Proceedings World Geothermal Congress 2020+1
Reykjavik, Iceland, April - October 2021

Case Study of the Yerka Mt Ida Geothermal Project, Canakkale Province, Turkey

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Keywords: Tuzla, exploration, fractured marble, development, well testing, fluid chemistry, production-injection strategy, electric submersible pumps, scale inhibition

ABSTRACT

Yerka Elektrik Üretim A.Ş. (Yerka) is developing the Mt. Ida geothermal project near the village of Tuzla, Çanakkale Province, Turkey. Exploration began in 2013, with the drilling of two intermediate-depth wells, followed by geological and geophysical surveying in 2014-2015. In 2016 and 2017, Yerka successfully drilled six deep wells. Four wells in the eastern part of the lease are planned for production, and two wells in the west are planned for injection, with a separation of about 1 kilometer (km) between production and injection areas. Well testing has indicated sufficient production and injection capacity for a binary geothermal plant with a capacity of 12 MW gross. As of July 2019, the plant and gathering system are under construction, with a planned commercial operation date in the summer of 2020. Development wells have been drilled to 2,300- 2,500 meters measured depth (mMD). The main permeable intervals are in fractured marbles at depths typically in the range of 1,500 to 2,200 mMD. Bottom-hole temperatures have ranged up to 157 °C, but temperatures in the production zones are about 126-127 °C. The salinity of produced fluids is relatively high (about 50,000 ppm), while concentrations of non-condensable gas are relatively low (0.5% to 0.7% by weight in total flow). The wells have shown significant benefits from acid stimulations through coiled tubing, with Productivity Indices post-acid ranging from 21 to 139 tons/hour per bar. Pressure-interference testing shows that the entire well-field is interconnected, which is beneficial from the perspective of maintaining pressure support by injection. However, the interference is low enough that thermal breakthrough by injection should not be a concern. Yerka plans to use electric submersible pump (ESP) technology to maintain steady production rates and provide a greater measure of operational control. The produced fluid will be allowed to boil in the column pipe above the ESPs. The ESP design incorporates the use of downhole scale inhibitor to avoid scaling above the pumps and in the surface facilities.

1. INTRODUCTION

The Mt. Ida project is located in Çanakkale Province, Turkey, near the Village of Tuzla. Yerka Elektrik Üretim A.Ş. ("Yerka") began geothermal resource exploration activities in 2013 with the drilling of two intermediate-depth wells, followed by geological and geophysical surveying in 2014-2015. In 2016 and 2017, Yerka successfully drilled six deep wells (Figure 1). Well testing indicates that the project has sufficient production and injection capacity for a geothermal plant with an estimated capacity of 12 MW gross. This paper presents an updated description of the project previously presented by Hackett et al. (2018). Yerka is now planning for a commercial operation date in the summer of 2020.

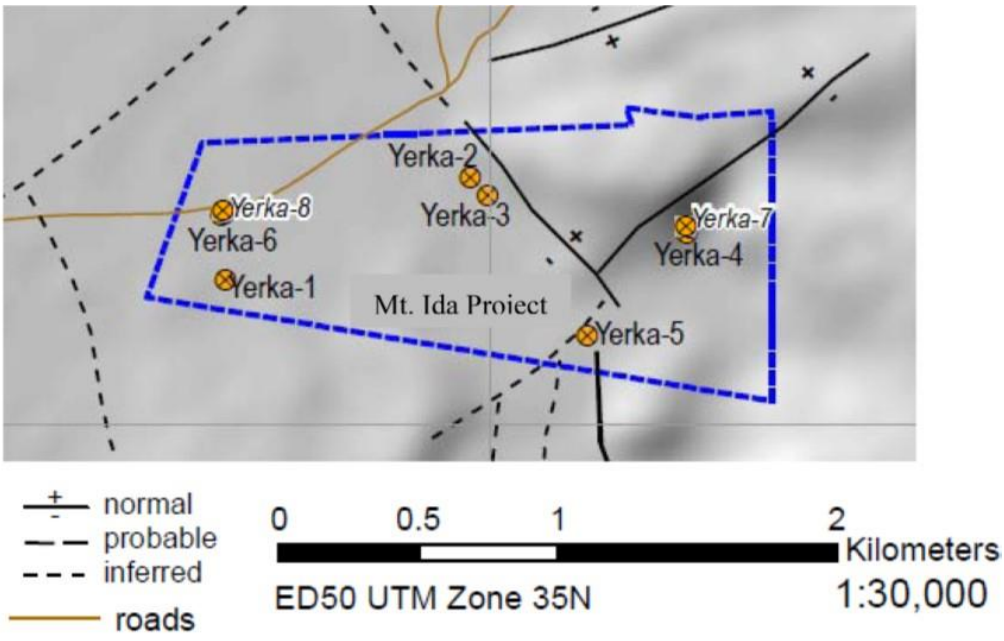

Figure 1: Yerka Mt. Ida Project, Well Location Map.

2. GEOLOGIC SETTING

Southwestern Turkey is a region of anomalously high heat flow that has developed as a result of crustal thinning in an area of tectonic extension of the earth's crust, in association with continental convergence. The Tuzla area is part of this region, where the regional background gradient is elevated to the range of 6.6 to 8.0 °C/100 m (Basel *et al.,* 2010); this gradient allows for elevated temperatures to be encountered during drilling, even in the absence of strong hydrothermal convection. Nearby and to the east of the Mt. Ida project, geothermal brine is produced for the operating Tuzla geothermal project from volcanic formations at depths of 350 m or less (Baba *et al.,* 2009). A deeper reservoir (below 1,000 m, within granodiorites) is also exploited for the project.

Beneath this Tertiary cover in the Tuzla area is a metamorphic basement made up of Paleozoic marbles, schists, and ophiolites. Wells drilled in the Mt. Ida license show alternating marbles and schists beneath ophiolites to the bottom of the well. In each of Yerka's wells that encounter basement rock, marbles host the primary zones of fluid production and continue beyond the total depth of these wells, indicating that these marbles are sufficiently widespread and thick enough to be targeted for production across the Mt. Ida license.

3. DRILLING AND TESTING RESULTS

Within the Mt. Ida project area, Yerka has drilled (in chronological order, with locations shown in Figure 1):

- two intermediate-depth vertical wells: Yerka-1 (1,783 m deep, in the southwestern part of the parcel) and Yerka-2 (912 m, in the north-central part)
- a deep vertical well (Yerka-3, 2,378 m) in the central part of the parcel near Yerka-2
- a deep vertical well (Yerka-4, 2,431 m) in the eastern part of the parcel
- a deep vertical well (Yerka-5, 2,476 m) in the southern part of the parcel (southeast of the Yerka-3 well and southwest of the Yerka-4 well)
- a deep vertical well (Yerka-6, 2,453 m) in the northwestern part of the parcel (north of the Yerka-1 well)
- a deep directional well (Yerka-7, 2,410 m), drilled in the northeastern part of the parcel (from the same pad as Yerka-4)
- a deep directional well (Yerka-8, 2,225 m), drilled in the northwestern part of the parcel (from the same pad as Yerka-6)

Individual testing of wells has allowed determination of the capacity of intended producers and injectors in the field (Table 1).

The first of two interference tests conducted by Yerka was carried-out to characterize the inter-well connections and overall behavior of the field when stressed by production. This testing was conducted from 30 May to 11 June 2017. Testing consisted of individually producing wells Yerka-6, Yerka-4, and then Yerka-5, while monitoring the reservoir pressure in all wells that were not under production.

Examination of pressure-monitoring data collected during this test indicates that a pressure response to each production well was observed in all other monitored production wells. This indicates that all wells in the Mt. Ida area are interconnected and that injection can be expected to support production pressure. The maximum observed pressure drawdown interference was between Yerka-4 and Yerka-3 at 0.14 bar. This degree of drawdown with 800 m of spacing between production (Yerka-4) and pressure observation (Yerka-3) indicates that the system contains high levels of permeability interconnecting the wells.

A second interference test was conducted by Yerka from 5 July to 11 July 2017 to again characterize the inter-well connections and overall behavior of the field. The testing consisted of periods of production and injection at Yerka-6, as well as a period of injection at Yerka-1. The reservoir pressure was monitored in wells that were not being tested. An example interference test plot is provided in Figure 2.

Results of interference and individual well testing have confirmed that all wells in the Mt. Ida license are hydraulically connected (that is, they are in the same reservoir), but the amount of pressure interference between wells is small.

4. COILED-TUBING STIMULATION RESULTS

All of the production and injection wells in the Mt. Ida field have been stimulated via acidizing with a coiled-tubing unit (CTU). Based on comparisons of pre-and post-acidizing production capacity, wells have shown marked improvement from this stimulation, as shown in Table 1. Capacity improvement measured in each well is summarized as follows.

- Yerka-1: The Injectivity Index (II) of this well was 8 tons per hour per bar (TPH/bar) before stimulation. Acidizing and nitrogen lift was conducted by CTU from late June to early July 2017, followed by a water-loss test on 6-7 July 2017. A post-acid II value of 15 TPH/bar was determined following testing, indicating nearly a doubling of the II value from stimulation.
- Yerka-3: The Productivity Index (PI) of Yerka-3 more than quadrupled, from an average of 9 TPH/bar before acidizing, to an average of 37 TPH/bar after acidizing.
- Yerka-4: Testing following acidizing indicated an improvement in the PI value of about 29% for an already prolific well (from 108 to 139 TPH/bar).

Table 1: Mt. Ida (Tuzla-West) Geothermal Project: Estimated Well Characteristics

Estimated values are in italics.

Production Wells

Well	Maximum Temperature At or Near Total Depth (°C)	Flowing Temperature at Shoe (°C)	Pure-Water Enthalpy Based on Temperature at Shoe (kJ/kg)	Enthalpy Adjusted for Salinity [a] (kJ/kg)	PI Before Acidizing (TPH/bar)	PI After Acidizing (TPH/bar)	Comments	Estimate of Maximum Pumped Rate at 8 barg WHP (TPH)	Estimate of Sustainable Rate for Steady Pump Performance (TPH)	Estimated Maximum Equivalent MWe [b]	Estimated Sustainable Equivalent MWe [b]	Pump electrical requirement (KW) to provide max/sustainable pumped rate (TPH) at 10 bar WHP	Pump electrical requirement (KW) to provide max/sustainable pumped rate (TPH) at 23 bar WHP
Yerka-3	137	126	529	503	9	37	Flow testing 26-29 Aug 2016	*450*	*350*	*3.2*	*2.5*	435.8/288.9	660.3/482.3
Yerka-4	148	127	534	508	108	139	Flow testing 1-4 June 2017	*550*	*450*	*4.0*	*3.3*	521.0/335.9	769.1/548.0
Yerka-5	148	126	529	503	9	21	Flow testing 7-10 June 2017	*450*	*350*	*3.2*	*2.5*	608.9/398.9	834.0/587.6
Yerka-7	157	127	534	508	19	74	Flow testing 26-29 Dec 2017	*450*	*350*	*3.3*	*2.5*	492.1/329.6	731.0/523.5
							Total:	*1,900*	*1,500*	*13.7*	*10.8*		

Mass-weighted average temperature:	*127*	532	*506*	Total flow if Yerka-4 is off-line for maintenance (other wells producing at their maximum rates):	*1,350*	*9.7*

Injection Wells

Well	Maximum Temperature At or Near Total Depth (°C)		PI/II Before Acidizing (TPH/bar)	PI/II After Acidizing (TPH/bar)	Comments	Estimated Injection Capacity (TPH)	Estimated Injection Pressure at Wellhead (barg)
Yerka-1	123		8	15	Injection test 6-7 Jul 2017	*400*	*30*
Yerka-6	139		< 19	21	Flow test 10-11 Jul 2017 [c]	*600*	*30*
Yerka-8	139		4	19	Injection test 5-6 Jan 2018	*600*	*30*
					Total:	*1,600*	

Notes:

[a] Enthalpy values adjusted downward by 26 kJ/kg to account for salinity of geothermal brine (about 55,000 ppm Total Dissolved Solids).

[b] MW estimates assume conversion efficiency of 10% (thermal to electric) and plant outlet temperature of 65°C. Power consumption by production pumps needs to be subtracted from these values.

[c] Estimate of Injection capacity assumes Injectivity Index (II) is equivalent to Productivity Index (PI).

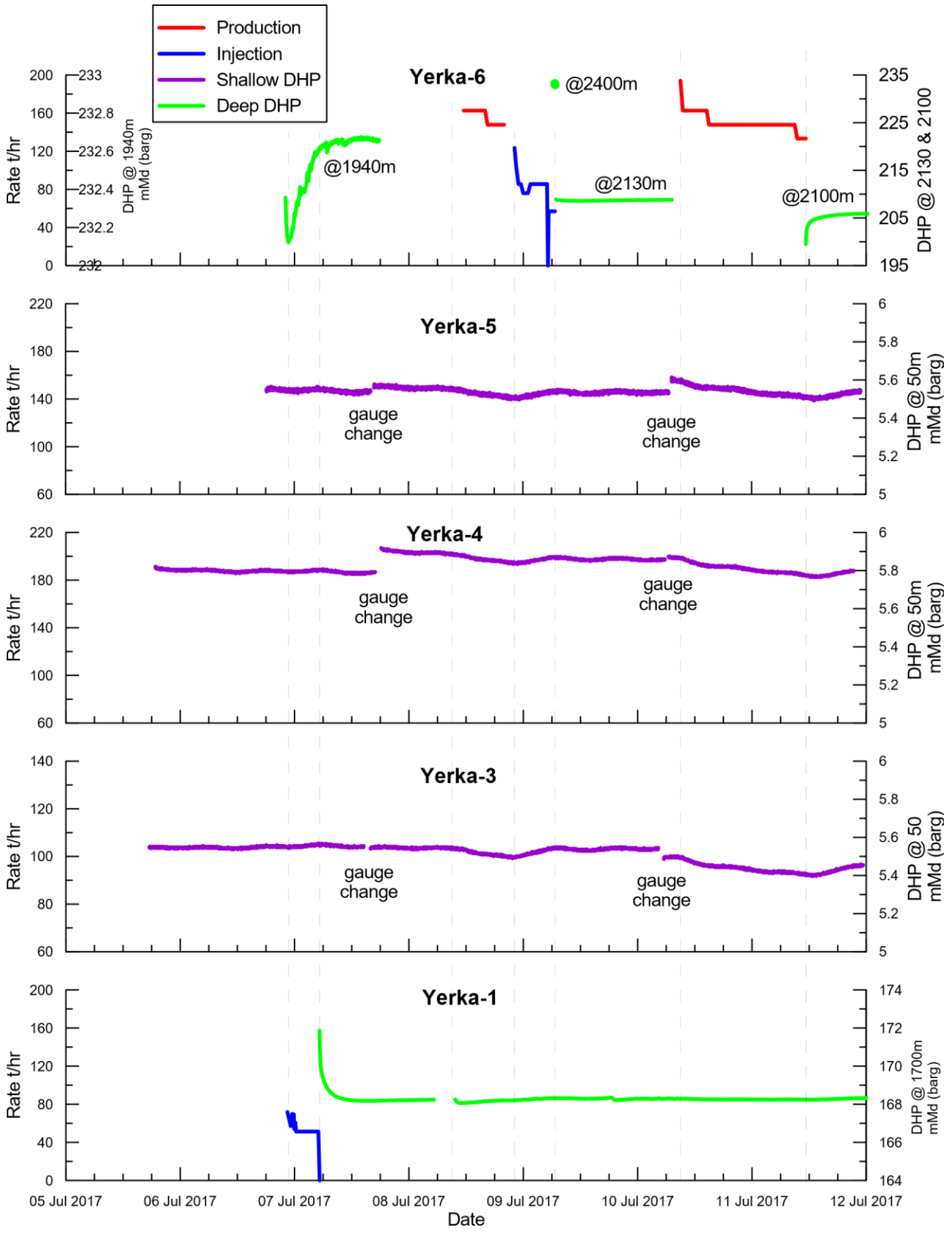

Figure 2: Mt. Ida Interference Test – July 2017.

- Yerka-5: Testing of the well after acid stimulation indicated more than a doubling of the PI value, from 9 to 21 TPH/bar.
- Yerka-6 testing following acid stimulation indicated an improvement from less than 19 TPH/bar to 21 TPH/bar.
- Yerka-7 had a PI value of 19 TPH/bar before acid stimulation. The PI value of Yerka 7 after acid stimulation almost quadrupled, rising to 74 TPH/bar.
- Yerka-8: the II value almost quintupled after acid stimulation, from 4 to 19 TPH/bar.

These results of acid stimulations via CTU indicate that each well treated in the field realized a significant increase in measured well PI/II values, with each well achieving a commercial PI or II value of 19 TPH/bar or better.

5. FLUID CHEMISTRY

The chemistry of produced fluids at Mt. Ida indicates a highly saline composition of (Na+K) >> Ca > Mg for cations and Cl >> $HCO_3 \approx SO_4$ for anions, with a total dissolved solids (TDS) content of up to 54,970 ppm. For comparison, the produced brine of the nearby operating Tuzla field has a TDS of 74,600 ppm, and typical seawater is 34,380 ppm. Calculations of weight percent (wt %) gas expressed as gas / (gas + steam) have indicated total non-condensable gas (NCG) concentrations of 0.51 to 0.59 wt % in total flow, based on analysis of samples solely from the Yerka-3 well (with a gas composition that is comprised of ~99% CO_2). For purposes of comparison, publicly available data indicate that produced fluid in the nearby ENDA Tuzla project contains 0.5 wt % gas (which provides a reasonable basis for comparison to the Mt. Ida project), the Kızıldere R1-A well contains 2.4 to 3.0 wt % gas (99% CO_2), and the Germencik OB-9 well contains 1.6 wt % gas (98% CO_2), with all values indicating gas in total flow (Yıldırım and Yıldırım, 2015).

6. PUMPING BENEFIT

Table 1 shows the anticipated performance of production and injection wells at the Mt. Ida Project under pumped conditions. In this table, production well output is estimated for two cases: a maximum pumped rate at 8-barg wellhead pressure, and an estimated sustainable rate for steady pump performance. The combined flow rates available for these two cases are estimated at 1,900 and 1,500 TPH, respectively. The corresponding estimates of generation are 13.7 and 10.8 MW gross. The MW estimates in this update are indicative values; actual output will depend on the performance characteristics of the plant equipment.

It is noteworthy that pumping power requirements to achieve the desired flow rates for the two cases average 15% and 13% of the estimated MWe for the maximum and the sustainable rates, respectively, for a wellhead pressure (WHP) of 10 barg. To achieve 23-barg WHP (as may be required to maintain a single-phase geofluid and avoid gas breakout), pumping power requirements would increase to 22% and 19% of the estimated MWe for the maximum and sustainable cases, respectively.

7. CONCLUSIONS

Since 2016, Yerka has successfully drilled six deep wells in the Mt. Ida project. Individual well capacities have been markedly improved by acidizing following initial drilling and completion. Well testing indicates that the project has sufficient production and injection capacity for a geothermal plant with an estimated capacity of 12 MW gross. Yerka is now planning for a commercial operation date in the summer of 2020. Yerka will rely on electric submersible pumps (ESPs) to achieve the required flow rates for geofluid production, which would not otherwise be possible without pumping. Results of interference and individual well testing have confirmed that all wells in the Mt. Ida license are hydraulically connected, but the amount of pressure interference between wells is small, indicating good resource suitability for the intended production scenario.

8. ACKNOWLEDGEMENTS

The authors wish to express thanks to Yerka Elektrik Üretim A.Ş. for permission to publish this paper. James Morrow provided valuable assistance in the preparation of the figures.

REFERENCES

Baba, A., Demir, M.M., Koç, G.A., and Tuğcu, C.: Hydrogeological Properties of Hypersaline Geothermal Brine and Application of Inhibiting Siliceous Scale via pH Modification, *Geothermics*, **53**, (2015), 406-412.

Başel, E.D.K., Serpen, U., and Satman, A.: Turkey Geothermal Resource Assessment, *Proceedings*, World Geothermal Congress, Bali, Indonesia, (2010).

Hackett, L., Lovekin, J.W., and Aydın, M.: Exploration and Development of the Mt. Ida Geothermal Project, Çanakkale Province, Western Turkey, *Transactions*, Geothermal Resources Council, **42**, (2018), 881-887.

Yıldırım, N., Yıldırım, A.: High Total Inorganic Carbon Concentration, Dependent Carbonate Scaling and Mitigation System, in Moderate- to High-Enthalpy Geothermal Fields in Turkey, *Proceedings*, World Geothermal Congress, Melbourne, Australia, (2015).