DESIGN OF THE THERMAL MANAGEMENT SYSTEMS FOR SODIUM–SULPHUR TRACTION BATTERIES USING BATTERY MODELS

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Sodium–sulphur batteries have an operating temperature between 300 and 370 °C. Therefore, the thermal management system (tms) must be able to heat the battery to these temperatures and maintain an even temperature profile under all operating conditions. The max. temperature differences within the cell matrix should not exceed 25 K horizontally and 20 K vertically.

The tms of B06 and B11 type NaS batteries consist of a vacuum insulation battery box, electrical heater plates, a direct cooling system and related electronic control systems.

To date it has been difficult to develop tms without experimental battery models or to fit a tms to a specific battery type for the following reasons:

(i) Pressure losses and heat transport processes within the front-plate cannot be calculated without unreasonable effort (geometry too complex).

(ii) There are no Nusselt-numbers known which are related to the specific geometry and flow conditions of the batteries.

(iii) The numbers of variables which are concerned with cell design, cell matrix, and dependencies of state charge and temperature are too numerous to be described in a simplified mathematical model.

To overcome these difficulties experimentally, two different battery models are used, the so-called 'cold model' for fluid dynamic problems, and a 1:1 hot model, which is identical with the real NaS battery except for the cells. The cells are simulated by electrically heated dummies. The hot model includes a separate, free programmable control system for the heater plates and the cooling fans, with which it is possible to test the control parameters.

The problems to be solved with the 'cold model' are:

(i) Design of the frontplate with regard to minimal pressure losses and minimal influence on the air distribution in the adjacent modules.

(ii) Proving the feasibility of the desired air distribution in the cell matrix.

(iii) Testing of the fans.

The measurement techniques consist of Pitot- and Prandtl tubes, orifice meters, and a constant temperature anemometer with on-line data processing.

The problems to be solved with the 'hot model' are:

(i) Final design of the air distribution system to reach equal cooling power at each cell with a minimal air flow.

(ii) Improving and testing the frontplate design with regard to heat losses.

(iii) Determining the parameters for the control system.

(iv) Improving and checking the control system.

Up to now the full compatibility between model and real battery has not been shown, but the data obtained from standard batteries show no significant deviation from the comparable data of the model experiments.

To reduce the experiments in developing thermal management systems two problems must be solved mathematically:

(i) Heating of the incoming air in the dividing header of the direct cooling system. This requires a knowledge of the Nusselt-numbers for the specific conditions, *i.e.*, thermally and hydrodynamically developing flow in a high aspect ratio tube with a prescribed velocity profile at the entrance, one porous wall and no constant axial and peripheral wall heat flux.

(ii) Transient heat transfer within the cell matrix. This requires the development of simple mathematical models, which must be verified experimentally.