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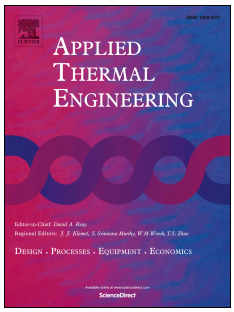

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HEAT TRANSFER IN HORIZONTAL GROUND HEAT EXCHANGERS

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Abstract: The mathematical model of a horizontal ground heat exchanger was presented. The model was based on a one-dimensional equation of the transient heat conduction with an internal source of heat. The model was correctly verified by comparison of computational results and experimental measurements presented in literature. Temporal changes of the ground surface temperature and rates of heat transferred from the ground to the working fluid and between the ground surface and the environment were determined. Moreover, temporal variations of the average temperature of the subsurface layer of the ground were determined. It was found that after about 10 years of operation, the ground temperature reaches a cyclic steady state. Thermal calculations concerning the ground under natural conditions were also presented.

1. Introduction

The heat contained in the ground can be utilized by using a working fluid circulation between the lower heat exchanger arranged in the ground and the upper exchanger, which is a part of a heat pump. During the heating season in the lower heat exchanger working fluid takes heat from the ground and transfers it to the boiling thermodynamic medium in the heat pump. The exchanger is turned off when the fluid temperature decreases excessively, and there is a risk that further extraction of heat will cause frost penetration near the exchanger pipes.

In parallel with transfer of heat to/from the working fluid, the ground receives/gives heat from/to the environment. The direction of heat transfer between the ground and the environment depends on the relationship between ambient temperature and the temperature of the surface of the ground. In order to characterize these relationships, semi-annual periods: warmer and colder were considered. In natural conditions (no heat exchanger installed in the ground), the amount of heat received by the ground from the environment during the warmer half of the year is equal to the amount of heat lost during the colder half of the year. This causes that the average temperature of the ground in a concerned area does not change over the years. When a ground heat exchanger is installed, the temperature averaged over the volume of the sub-surface layer of the ground changes in subsequent years because the amount of heat received by the heat pump from the ground in the heating season is not generally compensated by the amount of heat supplied to the ground during the next half of the year.

Vertical and horizontal ground heat exchangers are used. Vertical exchangers require to make deep holes in the ground while horizontal exchangers are installed in shallow subsurface layers but they need large surface of the ground. Modeling and design of both types of ground exchangers are based on different calculation relationships. Numerical simulation of a vertical ground heat exchanger is presented e.g. in the paper [13]. Benli [2] presented a comparison of both types of ground exchangers.

Horizontal ground heat exchangers have been widely used in many countries as a heat source for ground-source heat pump systems. Therefore, ground heat exchangers are the subject of many studies that are both experimental as well as numerical. An overview of the