Title of the doctoral dissertation:
Modelling a heat accumulator with dynamic discharge as an energy source in an electric-water heating system for a building

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Dissertation abstract

Jarosław Tokarczyk, M.Sc., constructed a test facility for investigating a hybrid central heating system for a building, in which a heat accumulator with ceramic filling is the main unit. Jarosław Tokarczyk, M.Sc., and Prof. Dawid Taler patented the construction of the investigated heat accumulator.

The accumulator is heated during the night with cheap electric energy using resistance heaters. During the day, the accumulator is discharged. The heat flow rate received by the air from the ceramic filling and the steel construction inside the heat storage unit is controlled by the adjusting velocity of the air. Due to the perfect insulation of its outer surface, the accumulator does not give off any heat to the environment. The heated air transfers heat in the air/water heat exchanger to the circulating water in the central heating system. The heat accumulator together with the fan and the water-to-air heat exchanger can be installed in a separate room (boiler room) in order to eliminate the noise generated by the air fan from the living areas. The proposed building heating system is modern and has a good chance of being put into practice as it makes it possible to eliminate gas, oil, coal or biomass-fired central heating boilers used as a heat source in domestic central heating systems. Hybrid water-electric heating systems, when used on a larger scale, can be used to balance electricity demand throughout the day. During the night they are powered by cheap electricity, which is in excess, and during the day they are not powered by electricity except for the energy consumed by the air fan and pump in the central heating system.

The author of the thesis took an active part in the construction of a test stand for flow-thermal tests of a hybrid system used for central heating of a building. The test stand is equipped with a computer data acquisition system enabling continuous measurement of the flow and thermal parameters of the air and filling.

The thesis presents a mathematical model of a heat accumulator for numerical simulation of its discharge, i.e. cooling of the filling. It should be added that the filling of the accumulator has a complex structure. Air flows in parallel inside tubes in which ceramic cylinders are arranged. The air flows in parallel inside the tubes in which the ceramic cylinders are arranged in an orderly manner and

through the space between the tubes. The partial differential equations describing the temperature of the filling and air were solved using two methods: the explicit finite difference method and the Crank-Nicholson method. The latter method allows calculations with a larger time step compared to the explicit finite difference method.

A new heat transfer correlation is proposed for the calculation of the average heat transfer coefficient as a function of the mass flow rate.

The calculation results using the proposed model are compared with the measurement results. Because of the assumption that ceramic cylinders are elements with concentrated heat capacity, a lower conformity of the measurement results and calculations at the beginning of the accumulator cooling process is observed.

The mathematical model of the heat accumulator presented in the dissertation makes it possible to determine its cooling time from the initial temperature to the set final temperature. Using the developed mathematical model of the accumulator, it is possible to select the mass of its filling so as to ensure correct heating of the building throughout the day.

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