CPN 321 Project Part 2

The temperature control lab development

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Contents

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1. Dynamic Simulation

Python was used in order to determine a dynamic simulation of the model equations. A comparison between the model, created in Part 1 of the project, and the experimental model obtained when running the TCLab unit was made. Results were obtained when a step as well as a rectangular pulse disturbance were used.

The heater input as well as the ambient conditions can be disturbed in order to analyse different outputs. Graphical representations were used to determine the error obtained between the model (model equations) and the experimental model. Euler integration was used in order to determine the results, when solving for differential equations.

2. Theoretical TCLab

2.1. Step input

The theoretical run of the TCLab was performed and included in the report in order to determine what to expect when running the actual TCLab. The model was first tested without connecting the actual TCLab unit. Figure 1 is a representation of the sensor temperatures as well as the heat supplied to the heaters. The heater input was disturbed by means of a step input. Both the first sensor as well as the second sensor tends to a second order response. A smooth gradient at the initial input change can be observed.

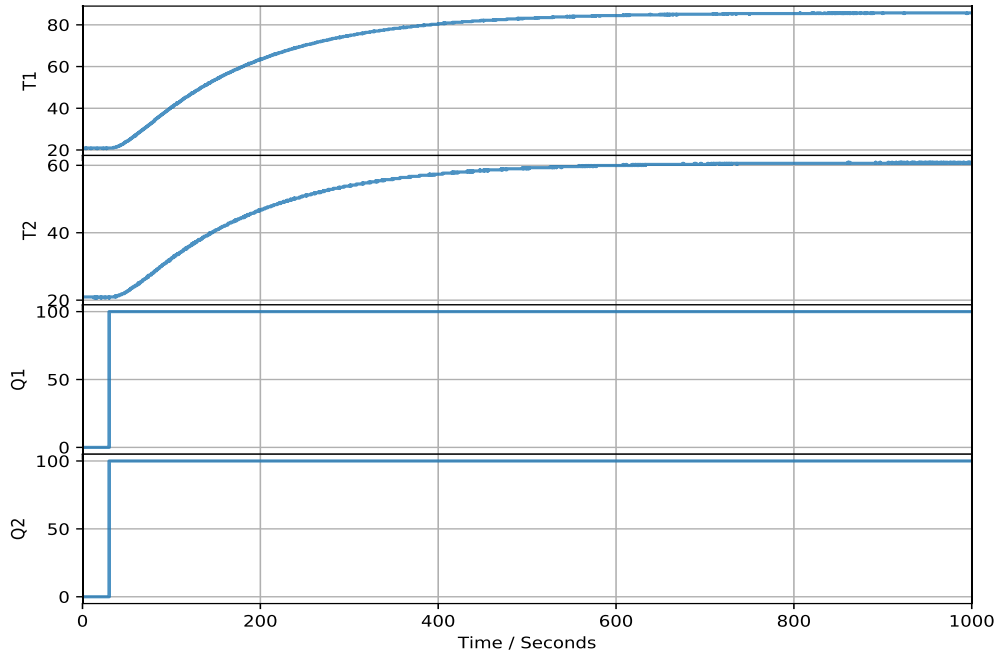

Figure 1: Sensor temperature as well as heat obtained when the TCLab is disconnected.

Figure 2 is an illustration of the temperature profiles obtained when the temperature of sensor 1, calculated by making use of the model equations is compared to the temperature of sensor 1 on the TCLab.

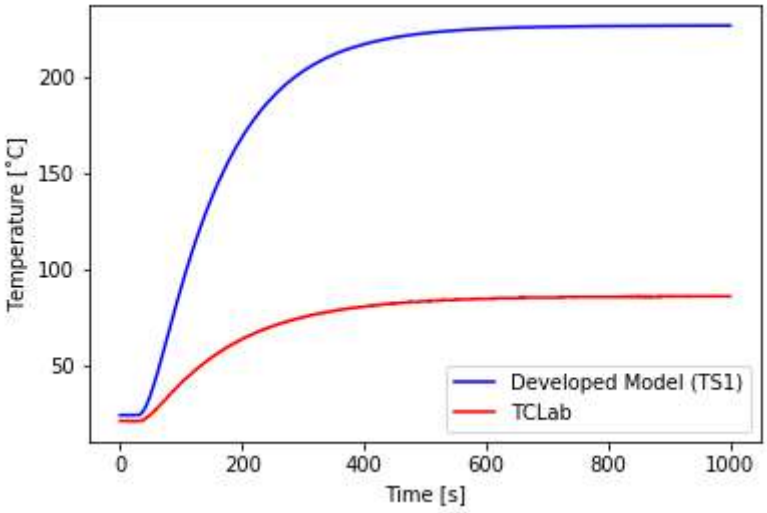

Figure 2: Temperature of sensor 1 for the model and the theoretical TCLab.

The shape of the TCLab response for sensor 1 is identical to the model, yet the gains are different. The model has a larger gain than the TCLab. Figure 3 is an illustration of the temperature profiles obtained when the temperature of sensor 2, calculated by making use of the model equations is compared to the temperature of sensor 2 on the TCLab.

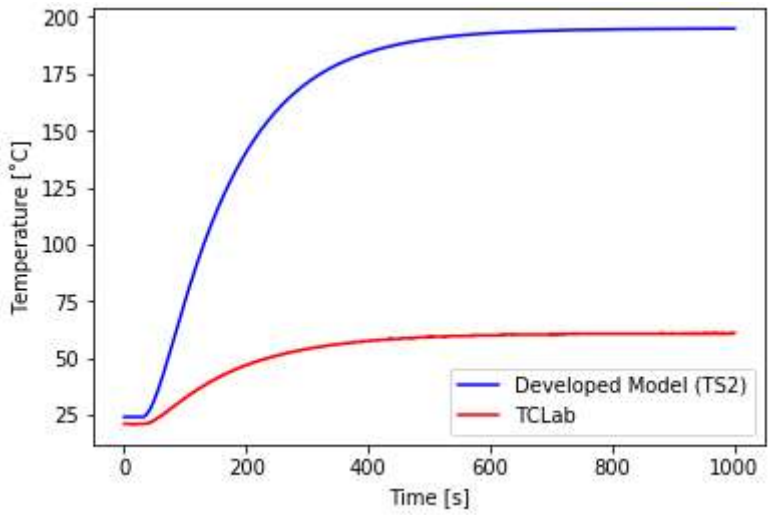

Figure 3: Temperature of Sensor 2 for the model and the theoretical TCLab.

The shape of the TCLab response for sensor 2 is identical to the model, yet the gains are different. The model has a larger gain than the TCLab. Sensor 2 has a lower heat factor. Less power is transmitted to the unit; thus, the magnitude of the gain is less than that of sensor 1.

2.2 Rectangular input

Figure 4 is a representation of the sensor temperatures as well as the heat supplied to the heaters. The heater input was disturbed by means of a rectangular input. At 900 seconds another step input was introduced. The gradient in absolute terms decreases in magnitude, until a new steady state was achieved, after the second step input.

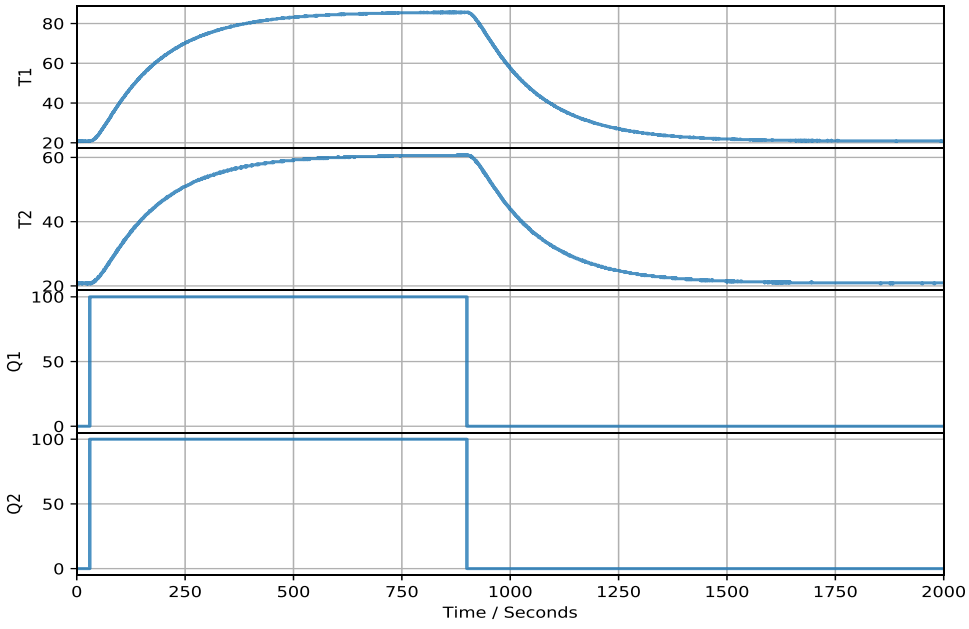

Figure 4: Sensor temperature as well as heat obtained when the TCLab is disconnected.

The shape of the TCLab response for sensor 1 is identical to the model, yet the gains are different. The model has a larger gain than the TCLab. Figure 5 is an illustration of the temperature profiles obtained when the temperature of sensor 1, calculated by making use of the model equations are compared to the temperature of sensor 1 on the TCLab.

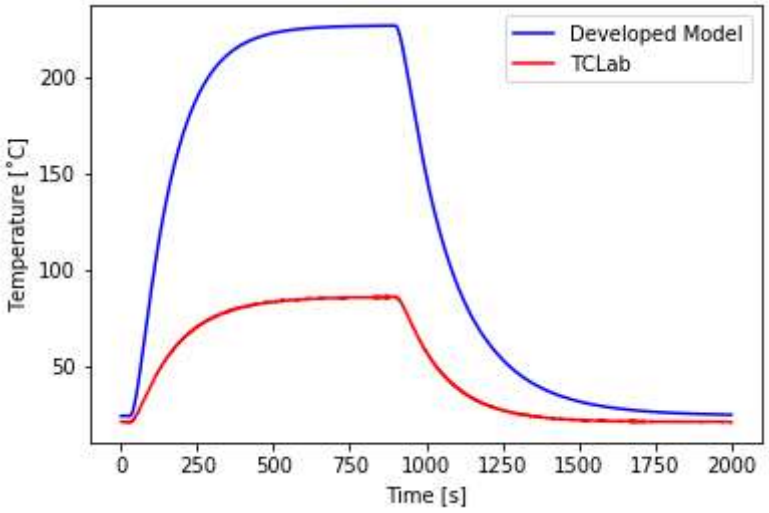

Figure 5: Temperature of sensor 1 for the model and the theoretical TCLab.

The temperature profiles in Figure 6 has the same trends but the gain for the developed model are larger than that of the TCLab unit.

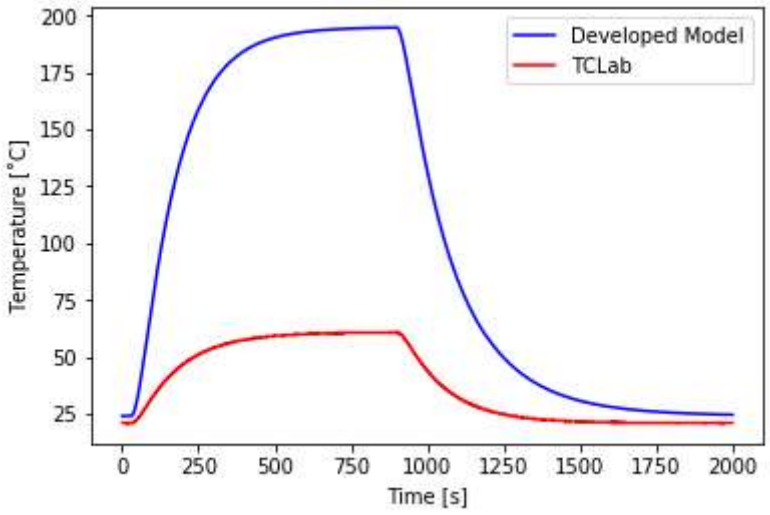

Figure 6: Temperature of sensor 2 for the model and the theoretical TCLab.

The shapes of the two curves are similar but the gains are different. Thus, the dynamic model is inaccurate. It is recommended to revise the parameters as well as the model equations in order to improve the model prediction.

3. TCLab connected

3.1. Step input

The TCLab unit was connected in order to determine the difference between the results obtained from the physical TCLab and the dynamic model. In Figure 7 the heater input was disturbed by means of a step input. A smooth gradient at the initial input change is an indication that both the sensors tend to a second order response.

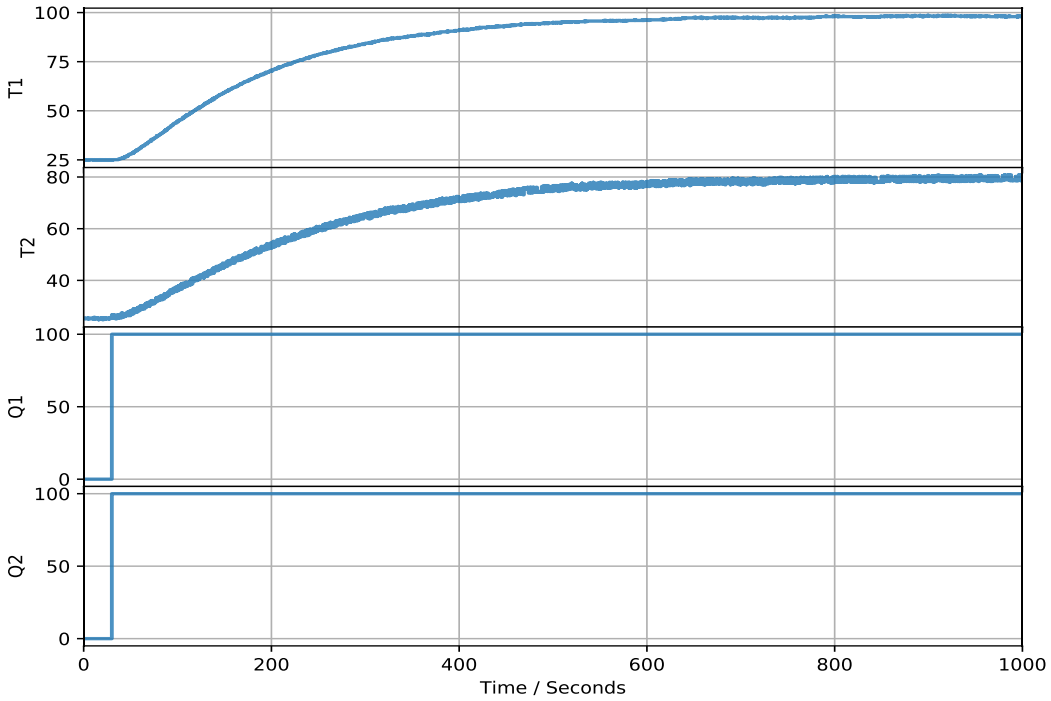

Figure 7: Sensor temperature as well as heat obtained when the TCLab is connected.

Figure 8 is an illustration of the temperature profiles obtained when the temperature of sensor 1, calculated by making use of the model equations are compared to the temperature of sensor 1 on the TCLab. In Figure 8 the curves follow the same trend. The gains are different. The dynamic model approximates the temperature relatively well.

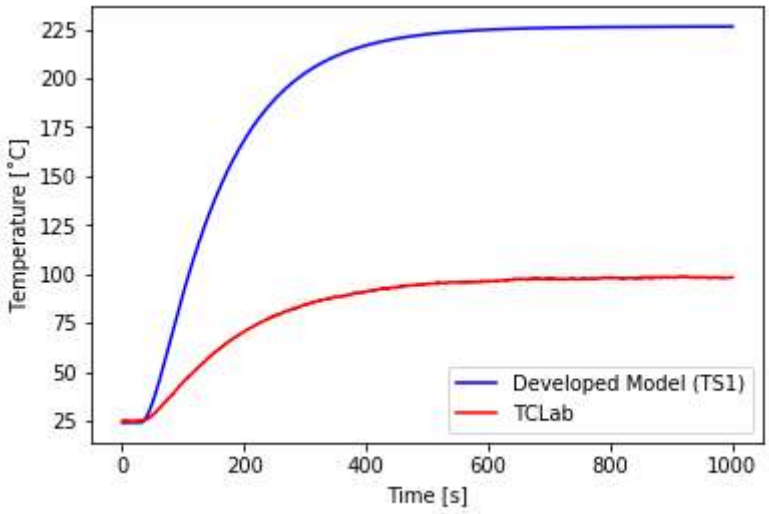

Figure 8: Temperature of sensor 1 for the model and the physical TCLab.

Figure 9 is an illustration of the temperature profiles obtained when the temperature of sensor 2, calculated by making use of the model equations are compared to the temperature of sensor 2 on the TCLab. In Figure 9 the curves follow the same trend. The gain of the temperature curve obtained by the dynamic model is larger than the gain achieved by the physical TCLab.

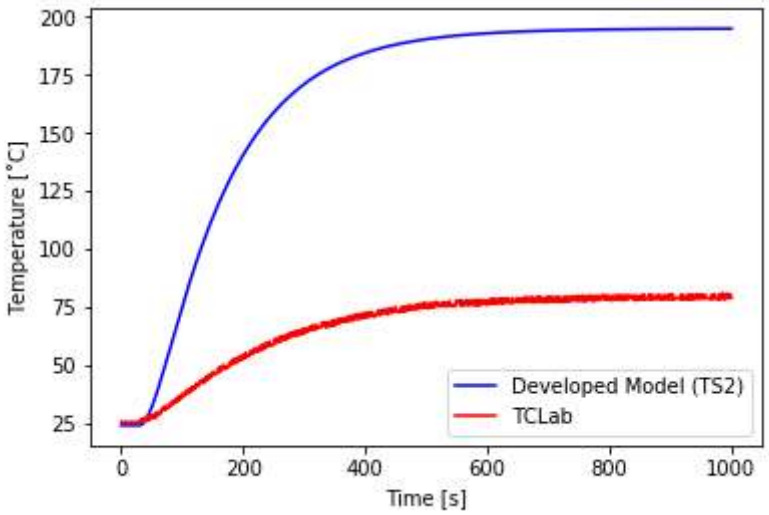

Figure 9: Temperature of Sensor 2 for the model and the physical TCLab.

The gain difference between the model sensor temperature and the TCLab sensor temperature are the same for sensor 1 than for sensor 2. More power was supplied to sensor 1 than to sensor 2. The TCLab sensor 1 achieved a temperature of approximately 90 °C, while the TCLab sensor 2 achieved a temperature of approximately 75 °C.

3.2. Rectangular input

Figure 10 is a representation of the sensor temperatures as well as the heat supplied to the heaters. The heater input was disturbed by means of a rectangular input. Both the first sensor as well as the second sensor tends to a second order response. At 900 seconds another step input was introduced.

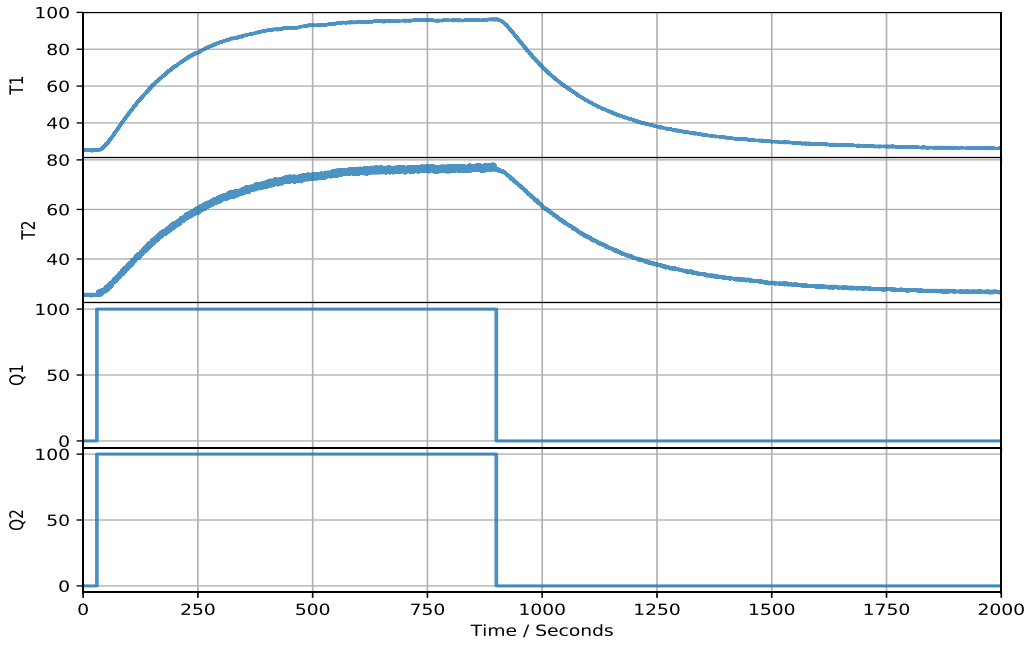

Figure 10: Sensor temperature as well as heat obtained when the TCLab is connected.

The shape of the TCLab response for sensor 1 is identical to the model, yet the gains are different. The model has a larger gain than the TCLab. Figure 5 is an illustration of the temperature profiles obtained when the temperature of sensor 1 was measured. The starting points for the two curves are identical, even though the TCLab ambient temperature and the ambient air temperature specified for the model are not the same.

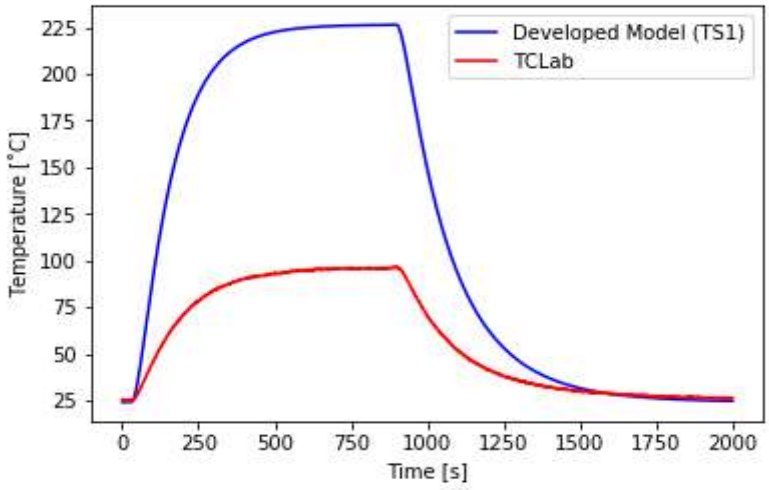

Figure 11: Temperature of sensor 1 for the model and the theoretical TCLab.

The temperature profiles in Figure 12 has the same trends but the gain for the developed model are larger than that of the TCLab unit.

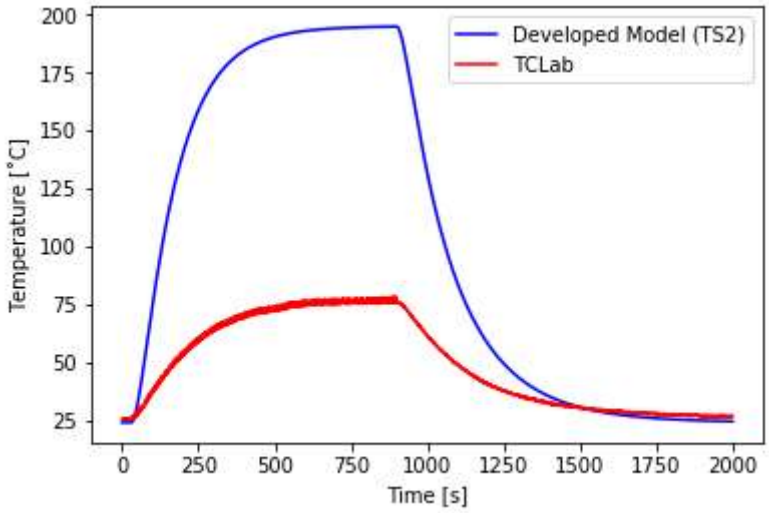

Figure 12: Temperature of sensor 2 for the model and the theoretical TCLab.

4. Conclusion and recommendations

The curves in the figures show that a larger gain was obtained in the temperature profiles for the dynamic model, when compared to the experimental TCLab unit values. The shapes of the temperature profiles are similar but the gains differ. The area of conduction was over calculated in Part 1 of the model. Reducing the area may reduce the gain to a lower value that is more comparable.

Sensor 2 has the same shape but a very small gain compared to the actual sensor TCLab results. It is due to the very small heat factor. Increasing the heat factor may produce better simulation results.

Due to the significant error obtained between the dynamic model results and the experimental results from the TCLab unit, the model can be presumed as inaccurate. Revising the parameters as well as the model equations is recommended to improve the model prediction.