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VI

AEGEAN STEAM: THE GERMENCIK DUAL FLASH PLANT

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SUMMARY

The Germencik 45 MW geothermal power station – a large new power station near Izmir – is the newest addition to Turkey´s renewable energy landscape. The plant is now being completed by the Turkish company Güri□ and will be operated by its subsidiary Gürmat. Power plant design was performed by POWER Engineers, Inc. of the USA. The chemical characteristics and energy content of geothermal resources varies widely from place to place, so design of the Germencik plant – as with geothermal plants everywhere – was customized to the resource found there. Specifically, the plant incorporated features and new technology in the steamfield, condenser, and gas removal systems directly tailored to improve efficiency, economy, and operational flexibility. Commissioning of the Germencik plant is expected in early 2009 and additional details on actual performance will be the topic of future reports. The purpose of this paper is to describe the design approach and options considered for key plant aspects such as cycle select*ion, scaling reduction, and condenser/gas removal equipment.*

Fig.1. View ro Germencik plant, 2008

1. TURKEY´S INCREASING GEOTHERMAL PRESENCE

Turkey is a country blessed with considerable geothermal resources, but as in the case of many nations with substantial such resources, their utilization has been limited to date. Fossil fuels are used to produce 70% of Turkey´s electrical power, compared to geothermal plants' contribution of 0.06% currently (Serpen et al 2008).

Further development of Turkey's geothermal energy resources will certainly benefit the nation's energy budget, since geothermal power plants are typically robust, reliable, highly available, and environmentally

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Geothermal resource utilization is also a conspicuous case of productive use of indigenous resources which can displace dependence on imports for critical energy supplies. Turkey imported 69 mtoe of fossil fuels in 2006 (IEA 2008), and improvements in its energy independence will enhance Turkey's economic stability and security.

2. PREVIOUS GEOTHERMAL POWER PLANT OPERATIONS IN TURKEY

The single-flash power station at Kizildere has been operating since 1984, with an average gross power around 10 MWe. The average output has been reduced from the rated capacity largely due to significant $CaCO_3$ scale buildup in the wells, which requires frequent mechanical cleaning to remedy (Serpen and Turkmen 2005).

Kizildere's owner, Zorlu, is now conducting a feasibility study and development program to expand and modernize the Kizildere power generation operations. In addition to Kizildere, an 8 MWe binary power plant has been operating at Aydin-Salavath since 2006. Serpen et al (2008) estimate that the identified geothermal capacity in eleven major fields may approach 3700 MWt.

Figure 2: A wellhead at Kizildere (H. Veizades photo, 2008)

3. GERMENCIK: A THOROUGHLY MODERN FLASH PLANT

The Germencik project owner and constructor is Güri, one of the leading construction and engineering companies in Turkey. Güri has more than 50 years of experience spanning thermal plants, civil structures, and pipelines. More detailed plant and project structure is presented in Table 1. The plant is located in western Turkey, approximately 50 km from the Aegean Sea in the Aydin province. The nearest major port is Izmir. Germencik is scheduled to be commissioned in 2009. With 45 MW nominal gross capacity, Germencik will be the largest geothermal plant in Turkey.

The Germencik liquid-dominated field has been studied since 1967, and drilling in the 1980s indicated downhole temperatures of 200-232 °C (Filiz et al 2000). Flow tests confirmed these temperature values, but have also indicated high proportions of non-condensible gases; initially predicted up to 12.4% in the high pressure steam flashed at 6.4 bara. A feasibility study funded by the U.S. Trade and Development Agency (Shaw 2005) had estimated that the resource was sufficient to support over 70 MW of generation.

Through its subsidiary Gürmat, Güri chose POWER Engineers, Inc. (POWER) of the U.S. for the plant design. POWER has considerable worldwide experience in flash and binary plant design. POWER's designs include the recently completed 110 MW Darajat flash plant in Indonesia, the 40 MW Stillwater and 15 MW Salt Wells binary projects in Nevada, the Olkaria II Units 1-3 flash plant in Kenya (total 96 MW), the 34 MW Heber binary plant in Nevada, the 104 MW Mindanao dual-flash project in the Philippines, and many other projects around the world including new plants in Mexico, the U.S., Costa Rica and Iceland. This breadth of experience made POWER well suited to review cycle options and execute the detailed design for the challenging resource conditions.

4. POWER CYCLE EVALUATION AND SELECTION

Using the TDA-funded feasibility study as a basis, POWER performed a thermodynamic and economic review of cycle options, focusing on the technology options conventionally applied to geothermal energy conversion and applicable to the Germencik resource: dual flash, single flash, and binary cycles. The review and evaluation was undertaken to determine the optimal technical fit between the resource and the technology, and also to determine the comparative cost-effectiveness of the candidate plants.

Flash Plant Alternatives: There are many geothermal power plants in the world, and it is no accident that flash plants – comparatively uncomplicated plants that "flash" the resource liquid into steam which drives a turbine directly – are responsible for most of the geothermal power generated. The single-flash plant is a famous workhorse throughout the world, contributing 40% of all geothermal electrical generation worldwide (Dagdas 2007). Such a plant is a compelling choice for simplicity, but sacrifices some efficiency due to the high temperature of the separated brine remaining after the initial flash. The addition of a second flash at a pressure slightly above atmospheric pressure allows the recovery of additional energy from this remaining high-temperature brine, which can be directed to the lower pressure stages of a dual-pressure turbine. Turbine manufacturers such as Mitsubishi, Fuji, and Toshiba have provided reliable machines of this type worldwide for many years.

Binary Alternatives: Binary units use the geothermal fluid to heat a working fluid, such as isopentane, isobutane, or a commercial refrigerant, in a closed-loop Rankine cycle to generate power. These cycles have the potential to operate with greater return of fluid to the reservoir and typically much lower non-condensible gas emissions, and can operate down to very low resource temperatures (Brasz et al 2005). Complete packaged units from Ormat or United Technology are available, or plants may be stick-built using turbines and components from a variety of vendors. In general, the need for heat exchangers renders binary plants less efficient than flash units in the temperatures under consideration for Germencik (HP flashed steam temperature >150 °C).

5. THE TALE OF THE TAPE

Cost estimation has become more challenging in the past decade due to high volatility in commodity markets that affect the costs for key ingredients in geothermal plants. However, with a wealth of historical and current cost data, POWER was able to assess the relative merits of the cycle choices for Germencik. Binary capital costs, which generally fall within the range of $2,000-4,000/kW (Lewis and Ralph 2008) for the plant exclusive of steamfield, were also found to be significantly higher than that estimated for the flash plant using this high-enthalpy resource.

POWER also considered alternative strategies to maximize efficiency and deal with the non-condensible gas found at Germencik. These strategies included the incorporation of reboilers and the application of "combined" cycles employing flash and binary energy conversion equipment in a topping/bottoming arrangement.

Reboilers incur an efficiency penalty, and due to the novelty of their application in a geothermal power cycle, installation on such a large scale would not have been prudent, and were ruled out. Geothermal combined cycles that use a steam turbine exhausting to the vaporizer of a binary cycle are not uncommon, and offer some advantages in efficiency. However, due to the cost and complexity of managing two distinct technologies, this would be a respectable operational challenge offering only a modest benefit.

Following this analysis, a dual-flash cycle was chosen for Germencik. The separator station, consisting of two HP separators, two LP separators, and HP/LP demisters, is shown under construction in Figure 3.

6. ANTISCALING STRATEGIES

One of the first challenges in the project was to devise a strategy to combat carbonate scaling in the production wells. The Germencik brine contains high concentrations of calcite and less striking concentrations of silica (Haizlip 2006), and may be prone to scaling if countermeasures are not taken. Another Turkish plant at a similar resource, Kizildere, has experienced significant problems with the production wells, leading to diminished output and frequent well rehabilitation required. To combat this, Gürmat selected a production well antiscalant regimen (Geosperse) devised by PowerChem Technology. (Osborn et al 2007).

Dosing of the antiscalant chemical is accomplished via downhole capillary tubing. Successful pilot testing of this technology was carried out at the site in 2007-2008, and observations of full operations in 2009 may be of interest to owners of similar resources in Turkey.

Figure 3: Separator station under construction (T. Dunford photo, 2008)

7. PROJECT STRUCTURE CONSIDERATION

A project functions best when it strives to maximize local content, while ensuring that specialized equipment suitable for the environment, which may not be available in the home country, is used where needed (Wallace et al 2008). A comprehensive division of labor between U.S. and Turkish subcontractors, including engineering and materials supply, was developed. Although some of the major equipment was procured from outside Turkey, procurement of significant quantities of manual and control valves, structural steel, electrical components, and process pumps was done locally. Table 1 describes some of the key participants and configuration of major components in the plant.

Table 1: Germencik plant and project configuration

Turbine	Dual pressure, dual flow, top exhaust
Condenser	Advanced Direct Contact (ADCC)
Non-condensible gas (NCG) system	Two-stage hybrid; ejectors and liquid ring vacuum pumps
Hotwell pumps	Vertical can
Cooling tower	Counterflow, seven cell
Owner	Gürmat
Constructor	Güri□ (parent company of Gürmat)
Reservoir engineering	Geologica, Inc
Steamfield engineering	Veizades & Associates, Inc (VAI)
Powerplant engineering	POWER Engineers, Inc. (POWER)

8. TURBINE AND CONDENSER CONSIDERATIONS

Detailed design commenced and after a competitive bidding process, Mitsubishi Heavy Industries (MHI) was selected as the supplier for the dual-pressure turbine. A layout of the powerhouse and turbine is shown in Figure 4.

The top exhaust turbine allows convenient arrangement of a compact powerhouse, with adequate provisions for laydown during overhauls. The condenser and gas removal systems are located adjacent to the powerhouse, and with the mild climate, freeze protection is not required. The condenser and gas removal system can be seen in Figures 5 and 6.

Due to the significant non-condensible gas loads, the design of the gas removal system had significant impact on the overall plant performance. With no compelling markets for waste heat at this location, the higher cost and lower efficiency of surface condensers excluded them from consideration.

Figure 4: MHI Turbine and Powerhouse (T. Dunford photo, 2008)

While conventional direct contact condensers are in wide use around the geothermal world, the Advanced Direct Contact Condenser (ADCC) design, developed by Ecolaire, was also considered as a way to reduce plant initial and operating costs. This is a new technology that was initially developed by the National Renewable Energy Laboratory (NREL) for use in ocean thermal energy conversion. A few geothermal plants in California and Mexico (Hiriart 2003) use this equipment, but none on the scale of the Germencik project.

The ADCC is a direct contact condenser with internal stainless steel fill, operating analogously to a film-type cooling tower. The large fill surface area enhances heat transfer, resulting in less condensate subcooling required and lower gas cooler exit temperatures. The predicted gas cooler approach is less than 2 °C; it remains to be verified during condenser testing in 2009 if this will be achieved.

Figure 5: Condenser and Gas Removal System. The condenser is the large drum-shaped vessel just left of center in the photograph.(T. Dunford photo, 2008)

Tender specifications for the condenser were prepared and responded to by a number of vendors. When the offerings were reviewed and assessed not only with respect to the condenser proper but also with an eye towards their effects on the plant in toto, the ADCC appeared to offer a number of quantifiable benefits compared to other designs. These benefits included:

- Lower condenser capital cost
- Lower circulating water flow required, with lower consequent circulating water system capital cost and parasitic loads
- Lower gas cooler outlet temperature and vapor flowrate, with lower NCG system capital costs, and steam and electrical consumption.

A more comprehensive assessment of this technology is planned in the future once operating data from the plant are available.

9. GAS REMOVAL SYSTEM CONSIDERATIONS

Non-condensible gas (NCG) levels in geothermal fluids are one of the more difficult parameters to predict for both initial operation and long-term trends. The design of a system to remove these from the condenser should ideally balance the competing demands of initial cost, efficiency, and flexibility to deal with changes in gas content over time.

Turbocompressors, which use a geothermal steam turbine to drive a compressor, might have been an ideal approach for this resource, and were carefully considered. Turbocompressors offer high efficiencies and some process flexibility, since the speed and capacity can be changed. They were not selected for the final solution due to two factors: there did not appear to be a compelling economic advantage, and the limited numbers of these devices in service made them less appealing for a new geothermal operator.

Figure 6. The vacuum pumps (blue components) and ejector trains at Germencik (T. Dunford photo, 2008)

A hybrid non-condensible gas removal system, consisting of first-stage ejectors and second-stage vacuum pumps, was selected to minimize steam and electrical consumption. First-stage ejectors are a low-capital-cost strategy to provide an initial stage of gas removal and compression for low-density, low-pressure gases from the condenser, which can be costly to accomplish with liquid ring vacuum pumps (LRVPs).

For the second stage, four large Gardner-Denver-Nash (GDN) 2BE3 LRVPs were required. The higher efficiency of LRVPs permits considerable savings on motive steam from what would have otherwise been required by second stage ejectors, extending the life of the resource. A 25% capacity backup afterejector is provided in the event of maintenance on a pump is required. An asymmetric first-stage ejector lineup of 25%/40%/60% capacity was chosen; this allows operators to adjust combinations to achieve the best balance of condenser vacuum and ejector steam consumption. There is excess capacity provided in the two intercondensers and the cooling water system in the event that operation at greater than 100% of design NCG load is necessary.

The total design consumption of over 40,000 kg/hr of ejector motive steam and over 2000 kW of vacuum pump power made features that allowed tuning and optimization of the system highly desirable. Due to the low H_2S content – approximately 250 ppmw in HP steam (Haizlip 2006) – no abatement system was required, and NCGs are diluted and exhausted to the atmosphere in the stacks of the cooling tower.

It must be noted that current regulatory conditions in Turkey do not assess costs per ton of CO_2 emitted. Due to the high gas content of this field, predicted emissions of ~1 kg CO_2/kWh are not insignificant, although the geothermal field itself doubtless naturally emits some fraction of this (Armannsson et al 2005). Monitoring of natural emissions would make a worthwhile future study of academic interest. These emissions approach those of coal-fired fossil plants on a per kWh basis, although this plant avoids many of the other damaging environmental aspects of coal-fired generation such as particulate emissions and refuse piles.

However, when Turkey joins a CO_2 regulatory framework, the cycle choices and mitigation options of future plants will require additional consideration. Some utilization options for the relatively pure streams of CO_2 from geothermal resources include recharge to the reservoir, a feedstock for fuel synthesis (Mignard and Pritchard 2006), enhancement of growing conditions in greenhouses (Dunstall and Graeber 2007), and the manufacture of dry ice.

10. CONCLUSIONS

As the largest new geothermal plant in Turkey and a project representing the latest ideas in geothermal turbine and flash cycle design, the Germencik project will blend the latest geothermal technology with a large proportion of in-country resources to improve Turkey's energy independence. The plant was designed with several features to enhance efficiency, ease of maintenance, operational flexibility under changing reservoir conditions, and plant economics.

The success of the new technology employed in the steamfield and gas removal systems will be evaluated in more detail once the plant is operational. Approaches such as these may be valuable new tools for economical plant design, and especially appropriate for the geothermal fluid characteristics of similar fields in Turkey.

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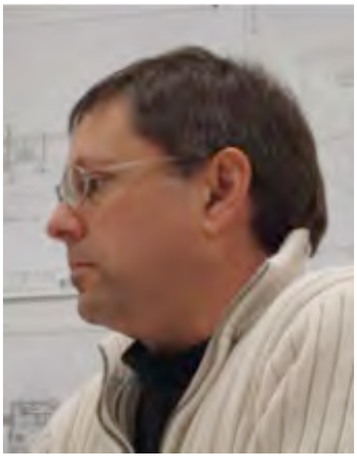

Kevin Wallis is a professional chemical/mechanical engineer and one of the design managers for the world's leading firm for large flash geothermal power generation plants. He has been a project director, project manager, project engineer and principal design and field engineer for more 400 MW of new geothermal plant capacity in Asia, Africa, Latin America and the U.S. in the past decade. He has been an engineering leader with POWER Engineers, Inc. of the U.S. since 1997, and is now a Senior Project Manager and POWER's Renewables Market Manager. Mr. Wallace is a notable specialist in gas extraction and sulfur abatement systems for geothermal plant optimization, and has a formidable background in field support engineering for the construction of large plants in remote locations. He also has extensive experience in project definition, detailed engineering supervision and consultation for geothermal flash and dry steam projects, and is now leading POWER's work in upcoming work in the Imperial Valley and Nicaragua, and dry steam generation projects at the Geysers in California.