# Cruachan The Hollow Mountain

Discover the secrets hidden inside the mountain that never sleeps!

### THE LEGEND OF CRUACHAN

The Cailleach Bheur, (the Old Hag of the Ridges) was the guardian of a fountain that welled up from the peak of Ben Cruachan. It was her duty to cover the spring with a slab of stone at sundown and lift away the rock at sunrise.

One evening she fell asleep and the well overflowed. The water, rushing down the mountainside, burst open a new outlet to the sea through the Pass of Brander. By the time the Cailleach awoke, the water had flooded the wide strath below and drowned all the people and their cattle.

So was formed the River Awe and Loch Awe.

The Cailleach was turned to stone and sits to this day high on the mountain above the Pass of Brander.

## Cruachan The Hollow Mountain

Cruachan is a 440 MW reversible pump-storage power station, situated on the banks of Loch Awe in Argyll.

One of only four pumped-storage facilities in Britain, Cruachan is owned and operated by Drax. It was constructed during the early 1960s and was officially opened on October 15th 1965 by Her Majesty Queen Elizabeth II.

The power station is built deep into the heart of Ben Cruachan. The only visible evidence of its existence is the high storage dam on the slopes of Ben Cruachan and the administration office block beside Loch Awe.

To meet peak demands, power stations must increase their output and bring on additional generating sets. During periods of minimum demand generator sets are switched off or run at part loads. For most conventional forms of generation, using fuel such as coal, this variation in output to match demand is inefficient. Pumped-storage power stations can provide a way of minimising these changes in output for conventional generating sets by, in effect, storing the excess generated electricity when demand is low. This allows the conventional generator to continue at full output and the stored electricity is then released to meet the peak demands, thereby reducing the need to turn on additional conventional generating sets.

Cruachan generates up to 440 MW of electricity during times of peak demand, using water from the upper reservoir on Ben Cruachan to drive the turbines. At times when the demand is low, the surplus electricity is absorbed from the grid system to enable the turbines to be driven in the reverse direction to act as pumps. These pumps lift water from Loch Awe, which serves as the lower reservoir on Ben Cruachan. Due to the large surface area of Loch Awe, the operation of the power station has little effect on its water levels.



## Deep inside the Hollow

The upper reservoir was created by building a concrete gravity buttress dam, 316 metres long and 46 metres high, across a wind swept corrie (a basin shaped hollow in the mountainside) high on the flanks of Ben Cruachan. The dam houses two water intakes, feeding water to the power station. Each intake can be closed by means of a 3.7m x 4.9m control gate which is backed up by a 3.8m x 5.9m bulkhead gate.

Nineteen kilometres of tunnels and piped aqueducts divert water from streams around the mountain into this reservoir, increasing the catchment area from 8 sq km to 23 sq km, thus supplementing the water pumped up from Loch Awe.

Deep in the heart of the mountain, almost 400 metres below the upper reservoir, a series of chambers were cut out of the solid rock to house the underground power station. In total, the excavations extracted 220,000 cubic metres of rock and spoil.



## Mountain

A gradually sloping tunnel, 1 kilometre long, was driven into the mountain to provide road access to the power station. This tunnel is about 7 metres wide and 4 metres high.

At the lower end of the tunnel is the 'cross-roads' which provides access points to the machine hall, transformer halls and the visitors' gallery.

The largest chamber, the machine hall, housing the turbine and generator sets is about 90 metres long and 36 metres high, large enough to contain a seven storey building erected on a full size football pitch. On one wall of the machine hall is a mural of inlaid woods depicting the legend of Cruachan. This mural was designed by London artist, Elizabeth Falconer.

# Cruachan

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# Machine Hall

36 metres high and about 90 metres long, the machine hall is large enough to contain a seven storey building erected on a full size football pitch.



### Cruachan Machine Hall

The machine hall houses four generator/ motor sets, capable of generating 440 MW of electricity. When pumping, each set absorbs approx. 110 MW.

The total weight of each combined generator/ pump and turbine/pump is 650 tonnes. The rotating parts alone weigh 250 tonnes per machine.

The part of each machine showing above the machine hall floor and which is visible from the visitors' viewing gallery is the pony motor. This is an induction motor rated at 10,000 horse power and its purpose is to spin the machine from rest up to synchronous speed in the pump direction. Once the main rotor is excited the pony motor is switched out and the main machine motor drives the pump to lift the water to the upper reservoir.

From standstill, each machine is capable of reaching full generating output in two minutes and full pumping load in eight minutes. This speed of response is a major advantage over conventional forms of generation.

For even faster response, the turbines can also spin in air with the machines synchronised to the system. This is achieved by using compressed air to lower the water level in the turbine casing to clear the turbine runner of water. When operated in this way, the machines can reach full output in seconds, providing immediate standby generating capacity.

Two of the machines are connected to a 230 MVA transformer, the other two are each connected to a 150 MVA transformer making three in total. These oil immersed water cooled transformers convert the generated voltage of 16,000v to the transmission voltage of 275,000v.

The supergrid transformers are housed in large chambers near the main machine hall.



Busbar galleries and cable tunnels connect these transformers to switchgear in the machine hall and to the cable shaft.

The cable shaft houses the main power connections from the station to the transmission grid. There are six 275kV oil filled cables in a 4m diameter vertical concrete lined shaft.

These cables emerge near the foot of the dam and connect to the terminal tower of a dual circuit 275kV transmission line which carries the power to the local switching sub station at Dalmally and then on to Windyhill near Glasgow. This transmission line is supported along its length by 254 steel towers and at its highest level, the line reaches 550m above sea level.

When the machines are generating, water flows from the upper reservoir through two concrete lined shafts, known as penstocks, each of which then splits into two steel lined pipes 2m in diameter. On entering the machine hall, these steel lined pipes are each terminated with a 1.8m diameter main inlet valve. This valve allows the water to flow into the turbine and is opened and closed every time the machine operates. The machine hall floor, which is visible from the viewing gallery, is 36m below the normal level of Loch Awe. There are four further floor levels beneath this with the turbine runners sitting 50m beneath the level of Loch Awe.

After the water passes through the turbines, it flows through a steel lined draft tube pipe up to a high rectangular surge chamber. All four machines are connected to this single surge chamber and from here, the water flows to Loch Awe along a 975m long, 7m diameter tail-race tunnel. This tunnel, which is concrete lined and horseshoe shaped in section, enters Loch Awe at the forebay area next to the visitor centre. The forebay encloses the tunnel exit with screens to prevent fish being drawn into the power station. When the machines are pumping, the flow of water is reversed from Loch Awe to the upper reservoir.

At the entrance to the road tunnel leading to the power station stands the administration building. Nearby, a purpose-built visitors' centre and parking facilities have also been constructed on ground reclaimed from Loch Awe by tipping the rock excavated from the tunnel and cavern.



The exhibition in the visitors' centre and the underground tours of the power station, provided by Drax, have proved very popular and each year thousands of people are attracted by the unique spectacle of....

#### Cruachan – The Hollow Mountain

**Generators/Pumps:** Units 1&2 – 120 MW (500RPM) Units 3&4 – 100 MW (600RPM)

Ventilation and Cable Shaft: 335m high 4m dia

Access Tunnel: 1100m long 6.7m wide

**Tailrace Tunnel:** 975m long 7m dia

Surface Area of Loch Awe: 15 sq. miles

**Upper Reservoir Capacity**: 7GWh

Dam: 316m long 46.6m high

**Steel Lined Tunnels:** 2 x 5m dia. 48m long

**Concrete Lined Shafts:** 2 x 5m dia. 304m long

Steel Lined Pressure Shafts: 4 x 2.7m to 2.4 m dia. 152 m long

Machine Hall: 91m long 37m high 23m wide

Main Transformers: SGT1 – 1 x 230MVA (16kV/275kV) SGT2 (a & b) – 2 x 150MVA (16kV/275kV)





### Cruachan in Numbers

#### Cruachan Dam

Gravity buttress type with free spillway intakes within the dam. Length 316m height 46m contains 200,000 tonnes of concrete

#### Aqueducts

14.4km of tunnel, 2.6m x 2.1m and 3m by 2.4m sections, and 4.5km of piped aqueducts diverting water from 16.8km<sup>2</sup> where annual rainfall is 292cm

#### Reservoir

23m operating range, provides 10x106m<sup>3</sup> storage equivalent to 6.9 million units of electricity

#### Low Pressure Penstocks

Two 5m diameter steel pipes encased in concrete

#### Shafts

Two, inclined at 55 degrees, concrete lined. Length 304.8m diameter 5m each dividing into 2 steel-lined tunnels 152.4m long reducing in diameter from 2.7m to 2.4m

#### Tailrace Surge Chamber

21.9m long, 7.6m wide, 30.5m high with two expansion galleries 88.4m long 7.6m horseshoe

#### Tailrace Tunnel

975.3m long 7m equivalent diameter. Concrete-lined

#### Motor Generators

100,000kW, 0.9 P.F as generators and 110,000kW. 0.79 P.F as motors. Two sets run at 600 r.p.m and two at 500 r.p.m. Voltage 16000V. Estimated annual output 350 million units, of which an average of 40 million units from natural catchment

#### **Pump-Turbines**

134,000 H.P vertical reversible Francis. Max net head 362.7m generating. 367.6m pumping. Discharge approximately 28.3m<sup>3</sup>/sec. Main inlet valves 1.83m diameter, setting of runner – 9.75m O>D> (i.e. 45.7m below level of Loch Awe)

#### Main Transformers

1x230 MVA, 2x150 MVA (16Kv/275Kv), Oil Filled, Water cooled – On load Tap Changers + or – 10% Site assembled

Switchgear - 16kV SF6 6300A

#### Station Transformers

1 x 5 MVA 16/3.3kV 1 X 7.5 MVA 16/3.3kV

#### Standby Station Transformer

1 x 5MVA 33/3.3KV

#### Main Cable/Ventilation Shaft

3.96m diameter sectionalised lining. 335.3m vertical

#### Drainage/Dewatering Pumps

4-200 gpm (0.91m3/min) / 4-2500 gpm (11.4m3/min)

Standby Diesel - 1500 kW at 0.8 P.F

#### 275kVCables

6 - 275kV single core, 3.2 cm<sup>2</sup> oil-filled cables up vertical shaft



### Cruachan's Timeline

- 1921 The final report of the Water Power Resources Committee, set up to investigate potential sources of hydro power in Britain, contained two schemes, one for Loch Awe, the other for Loch Nant.
- 1956 A scheme was drawn up for a 400 megawatt development at Cruachan with four 100 megawatt machines.
- 1959 The construction of Cruachan began, with the main works taking place over a six-year period. These started with the excavation of the access tunnels and adits, and then of the large caverns needed to house the main machinery and transformers. The massive buttress dam was built over a period of two years.
- 1965 Two of the generator/turbine sets were completed by 1965; and on
  15 October of the same year Cruachan Power Station was officially opened by Her Majesty The Queen.
- 1967 The last of the four generator/turbine sets came into service.

At Drax, we do things differently from other power companies. Most want to grow their businesses in wind and solar. These are intermittent renewables, reliant on the weather. We will be there when the wind isn't blowing and the sun isn't shining, with biomass, hydro power and - such as at Cruachan - with pumped storage.

We are committed to supporting the UK and Scottish governments meet their climate change commitments and move towards a low carbon economy. By working together, we are enabling a zero carbon, lower cost energy future.

