Well engineering and simulation for Non-Condensable Gases Total Reinjection systems

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ABSTRACT

Magma Energy Italia aims to develop several geothermal projects in Tuscany (Italy) using "closed loop" power systems which include the total rejection of geothermal fluids.

Thermo-fluid dynamic modelling and wellbore engineering have been performed in the area of Castelnuovo and South-West Mensano in order to simulate the production and total reinjection in high temperature (>200 °C) and deep (> 3000 m) geothermal reservoir.

Several simulations have been carried out assuming multiple production/reinjection wells drilled from a single rig site adjacent to a small-sized (5-10 MWe) power plant. The reservoir simulations provided the main data for the design of 5 MWe "closed loop" generation capacity and indicated that temperature and NGCs breakthrough to the production wells from the injectors are negligible.

Moreover, OLGA multiphase simulations have been performed to demonstrate the feasibility of total reinjection of geothermal fluid (condensed steam and NCGs) in a single well, using specifically designed equipment.

1. INTRODUCTION

Magma Energy Italia S.r.l., owned by Graziella Green Power, Arezzo (Italy) and Alterra Power Corp., Vancouver (Canada), is involved the development of the following geothermal projects in Tuscany, Italy (fig. 1):

- Mensano (215 km^2) and Roccastrada (272 km^2) exploration leases,
- Castelnuovo (7.5 km^2) pilot project.

Magma Energy Italia will develop these projects by using "closed loop" power systems which include the total rejection of geothermal fluids.

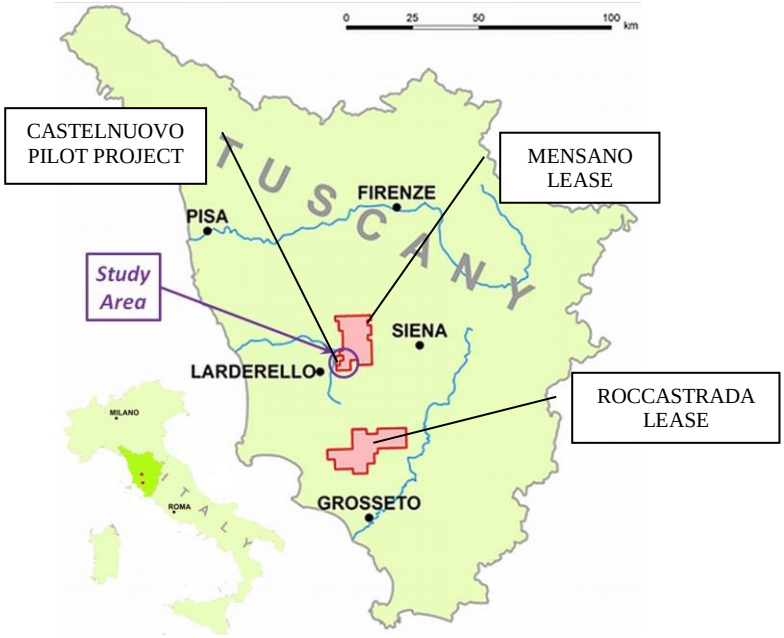

Figure 1: Geographic location of the geothermal projects

The strategy of exploitation includes the total reinjection of the condensed fluids and NCGs back into the reservoir and the installation of small-sized plants (5-10 MWe) each close to a single drilling pad. (fig. 2).

The drilling program will be carried out using directional wells from a single pad in order to reduce land use resulting in less environmental impact from the project.

The power system will be constituted by integrating a binary cycle power unit with a suitable plant infrastructure designed by Magma Energy Italia and GE Oil&Gas Nuovo Pignone (Florence, Italy) (Vaccaro et al., 2016).

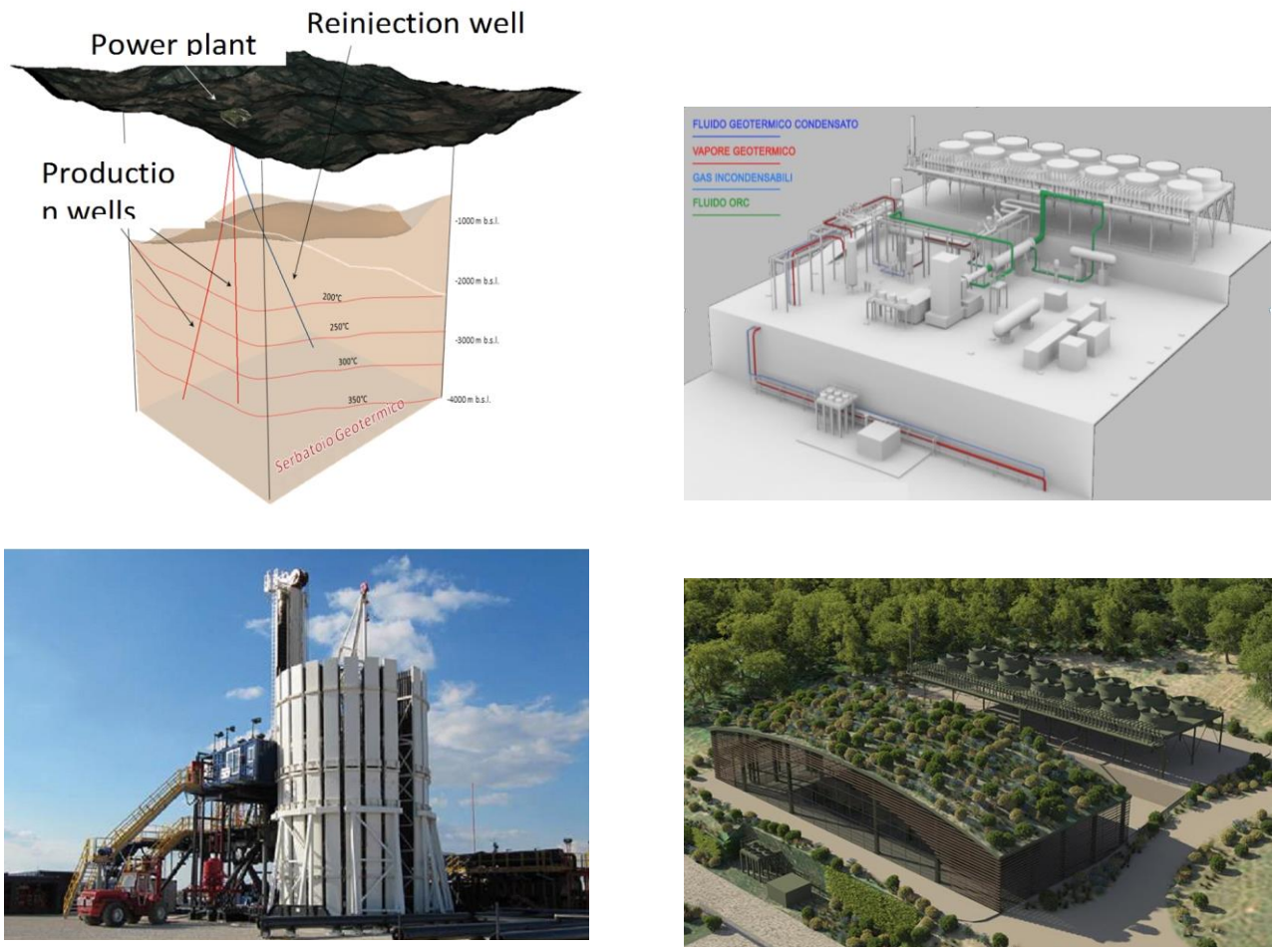

Figure 2: Main features and layout of a "closed loop" geothermal project.

2. OUTLINE OF THE FEASIBILITY STUDY

The area shown in Fig. 3 has been selected to carry out the thermo-fluid dynamic modelling and wellbore engineering to demonstrate the feasibility production and total reinjection in a "closed loop" geothermal project.

The area is located in the northern part of the Larderello-Travale high-enthalpy geothermal field and adjacent to the "Sesta" well-field operated by Enel Green Power . The presence of high-enthalpy fluids in the Larderello-Travale fields is well known within the deep reservoir (about 2.5-4 km) in the metamorphic core complex, consisting mainly of Phyllites and Micaschists in which a few granitic intrusions and related Hornfels were found. In the study area the temperature and the pressure in the reservoir ranges from about 220°C to 320°C and from about 50bars to 70bars (Barelli et al., 2000).

Many seismic reflection data highlighted the existence of anomalous reflections (known as "H" marker) often correlated with productive fractures (Bertini et al., 2005).

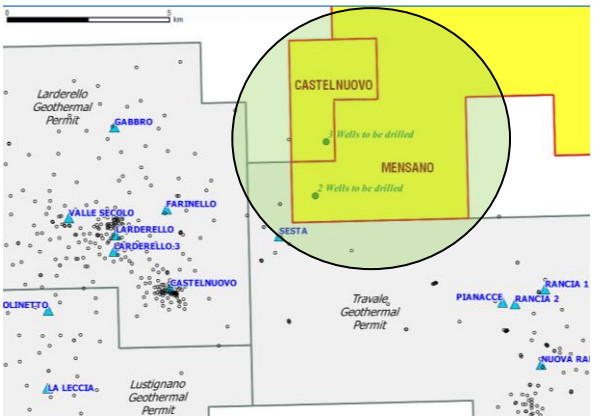

Figure 3: Location of the area (green circle) selected for thermo-fluid dynamic modelling

Moreover, extensive geostructural and geophysical surveys (Magnetotelluric, Gravity, Magnetic) have been executed by Magma Energy Italia, in partnership with the Universities of Siena and Bari and through WesternGeco-Schlumberger, allowing the development of a geothermal reservoir model (fig. 4).

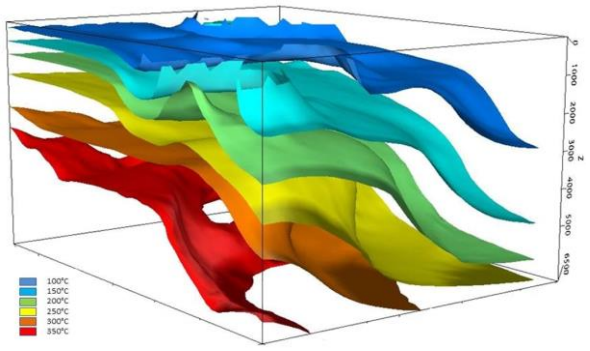

Figure 4 : Temperature model of the study area.

3. RESERVOIR MODELLING

A numerical model has been developed for the local reservoir. A double-porosity model was successfully calibrated by trial-and-error against the interpreted temperature distribution and the static temperature profile from wells, to achieve an initial-state model that adequately represent the geothermal reservoir in its natural state, and therefore is suitable for forecasting reservoir behaviour during exploitation.

Various productions and injection schemes have been simulated, constrained by the minimum requirement of 200°C and 15bars at the wellheads. The results of the forecasts indicate that the reservoir is able to sustain a total steam production rate of 140 t/h over a period of 30 years, without adversely affecting the production assumed at the Sesta wells.

The reservoir model developed has been used to forecast the production operations, with particular focus on the total reinjection of the fluids. The reinjection strategy provides that the CO_2 and all the Non-Condensable Gases extracted from the reservoir will be reinjected along with the liquid phase (condensed steam).

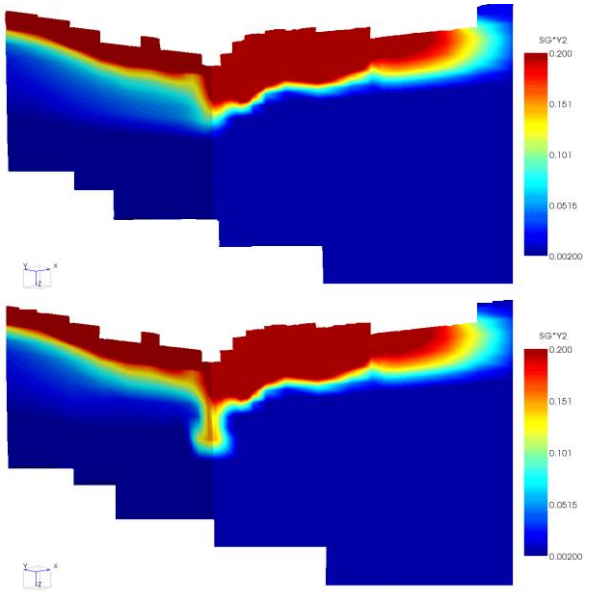

Figure 5: CO_2 concentration in the initial and final state

The evaluated production-injection configuration is predicted to result in minimal pressure support and minimal – almost negligible – temperature and CO_2 breakthrough from the injection wells to the production wells. (Fig. 5)

4. GAS/LIQUID INJECTION IN SINGLE WELL

Several simulations and sensitivity analyses of the gas and liquid (condensed steam) in a single reinjection well have been carried out by Schlumberger, using the OLGA simulation software. OLGA is a general transient multi-phase simulator used in oil industry to model multi-phase flow in pipes and wellbores (for further reference, see Aziz I. et al., 2015).

The primary variable investigated was the depth at which the non-condensable gas (NCG) could be injected into the down flowing brine stream. The depths investigated ranged from 0 to 1250 m (MD).

The secondary variable investigated was the injectivity of the fractures (e.g., data in Barelli et al., 2000; Batini et al., 2002), in order to understand what impact the injectivity would have upon selecting the proper NCG injection depth.

The modelling allowed to successfully verify the feasibility of the approach and derive the optimum gas reinjection depth to minimize the injection pressure. (Fig. 6)

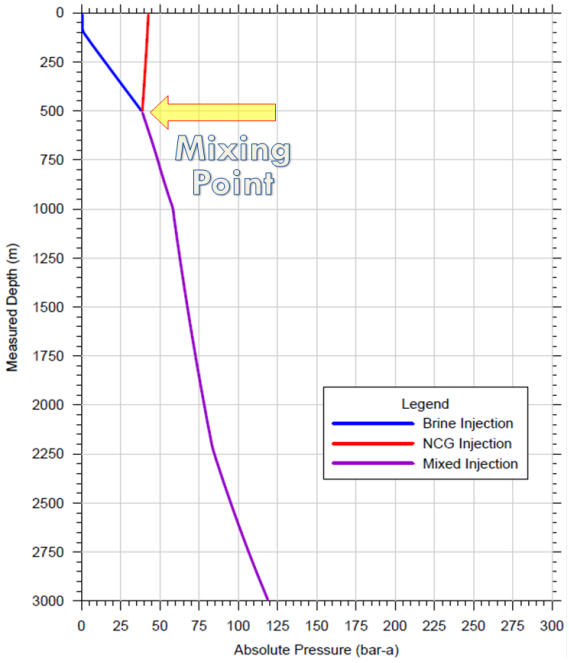

Figure 6 OLGA simulated pressure profiles for brine and NCG, for mixing at 500 m in case of injectivity of 1.8 t/h/bar.

The simulations indicate that the NCG-water mixture can be injected under all conditions examined. The optimal depth of reinjection is between 300 and 500 m (Stacey et al., 2016), allowing to inject the brine at atmospheric pressure at wellhead, even in case of low injectivity, and requiring just about 35-40 bar at

wellhead to inject the gas in the descending liquid flow.

To operate the reinjection of a NCG-water mixture, a single-well injection system was designed (fig. 7), consisting of two different coaxial pipes inserted into the well up to the required NCG injection mixing depth.

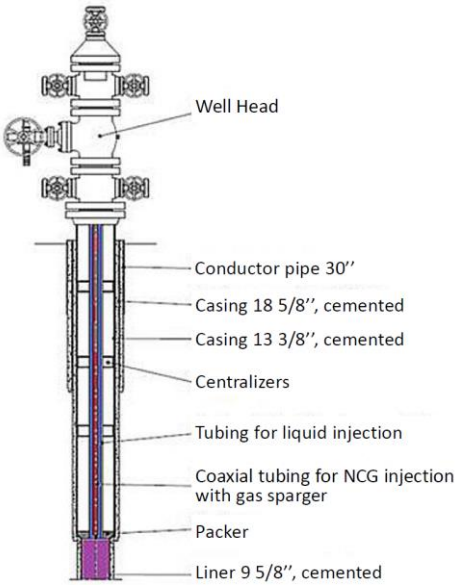

Figure 7: Bore hole gas/liquid injection system.

5. CONCLUSIONS

Thermo-fluid dynamic modelling and simulations of the gas/liquid injection in a single well have been performed in high temperature (>200 °C) and deep (> 3000 m) geothermal reservoir in order to evaluate the viability of 5 MWe "closed loop" generation power plant.

The main achievements demonstrate:

- the feasibility of total reinjection of geothermal fluid (condensed steam and NCGs) in a single well, using specifically designed equipment.
- the optimal depth to inject the gas in the descending liquid flow is between 300 and 500 m
- even in case of low injectivity, and requiring just about 35-40 bar at wellhead allowing to inject the brine at atmospheric pressure at wellhead
- NGCs breakthrough to the production wells from the injectors are negligible when the spacing among production and reinjection well is properly estimated.

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