RJBS
Romanian Journal of Building Services
Revista Română de Instalații
Volume 1 / No. 3 / 2015 / www.rjbs.ro

Calculation methods for geothermal heat exchangers with special geometry

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Abstract: *The paper presents the algorithm for calculating the size cylindrical spiral type exchangers, used for the cold source systems installations equipped with heat pumps.*
Common types of geothermal exchanger both the surface and the depth is characterized by uneven soil application. Uniform thermal load of the massive earth energy may be the solution in the sense of optimizing storage capacity and therefore reduced surface / volume of land used.

Key words : *geo exchangers cylindrical spiral , compact geometry, calculation methods*

1. Introduction

Geo exchangers cylindrical spiral heat of a solution are rarely used for making cold sources of low and medium depth in heat pump systems.

Compact geometry and the use of high thermal conductivity material: stainless steel pipe, brass or copper Provides the heat transfer system capacity superior to conventional solutions which are used in usual plastic pipes (polyethylene).

Possibility of manufacture to the desired dimensions and mounting in drilling wells with higher diameters (deep wells), geothermal provides an additional advantage to the wells to the surface and deep geothermal wells.

2. Paper content

Designed modular with elements connected in series or in parallel, offers the possibility of reducing the amount of land required and adapt to the available ground conditions.

Dimensioning of this type of heat exchange with the ground can be achieved by adjusting the ‘‘linear source model’’, according to the algorithm shown below.

Knowing the heat load calculation, functional parameters of the heat pump, water flow heat transfer and temperature input / output thereof, may enteritis required length exchanger that heat the parameters Geothermal forced diameter and up the spiral and the diameter pipes used.

Given the possibility of mounting the modules to an average depth of the source and isolation from the external environment can accept the application of the general equation of heat transfer in steady state, considering the constant ground temperature corresponding to the respective operating conditions 10-150 C under a 15-250C conditioning and heating regime.

The calculation is performed considering the semi-circular elements made up of modules connected in series, and the temperature of the fluid to enter in one module is equal exit temperature to the previous item.

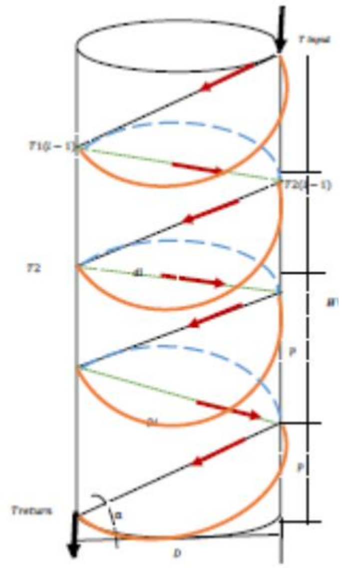

Figure 1. Geo spiral heat exchanger cylinder

Knowing the total load ($Q_{\text{useful flow}}$), Work flow agent (G), and T temperatures: T_{input}, T_{return}, can be determined: diameter pipes for a setpoint speed (v) is:

$$d_{int} = \left(\frac{G}{0{,}785\, v}\right)^{1/2} \qquad (1)$$

- The total length of the spiral is the result of balance equation :

$$Q_{useful} = k(\bar{T} - \theta)\,(\pi d_{out})L \qquad (2)$$

$$L = \frac{Q_{use}}{\pi k d_{out}(\bar{T} - \theta)} \qquad (3)$$

Where: $\bar{T} = \frac{T_{imput} - T_{return}}{2}$ and $k = \frac{1}{\frac{1}{\pi\,\alpha\,d_{int}} + \frac{1}{2\pi\lambda} ln\frac{d_{int}}{d_{out}} + \frac{1}{\alpha^*}}$ (4)

If adopted geothermal main parameters:

- D - diameter of the cylinder generator
- H - the final height of the heat exchanger and
- p - step spiral

It can cause:

- the number of modules semicircular: n
- Module diameter Di
- the length of a single module Li
- starting angle α

n = $\frac{H}{p}$ = number of modules, (5)

$D_i = \sqrt{D^2 + p^2}$ - module diameter (6)

$L_i = \frac{1}{2}\pi D_i$ - the length of a single module (7)

$tg\alpha = \frac{p}{D}$ (8)

As a result of the fact that the modules are connected in series , the inlet temperature in a modul(T_1i) is equal to the output of the previous module temperature ($T_{2\ (i-1)}$).

$T_1i = T_{2(i-1)}$ (9)

The evolution of the temperatures along the way can be determined from the differential equation for heat transfer :

$G(\rho\cdot c)dt = k\ (T - \theta)ds$, cu $ds = \pi d_{out}\cdot dL$ (10)

Substituting and separating the resulting variables:

$$-\frac{dT}{(T-\theta)} = \frac{K}{G\rho C\pi d_{out}}\,dL \qquad (11)$$

It integrates the limits T_{1i}, T_{2i}, and 0, $\frac{\pi D_i}{2}$.

$$-\int_{T1i}^{T2i}\frac{dT}{T-\theta} = A\int_0^{\frac{\pi D_i}{2}} dL \quad \text{with } A = \frac{k}{G(\rho c)\pi d_{out}} \qquad (12)$$

By changing the limits of integration in the left- result:

$$\ln\frac{T1i-\theta}{T2i-\theta} = \frac{\pi D_i A}{2} \qquad (13)$$

Where: $$T2i = \theta + \frac{T1i-\theta}{e^{\frac{\pi D_i A}{2}}} \qquad (14)$$

Heat flow effectively ceded / received by each module / element has value:

$q'_{i\ efectiv} = k_i(\overline{T_i} - \theta)s_i$, with s_i=(πd_{out}) ($\pi \frac{D1}{2}$) = $\frac{\pi^2}{2} d_{out} D_i$ (15)

Where : $\overline{T_i}$ = $\frac{1}{2}$ (T1i – T2i) (16)

It follows the final form:

$$q'_{i\ efectiv} = \frac{\pi^2 d_{ext} D_i}{2}\ k\left[\left(\frac{\text{T1i+T2i}}{2}\right) - \theta\right] \quad (17)$$

In previous relationships , global transfer coefficient is determined by the relationship:

$$K= \frac{1}{\frac{1}{\pi\alpha d_{\ out}} + \frac{1}{2\pi\lambda} ln\frac{d_{int}}{d_{out}} + \frac{1}{\alpha^*}} \quad (18)$$

$$d_{out} = d_{int} + 2e \quad (19)$$

Where : $\alpha = \frac{4\lambda}{d_{i\ int}} Nu,\quad with\ Nu = 0{,}664 Re^{1/2} Pr^{1/3}$, (20)

$$\text{Re} = \frac{v d_{int}}{4\vartheta},\ \text{Pr} = \frac{\vartheta}{\rho c},\ v = \frac{G}{0{,}785 d_{int}^2} \quad (21)$$

Specifying the above value, resulting:

$$\alpha_i = \frac{4\lambda}{d_{i\ int}} * 0{,}664\left(\frac{G}{\pi\vartheta d_{i\ int}}\right)^{1/2} * \left(\frac{\vartheta}{\delta c}\right)^{1/3} \quad (22)$$

and $\alpha^* = \frac{1}{\rho_{granules}}\left(0{,}06\frac{2\lambda \cdot \lambda_{ground}}{\lambda + \lambda_{ground}} + 0{,}94\lambda_{air}\right) \cong \left(0{,}12\frac{2\lambda \cdot \lambda_{ground}}{\lambda + \lambda_{ground}} + 0{,}024\right)10^3$ (23)

Calculated step by step, starting with inlet temperature equal to the temperature element first year out of the previous element (temperature of the working fluid):

$$T_{11} = T_{imp} \quad (24)$$

Finally, check the actual heat flux:

$$Q_{\ actually} = \sum_{I=1}^{n} q'_{actually} \geq Q_{useful} \quad (25)$$

3. Conclusions

Possibility of manufacture to the desired dimensions and mounting in drilling wells with higher diameters (deep wells), geothermal provides an additional advantage to the wells to the surface and deep geothermal wells.

Designed modular with elements connected in series or in parallel, offers the possibility of reducing the amount of land required and adapt to the available ground conditions.

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