Detail of inverted double 'T' fitting of the pole bricks to the hub, and the cast steel pole end-plates giving support to the ends of the rotor coils particularly during overspeeds.

Fig. 19. Fitting the completed pole to the hub.

A flywheel can also have a secondary function as a brake ring whenever a mechanical braking system is deemed necessary.

Bearings

To maintain a compact design and minimise costs, where practical, a single shaft system is employed supported by two bearings. Endframe mounted or pedestal type bearings are available, and in either case the steel bushes are split on the horizontal centre line for ease of inspection and maintenance.

Fig. 20. Detail of pedestal bearing and flywheel guard on 3.3 MW generator.

Fig. 21. Sub-assembly in the factory showing flywheel cover removed from a 686kW hydro-generator for installation in Peru.

The bearings, of the white metalled sleeve type, are sized to accommodate the axial and radial loads of the system

In order to prevent circulation of shaft currents at least one bearing is insulated from earth. For average axial load, the force is absorbed by taper land sections on the bearing bush, and for high axial load the force is absorbed by thrust pads.

Wherever possible self-contained bearings are used and, if necessary, a water cooler is fitted in the oil sump to eliminate the heat generated. In the case of excessive axial forces where a forced lubrication system is required, the associated oil module is designed and supplied by Brush.

To overcome the stiction effect, where high radial bearing load exist, an oil jacking system may be necessary.

On small machines grease lubricated cartridge bearings may be used which are completely encased in self-contained housings enabling the machine to be dismantled without disturbing the bearings or exposing them to the environment. Lubricators and grease escape valves are fitted to allow adequate greasing.

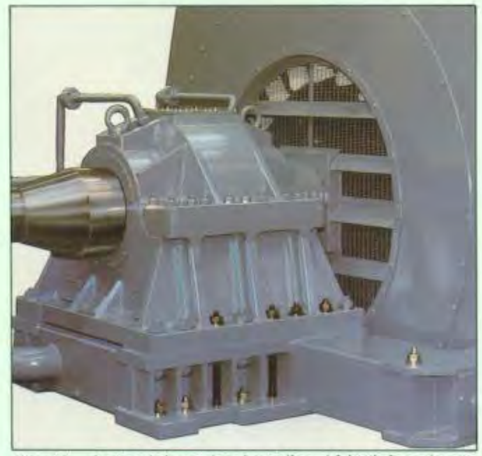


Fig. 22. A special marine type thrust block bearing to take high axial thrust was fitted to this 5.2 MW generator.

Fig. 24. Typical endframe mounted bearing.

Fig. 23. Fitting the thrust pads into the bearing shown in fig. 22.

Fig. 25. Bidwell Ditch Site construction.

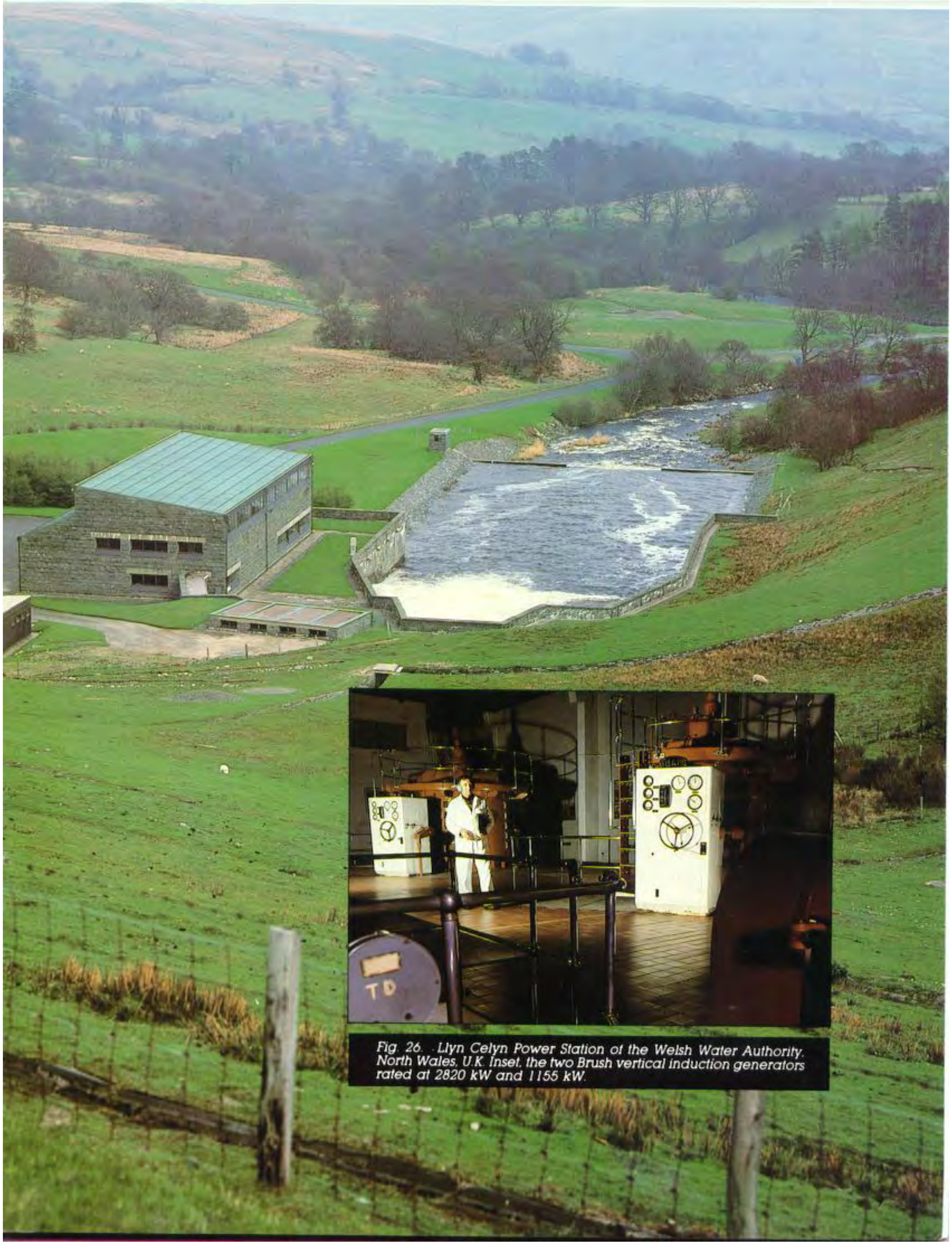


Fig. 26. Llyn Celyn Power Station of the Welsh Water Authority, North Wales, U.K. Inset, the two Brush vertical induction generators rated at 2820 kW and 1155 kW.

Pressure Lubrication Systems

A rectangular tank, adequately sized to contain the required oil for the system has all the lubrication control equipment mounted to it. From the tank an electrically driven oil pump delivers the oil through a cooler and filter to the bearings. Interruption of the oil supply would necessitate immediate shut down of the generator, consequently duplicated oil pumps, fed from alternative electrical supplies, are fitted and controlled by flow relays with automatic changeover to the pumps. Various controls and meters are mounted in the circuit for sensing oil pressure and temperature etc.

Control Equipment & System Engineering

The Projects Division of Brush Electrical Machines Ltd. is responsible for the design of the wide range of control and instrumentation equipment manufactured by the Company, including brushless and static excitation systems, automatic synchronizers, and voltage regulators, sensing relays etc. and to complement the machine manufacturing resources, will undertake design, installation and commissioning of complete electrical power packages including generators, motors, control panels, HV and LV switchgear, transformers and incorporating, if required, Brush PRISMIC micro-processor based power management systems.

Computer Aided Design

Extensive use of CAD/CAM systems and sophisticated analytical computer programmes have enabled Brush to optimise their hydro-electric generator design philosophies in both the electrical and mechanical disciplines, while avoiding cost and manufacturing penalties affecting the design flexibilities, quality, and short deliveries for which the company is known throughout the industrial world.

Product Support

Brush Electrical Machines Ltd. operates a world-wide product support service covering all products of the company with particular emphasis on larger machines and combined projects. These represent considerable capital investment for users and rapid and efficient product support is vital to complement good design and manufacture. The Product Support Group is based at Loughborough and consists of a team of experienced electrical and mechanical engineers who undertake anywhere in the world complete installation and commissioning, or supervision of these functions and repairs and servicing.

There are also many associated overseas companies which whilst not necessarily possessing the specialised techniques and equipment to undertake service work are in a position to give advice and investigate any problem. This is often invaluable in obtaining a quick initial diagnosis so that further remedial action can be taken.

Fig. 27. Complete lubrication module supplied for a 5.2 MW generator.

Fig. 28. Combined L.V. switchgear, control gear, and protective relay panel for two induction generators rated at 696 kW and 318 kW supplied though Gilbert, Gilkes and Gordon for installation at Littlewood River, Idaho, U.S.A.

Fig. 29. With a sophisticated CAD/CAM system installed, detailed design analysis and drawings are rapidly and accurately produced.

Fig. 30. 300 kW, 1200 rev/min (overspeed 1310 rev/min) 415 V, 3 ph, 50 Hz generator for the South of Scotland Electricity Board's Loch Braden Site. Supplied through Gilbert, Gilkes and Gordon.

Fig. 31. One of two 830 kW, 1200 rev/min (overspeed 2052 rev/min), 4160 V, 3 ph, 60 Hz, generators for Quiroz, Peru. Supplied through Balfour Beatty and Weir Pumps.

Fig. 32. 1.976 MW, 514 rev/min (overspeed 1000 rev/min) 4160 V, 3 ph, 60 Hz, generator for Dillon Dam, U.S.A. For other details see caption Fig. 9.

Fig. 33. 5.2 MW, 360 rev/min (overspeed 1041 rev/min) 4160 V, 3 ph, 60 Hz, generator for Weeks Falls, U.S.A. Supplied through Kvaerner Hydro Power Inc.

Fig. 34. Two 1.686 MW, 720 rev/min (overspeed 1450 rev/min), 4160 V, 3 ph, 60 Hz, generators supplied to Chalhuamayo, Peru, through Balfour Beatty and Weir Pumps.

Where to find us...

From St. Pancras Station in London 1½h.

By M1 Motorway to exit 23 from London 2h.

Heathrow to East Midland Airport (5 Flights per day) 50 min.

Principal Cities.
London 110 miles (177km).
Glasgow 320 miles (500km).
Manchester 80 miles (130km).
Birmingham 40 miles (65km).
Newcastle 170 miles (270km).

Fig. 35. Aerial view of the Brush Factory, Loughborough, U.K.

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