SUPPLEMENT TO THE HISTELEC NEWS

DECEMBER 2010

GEOTHERMAL ELECTRICITY

by Marcus Palmen

In 2008, while on holiday in New Zealand we visited a geothermal site at Wairakei on the North Island. It made me realise how little I knew of the fundamentals and history of such sites. This is a summary of the relevant details I gathered to correct this situation.

The first plant producing electric power from geothermal fluids in the world started operating in 1904 in Tuscany, in the area of Larderello. Prince Piero Ginori Conti seen here with the engine and generator was the originator.

First Geothermal Power Plant, 1904, Larderello, Italy

This plant was destroyed in WW2 but rebuilt and was by 1948 generating 140MW with another 142 MW station in an advanced stage of construction. The field is still producing today after more than 90 years.

Wairakei

The second commercially active plant came into being much later at Wairakei in New Zealand in the late 50's. The engineers involved in the development worked closely with the enthusiastic Italian engineers whose success with this type of power plant strongly influenced New Zealand's decision to proceed with the development.

On the 15th November 1958 the first set in the Wairakei "A" Station was synchronized to the national grid. A total capacity of 192.6 MW was installed in the "A" and "B" developments, the last machine being synchronized to the grid in October 1963.

The countries now with the highest installed capacity of geothermal energy are the United States, Japan, Philippines, Italy and Mexico.

To consider all the aspects of Geothermal Electricity production I shall make use of the specification for a new generating station at Te Mihi to replace the 50 year old Wairakei station.

The Energy Source

The Wairakei geothermal system has two bore fields, The Western Borefield and The Te Mihi Borefield. This latter contains pressurised water at a temperature of 250°C and at a depth of about 2.5 km. When this water is brought to the surface the pressure on the water drops and the water boils to become a mixture of about 80% water and 20% steam. At the surface, the steam and water/brine components are separated, with the steam component used in a turbine to generate electricity.

The proposed Te Mihi Power Station site is located within the boundaries of the Wairakei geothermal system 5 km from the Wairakei Power Station, which was originally served by the Western Borefield but now also by the Te Mihi Borefield with energy losses in the long pipe lines. The main reason for the long pipe lines is the location of the old power station by the river in order to make use of river for cooling water and the discharge of surplus water/brine condensates and dissolved H_2S.

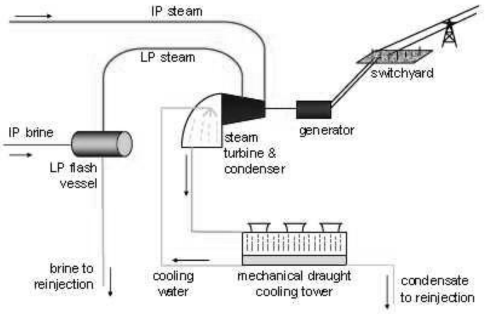
The new station will utilise air cooling and will exhaust the unwanted CO_2 and H_2S gases in the steam to the air. The site is well away from the tourist areas of the Wairakei Village, Huka Falls Walkway and the Prawn Farm so the discharge of hydrogen sulphide gas to air will not affect these localities with its rotten egg smell in the way it would do if this gas was released at the old power station (ie. after the H_2S can no longer be dissolved into the river, it would be discharged to the air).

The Power Plant

The proposed new power plant consists of three two-pressure condensing steam turbines with steam condensers, closed circuit evaporative cooling towers, and other ancillary plant and services. About 20-25% more power can be generated from the same amount of extracted geothermal fluid by using double-flash technology compared with single-flash plants. The secondary, low-pressure steam produced by throttling the separated liquid to a lower pressure is sent to an appropriate stage of the steam turbine (i.e. dual-pressure, dual admission turbine). This dual pressure, dual admission technique is already used on the existing Mixed Pressure (MP) units in the Wairakei B station.

Intermediate Pressure (IP) steam would be piped from the steam field to the power house, before splitting for distribution to each turbine unit. Steam vents on the main steam lines for start-up and pressure control during process upsets would be provided adjacent to the power station. The vents would discharge through rock mufflers for silencing. Condensate from the rock mufflers and general steam drains would be collected in a condensate drains pond.

IP separated water/brine would also be piped to the station, supplying individual Low Pressure (LP) flash plants adjacent to each generating unit. Steam from the LP flash plants would be fed into the LP stages of the steam turbines.



All in all 235MW gross 220MW net is the target output 15MW being used on site for the injection pumping and other auxiliaries.

The Alternative Power Plant

A Binary Power Station could be built in place of a new standard Steam Power Station. The possible new power plant would consist of a number of modular binary power plants (also known as organic rankine cycle plant). In binary plant, the heat in the geothermal fluid is transferred to a secondary working fluid with low boiling point that circulates in a closed plant cycle. These types of plant consist of heat exchangers, organic fluid turbines, air cooled condensers, and other ancillary plant and services. The organic fluid is expected to be pentane.

The geothermal fluid is separated into steam and water/brine components before being used, similarly to steam plant. In a 2-phase binary plant, the separated steam is used to vaporise the binary fluid, and the mixture of condensed steam and brine is used for preheating the binary fluid prior to evaporation. Binary plants typically use an air-cooled condenser. This type of cooling system is larger and more expensive than that used in flash steam plant.

Due to its modular construction, the binary plant can easily be built in stages of the desired capacity. Each module would be expected to be approximately 10MW, and approximately 22 modules would be required for the complete development. Care has to be taken in the design to minimise the possibility of pentane leaks and sensitive detectors must be fitted.

In conclusion

The energy source changes over time – old bore holes can turn from supplying steam to receiving spent water/brine to be injected underground or they may be abandoned. Up to now some 600 boreholes have been used on the geothermal site. About half of these are still active either for steam supplies or as injection points.

The plant used must effectively cater for gradual changes in the quality of the supply. The double flash steam turbines or the binary plant methods appear to cater for the varied thermal energy supplies available on site.

If you visit these sites in New Zealand you can be guaranteed a **warm** welcome. Contact Energy is the Electricity Supplier who owns and develops the power stations. Their website provides detailed technical reports and short publicity brochures that anybody wishing to do further studies will find useful.

In the UK the Use of Geothermal Energy has been limited to two main types of scheme

1) The Aquifer Scheme which relies on drawing water from a hot basin nearly 2 km below surface/ Southampton supply heat to a district heating scheme at 16 GWh per year.
2) Hot Rock Schemes Trials for this type of scheme were carried out at Rosemanowes Quarry near Penryn in Cornwall. A new plant is under construction on the United Downs industrial Estate near Redruth by Geothermal Engineering Ltd. The plant will produce 10MW of Electricity and 55MW of renewable heat.

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Bibliography:

www.contactenergy.co.nz and in particular the full technical report, which is available on the following address as a PDF file.

http://www.contactenergy.co.nz/web/pdf/our_projects/temihi/TeMihiFullTR1-ProjectDescriptionGeothermalPower.pdf

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