High Efficiency-based Geothermal Probe

L. Blois[1], C.A. Blois[2], M. Caponi[2], A. Lay-Ekuakille[3], R. Velázquez[4]
[1]Dept of Sustainability Engineering, Guglielmo Marconi University, 00193 Roma, Italy
[2]IRIDE Srl, 06135 Perugia, Italy
[3]Dept. of Innovation Engineering, University of Salento, 73100 Lecce, Italy
[4]Facultad de Ingeniería, Universidad Panamericana, 20290 Aguascalientes, Mexico
lublois@hotmail.it

***Abstract*—Vertical geothermal exchangers (geothermal probes) are very complex, especially in presence of diverse and possible lithotypes which values of thermal conductivity expressed in W/mk, are necessary for the determination of thermal resistance; they also influence the design of the thermal probe. One the simplified methods to design thermal probes is based on its capability to interact with lithostratigraphy that permits to know the thermal conductivity. The efficiency of the thermal probe is highly related to the nature of the filling fluid because it steers the thermal exchange with the soil under test. That is why it is important to study and formulate ad hoc mixture.**

***Index Terms* - Geothermal probe, renewable energies, pollution reduction, environmental protection**

I. Introduction

Geothermal energy is a renewable source of an important form of energy, coming from subsoil [1]. To use it, it is necessary to design geothermal vertical exchangers (geothermal probes) even if it is very complex to design them because of the presence of multiple possible lithotypes, which values of thermal conductivity in W/mk, necessary for the calculation of the thermal resistance, influence, in a certain way, their dimensions. Current experience has shown that a simplified method to design thermal exchangers depends upon a limited number of plants for commercial usages, regardless to information related to the long term effects of energy interaction with subsoil that provokes variations of the level of aquifers [2], and potentially on the surfaces of the thermal exchange. An important element is the study of fluid mixtures for filling so that we can increase the thermal exchange of the neighboring terrain. The characterization of the lithostratigraphy allows to find necessary thermal conductivity values for calculating the thermal resistance between the geothermal probe and the surrounding terrain, specifically, single values are averaged to obtain the value of averaged thermal conductivity of the terrain.

The lithostratigraphic characterization [3] [4] of the terrain can be, initially, carried out by means of geoelectrical prospection and geological surveys to obtain significant parameters for study and energy optimization of geothermal probe.

The extraction and utilization of this large quantity of heat requires a carrier to transfer the heat toward accessible depths beneath the Earth’s surface. Generally the heat is transferred from depth to sub-surface regions firstly by conduction and then by convection, with geothermal fluids acting as the carrier in this case. These fluids are essentially rainwater [5] that has penetrated into the Earth’s crust from the recharge areas, has been heated on contact with the hot rocks, and has accumulated in aquifers, occasionally at high pressures and temperatures (up to above 300°C). These aquifers (reservoirs) are the essential parts of most geothermal fields. In most cases the reservoir is covered with impermeable rocks that prevent the hot fluids from easily reaching the surface and keep them under pressure. We can obtain industrial production of superheated steam or steam mixed with water, or hot water only, depending on the hydrogeological situation and the temperature of the rocks present (Fig. 1) [6].

Wells are drilled into the reservoir to extract the hot fluids, and their use depends on the temperature and pressure of the fluids: generation of electricity (the most important of the so-called high-temperature uses), or for space heating and industrial processes (low-temperature uses).

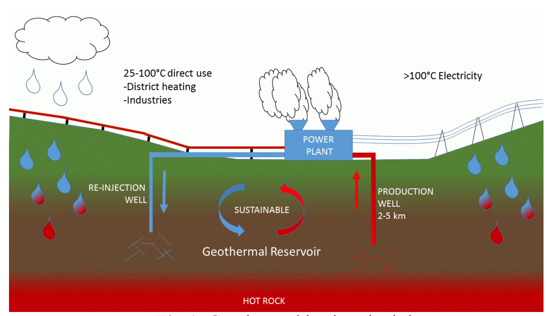

Fig.1. Geothermal basic principles.

Geothermal fields, as opposed to hydrocarbon fields, are generally systems with a continuous circulation of heat and fluid, where fluid enters the reservoir from the recharge zones and leaves through discharge areas (hot springs, wells). During industrial exploitation fluids are recharged to the reservoir by reinjecting through wells the waste fluids from the utilization plants. This reinjection process may compensate for at least part of the fluid extracted by production, and will to a certain limit prolong the commercial lifetime of the field. Geothermal energy is therefore to some extent a renewable energy source, hot fluid production rates tend however to be much larger than recharge rates. The growing awareness and popularity of geothermal (ground source) heat pumps have had

978-92-990075-8-7

the most significant impact on direct-use of geothermal energy. The annual energy use for these units grew 2.29 times at a compound annual rate of 18.0% compared to WGC2005 [7]. The installed capacity grew 2.15 times at a compound annual rate of 16.6%. This is due to better reporting and to the ability of geothermal heat pumps to utilize groundwater or ground-coupled temperatures anywhere in the world. The five countries with the largest installed capacity are: USA, China, Sweden, Germany and Japan accounting for 63% of the world capacity, and the five countries with the largest annual energy use are: China, USA, Sweden, Turkey, and Japan, accounting for 55% of the world use. Japan and Germany are new members of the "top five" as compared to WGC2005. However, an examination of the data in terms of land area or population shows that the smaller countries dominate, especially the Nordic ones. The "top five" then become for installed capacity: (MW/population) Iceland, Sweden, Norway, Finland, and Switzerland; (MW/area) Netherlands, Switzerland, Iceland, Sweden and Hungary; for annual energy use: (TJ/yr/population) Iceland, Sweden, Norway, New Zealand, Denmark and Finland; (TJ/yr/area) Netherlands, Iceland, Switzerland, Hungary and Sweden.

For an infinitesimally small heating spot and a constant velocity, the temperature rise of homogeneous bodies shortly after heating is reciprocal to their thermal conductivity. The influence of the volumetric heat capacity of the material is theoretically zero and is negligible in the experimental set-up. For determination of thermal conductivity, the temperature before and after heating is measured by optical sensors. The thermal conductivity of the specimen is calculated based on Popov et al. [8]:

$$\lambda_{test} = \lambda_{ref} \frac{\Delta T_{ref}}{\Delta T_{test}} \tag{1}$$

where λ_{test} is the thermal conductivity of the specimen, λ_{ref} the thermal conductivity of the standard, ΔT_{ref} is the temperature rise of the standard and ΔT_{test} is the temperature rise of the specimen. It is worthy to understand that geothermal process has something similar to thermoelectric generator [9] that is a transformation of heat by means of Seebeck effects. Thermoelectric cells work on the principle of Seebeck effect and their efficiency Z is determined by the following expression

$$Z = \alpha^2 \frac{\sigma}{k_{tot}} \tag{2}$$

where α and σ are the Seebeck coefficient and electrical conductivity, respectively, while k_{tot} is the total thermal conductivity, which is equal to sum of the electron (k_{el}) and phonon (k_{ph}) thermal conductivities. The increase in efficiency of thermoelectric generators depends, first of all on decrease in phonon thermal conductivity (k_{ph}). Eq.(2) can be also reported in terms of temperature so that it can display the almost representation as Eq.(1). Some additional considerations regarding the location where to extract geothermal energy. The location must not be contaminated [10] [11] in terms of soil, subsoil and aquifers. That is to avoid extracting thermal energy along with pollution [12]. Fig.2, instead, illustrates an example of a house with a nearly zero energy building (NZEB) criterion [13]. It is a private house constructed with a supervision of the co-author of this paper, faculty member of the University of Salento, Department of Innovation Engineering. As it is possible to see by the arrow, the house, under construction, located in province of Lecce, takes geothermal energy from the subsoil for a thermal equilibrium.

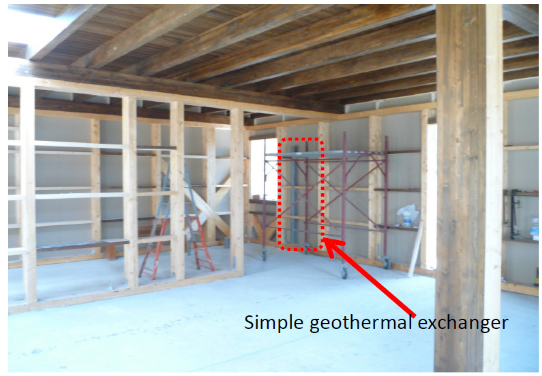

Fig.2. Simple geothermal exchanger in a house under construction.

NZEB is a great objective because it allows lowering the energy necessary for the building. For the case of Fig.2, the building is mostly in XLAM technology [14], and there is no conventional heating system since energy is based on geothermal, photovoltaic, and solar panels for hot water. Fig.3 shows a plot illustrating a diagram of different request and production of energy, and how it is possible to reach NZEB conditions.

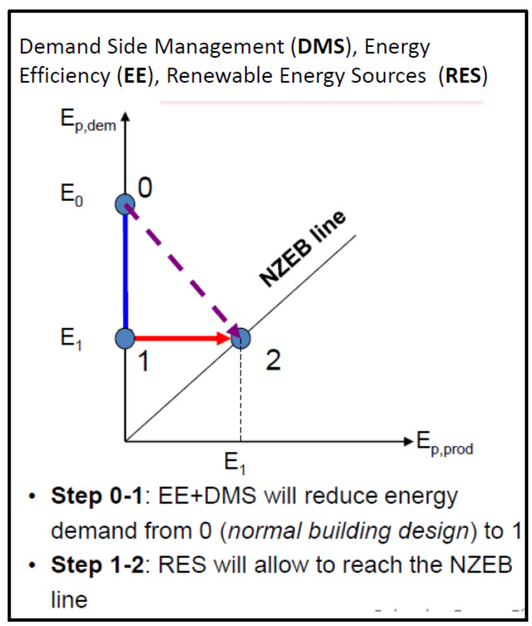

Fig.3. Energy balance for reaching Nearly Zero Energy Building.

II. PROPOSED GEOTHERMAL PROBE

The analysis of the thermo-conductive material is very essential to obtain a mixture of high thermal exchange. The studied thermo-conductive material is a mixture that includes a thermo-conductive material and a thermo-conductive liquid. In particular, the solid material is in a granular shape, with granulometry ranging from 0.02 mm and 8 mm, and it is chosen among sand of conductive rock, basaltic rock, granitic sand or metallic sand or others with the same characteristics, see Fig.4. Instead, the thermo-conductive liquid is chosen between water or mixtures in variable percentages of water and thermo-conductive liquids. Components of the mixture of thermo-conductive material are in a concentration greater than 20% of thermo-conductive liquid, preferably up to the saturation of solid conductive material. In fact, once the hole is filled with sand, it is possible to fill the thermo-conductive liquid within it until its complete filling, see Fig.5.

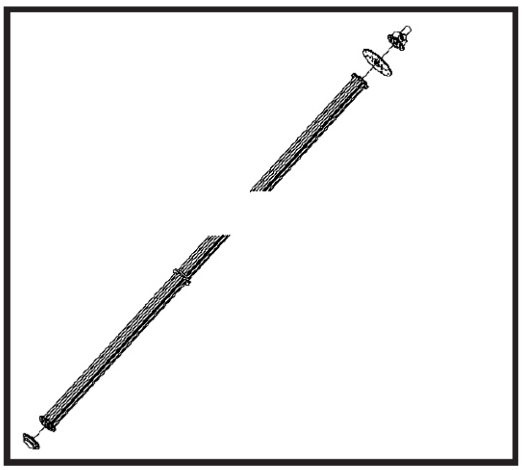

Fig.4.Overall displaying of the proposed geothermal probe

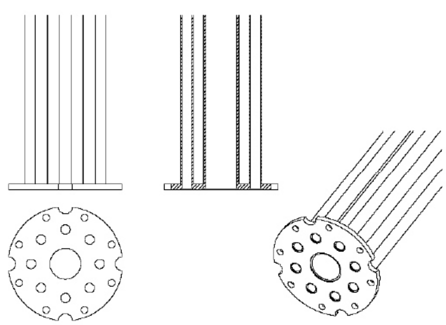

Fig.5. Partial illustrations of the proposed geothermal probe.

In the event of thermo-conductive material in liquid composition, this can be chosen between water and ethylene glycol. In the case of probe realized in non rocky terrain, then not stable, it is possible to include an external coat that includes, in its inner area, a pipe of flow and a return one, partially filled with the above thermo-conductive material.

III. RESULTS AND FINAL COMMENTS

The modeling and the realization of the geothermal probe, in a preliminary way, are subject to simulation before using it on the field. The simulations take inspiration from the field of biomedical, trying to detect "bubbles" within the flow [15]. For some geothermal probes it is possible to include an array of sensors for allowing to regulate and to control the flow in all areas internal to the probe. Beamforming is an interesting topic for that [16] and the collected signals must be further processed [17]. Fig. 6 and Fig.7 detail the flow conditions within the probe respectively. The type of flow has a specific influence in the geothermal exchangers.

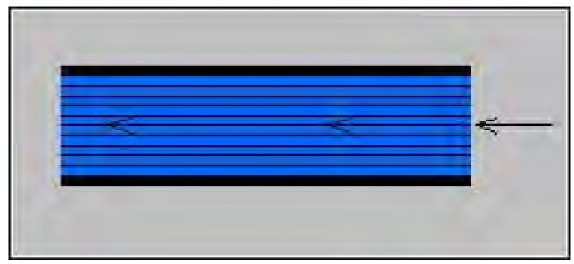

Fig.6. Trend of strata during laminar flow within the probe.

Fig.7. Trend of strata during turbulent flow within the probe.

REFERENCES

[1] A. Leombruni, L. Blois, M. Mancini, "First evaluation of soil erosion and sediment delivery in the high part of the Tevere watershed", Electronic Journal of Geotechnical Engineering, Vol. 14, pp.1-26, 2009.

[2] L. Blois, "Geological Engineering investigations in situ and Geotechnical Engineering solutions to support the realization of the third lot of the Water Treatment Plant in Calabar, Nigeria", Electronic Journal of Geotechnical Engineering, Vol. 13 J, 2008.

[3] E. Kiseleva, V. Mikhailov, E. Smolyaninova, P. Dmitriev, V. Golubev, E. Timoshkinaa, A. Hooperb, S. Samiei-Esfahanyc, R. Hanssen, " PS-InSAR monitoring of landslide activity in the Black Sea coast of the Caucasus ", Procedia Technology, Vol. 16, pp. 404 – 413, 2014.

[4] L. Blois, P. Berry, "Measurements to characterize discontinuities of quarry faces of chalk "Monte Tondo" in Riolo Terme (Italy) through terrestrial 3d laser scanning method and to

compare them at survey techniques data traditional", Electronic Journal of Geotechnical Engineering, Vol. 13 H, 2008.
[5] L. Blois, "Coastal erosion studies on the Capo Colonna cliff, Italy", Proceedings of Institution of Civil Engineers, Vol. 161, n.3, pp.117-141, 2008.
[6] http://arcticgreencorp.com/geothermal-energy/
[7] Proceedings of the World Geothermal Congress 2005 (WGC 2005), April 2005, Turkey.
[8] Y. A. Popov, V.G. Semenov, V.M. Korostelev, V.V. Berezin, "Non contact evaluation of thermal conductivity of rocks with the aid of a mobile heat source", Earth Phys. Vol.19, n.7, 563–567, 1983.
[9] A. Lay-Ekuakille, G. Vendramin, A. Trotta, G. Mazzotta, "Thermoelectric generator design based on power from body heat for biomedical autonomous devices. IEEE MeMea 2009, May, Cetraro, Cosenza (Italy), 2009.
[10] V. Pelillo, L. Piper, A. Lay-Ekuakille, A. Lanzolla, G. Andria, R. Morello, "Geostatistical Approach for Validating Contaminated Soil Measurements", Measurement, Vol. 47, n. 1, pp. 1016-1023, 2014.
[11] A. Lay-Ekuakille, A. Trotta, "Predicting VOC Concentration Measurements: Cognitive Approach for Sensor Networks", IEEE Sensors Journal, vol.11, issue 11, pp.3023-3030, 2011.
[12] A. Lay-Ekuakille, I. Palamara, D. Caratelli, F.C. Morabito, "Experimental Infrared Measurements for Hydrocarbon Pollutant Determination in Subterranean Waters", Review of Scientific Instruments, Vol. 84, pp. 015103-1 (8 pages) 2013.
[13] EU Directive 2010/31.
[14] http://www.xlamdolomiti.it/a_ENG_1_1.html
[15] S. Casciaro, F. Conversano, L. Massoptier, R. Franchini, E. Casciaro, A. Lay-Ekuakille, "A Quantitative and Automatic Echographic Method for Real-Time Localization of Endovascular Devices", IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, Vol. 58, n.10, pp. 2107-17, 2011.
[16] A. Lay-Ekuakille, P. Vergallo, D. Saracino, A. Trotta, "Optimizing and Post Processing of a Smart Beamformer for Obstacle Retrieval", IEEE Sensors Journal, vol.12, issue 5, pp.1294-1299, 2012.
[17] G.V.S. Karthik, Sk. Yasmin Fathima, Muhammad Zia Ur Rahman, Sk.Rafi Ahamed, A. Lay-Ekuakille, (2013) Efficient Signal Conditioning techniques for Brain activity in Remote Health Monitoring Network, IEEE Sensors Journal, vol.13, n.9, pp.3276 – 3283, 2013.