Report

www.bsria.co.uk

CFD Analysis of ThermaSkirt

Report 51397/1
January 2008

Carried out for: **DiscreteHeat Company Ltd**
1 Victoria Works
Atherton
M46 0RY

Compiled by: Chunli Cao

Total pages 50

Quality Approved: GREG KING BSc MSc M.InstR
Group Manager
MicroClimate & Test

BSRIA Limited
Old Bracknell Lane West, Bracknell, Berkshire RG12 7AH UK
T: +44 (0)1344 465600 **F:** +44 (0)1344 465626
E: bsria@bsria.co.uk **W:** www.bsria.co.uk

CONTENTS

TABLES

FIGURES

1 INTRODUCTION

This project was carried out in response to a request from Martin Wadsworth of DiscreteHeat to simulate by Computational Fluid Dynamics (CFD) a room being heated with radiators compared with the same room being heated with ThermaSkirt. The CFD analysis shows simulations of the internal environment using a given set of conditions, and predicts temperature gradients and air circulation for the room. Two models are set up using radiators at two locations and one model is using ThermaSkirt heating.

2 OBJECTIVES

The objective of this study is to compare the performance of DiscreteHeat ThermaSkirt with radiators. This will predict conditions in the room for each of the scenarios. In order to achieve this, BSRIA carried out a CFD analysis to predict thermal comfort, temperature gradients and air circulation in the room for each of the three scenarios.

3 METHOD

3.1 INFORMATION RECEIVED FROM THE CLIENT

The following information was supplied by the Client.

3.1.1 Room configuration

The room size is 4 m x 4 m x 2.4 m height, two external walls and external roof. Two windows are 1.5 m x 1 m and 1 m x 1 m respectively. The geometry of the room is shown in Figure 1.

U values are as per part L1 of the Building Regulations, which are shown in the table below.

Table 1 U value used

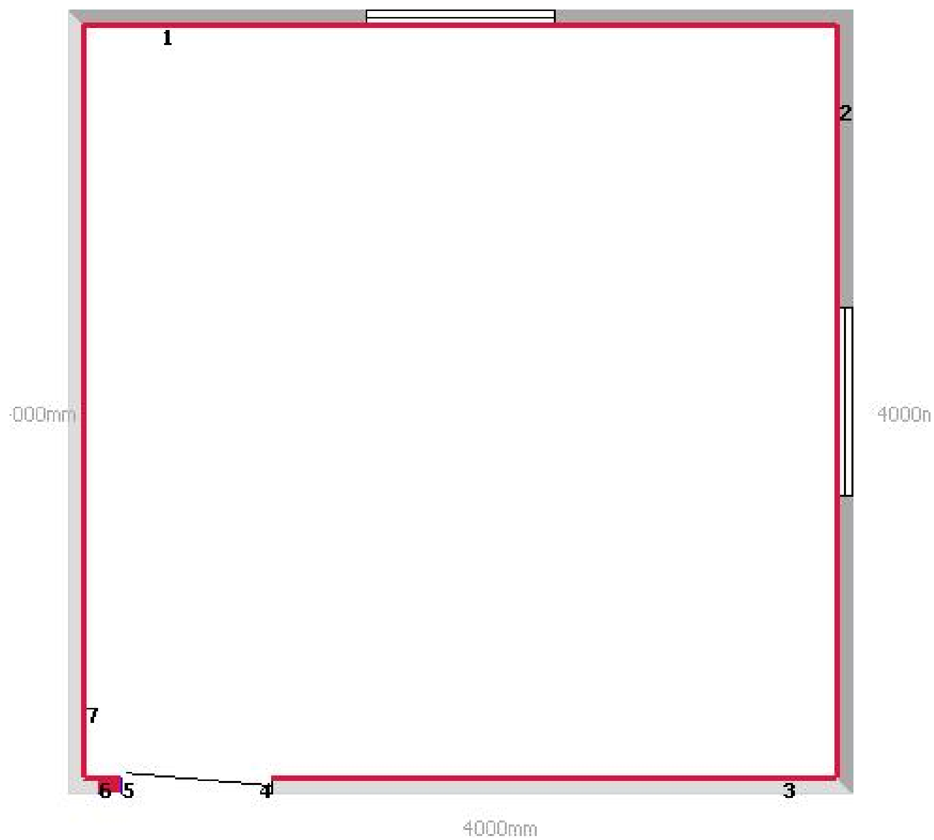
Items	Units	Walls	GND	Windows	Ceiling
U-value	$W.m^{-2}K$	0.35	0.25	1.8	0.24

3.1.2 Thermal and aerodynamics information

Typical thermal conditions are to BS5449: the targeting room temperature is 21°C and the external temperature is -1°C, with the air changes rate of 1.5 per hour. Trickle vents are used for modelling air exchange. The radiator is Double convector type Myson 21DC 33 with 1326 W output at ΔT 50 (21" high, 33" long double convector), which is simulated for two scenarios. (a) Under the 1.5 m x 1 m window and (b) on the internal 4 m wall opposite. The installation configuration is the standard one from the manufacture's manual (see www.bhl.co.uk for detailed information). The geometry and installation configuration of ThermaSkirt are same as the test of 442-1 by BSRIA Report Number 40079/1. 15 m of ThermaSkirt with output of 1326 10W at ΔT 36°C is simulated.

As radiators are very often sized 20~30% larger than required and thermostat is generally used to control the room temperature, averaged heat loss in accordance with BS5449 heat loss calculation are estimated and used in the three CFD models. Hence, to achieve heat balance in the room, the estimated averaged heat loss of 800W is used for the heat load of radiator and ThermaSkirt, even though both of them are capable of generating 1326 W output.

Figure 1 Geometry of the model



3.2 CFD MODELS

CFD models were created using the information given above. The salient features of the models are shown below.

Table 2 Model set up

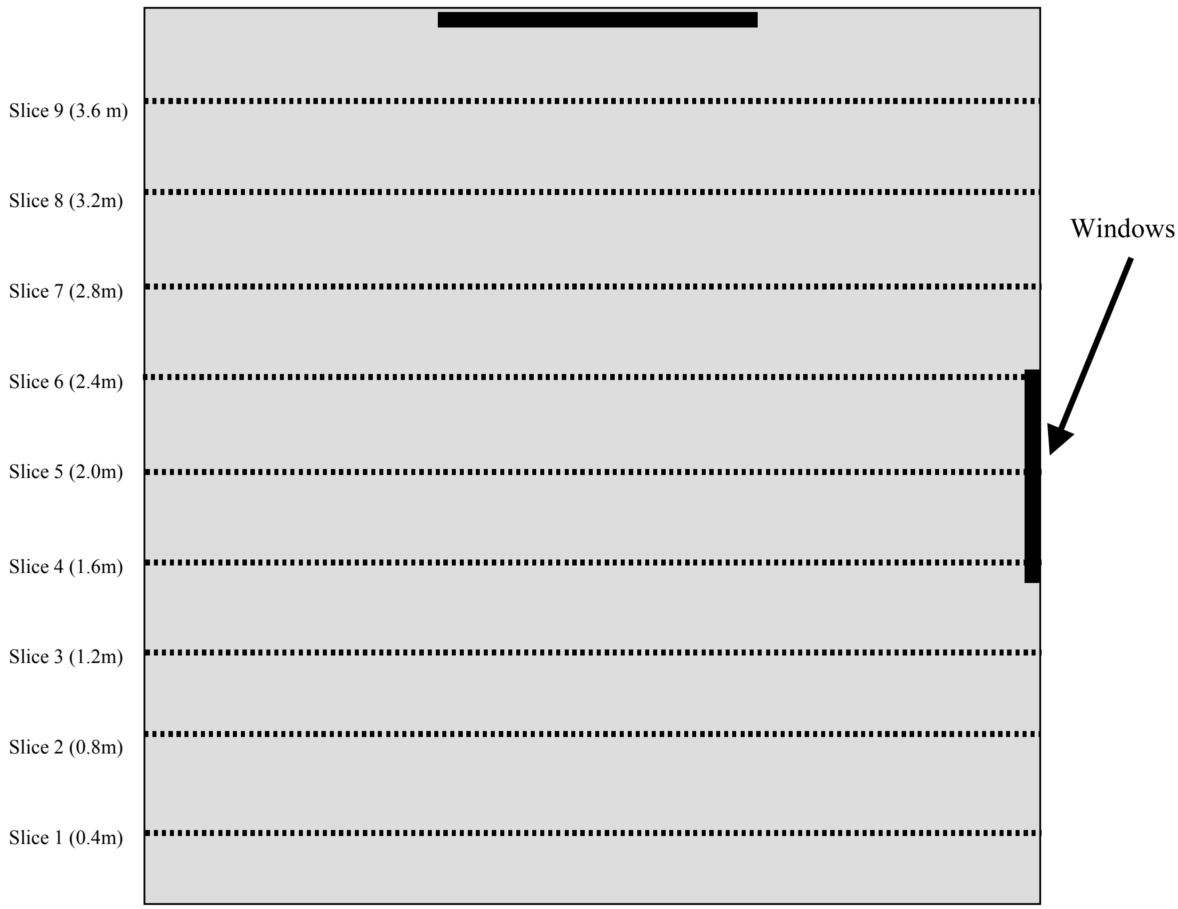
Model No.	Heater Type	Location
Model 1	Radiator	Under 1.5 mx 1m window
Model 2	Radiator	Opposite 1.5 mx 1m window
Model 3	ThermaSkirt	Equally distributed along walls

The steady state CFD simulations are carried out with Flovent 7.2 by using the segregated conjugate residual solver with radiation turned on. More dense grids are used in the regions with higher temperature and velocity gradient (e.g. surrounding area of the heaters). The meshes for three models are about 0.4 million cells. The most advance turbulence model LVEL k-ε model is used. False time steps for velocity and temperature are decreased from the automatic calculated level to obtain better convergence. The heaters are simulated as cuboids with heater source built in and radiation turned on for participating radiation calculations. The room surfaces were defined with corresponding U values.

4 RESULTS

Post processing was carried out in Flo-motion of Flovent. Contours for thermal comfort temperature, temperature and velocity for the three models are shown in the following sections. Figure 2 illustrates the locations of the contours

Figure 2 Position of the data slices (plan view)



4.1 MODEL 1 (RADIATOR UNDER WINDOW)

4.1.1 THERMAL COMFORT TEMPERATURE

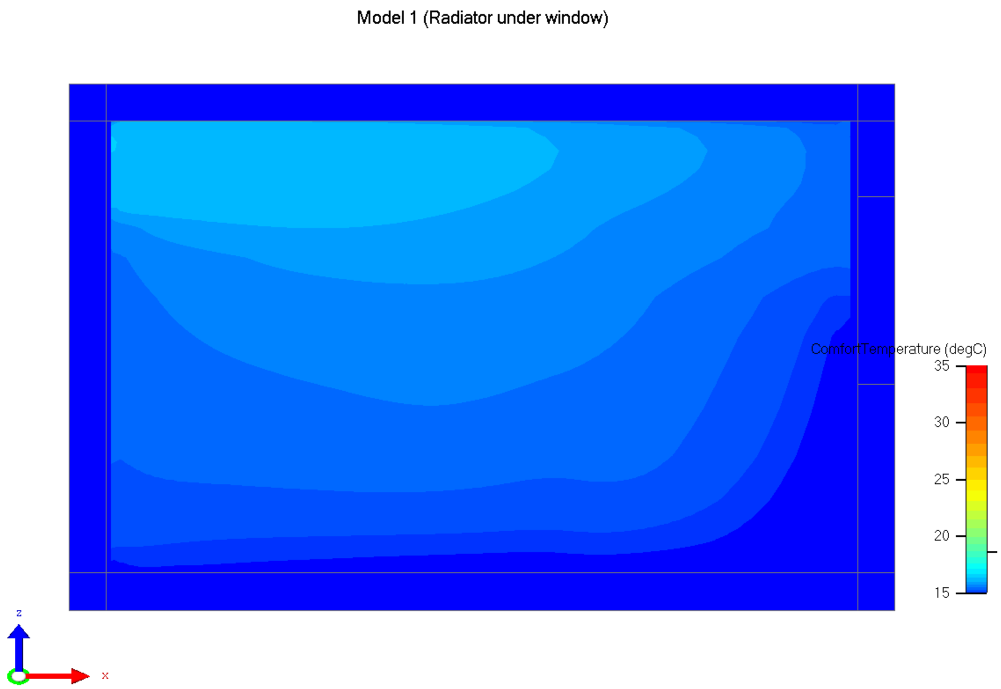


Figure 3 Model 1 Thermal Comfort Temperature Slice 1

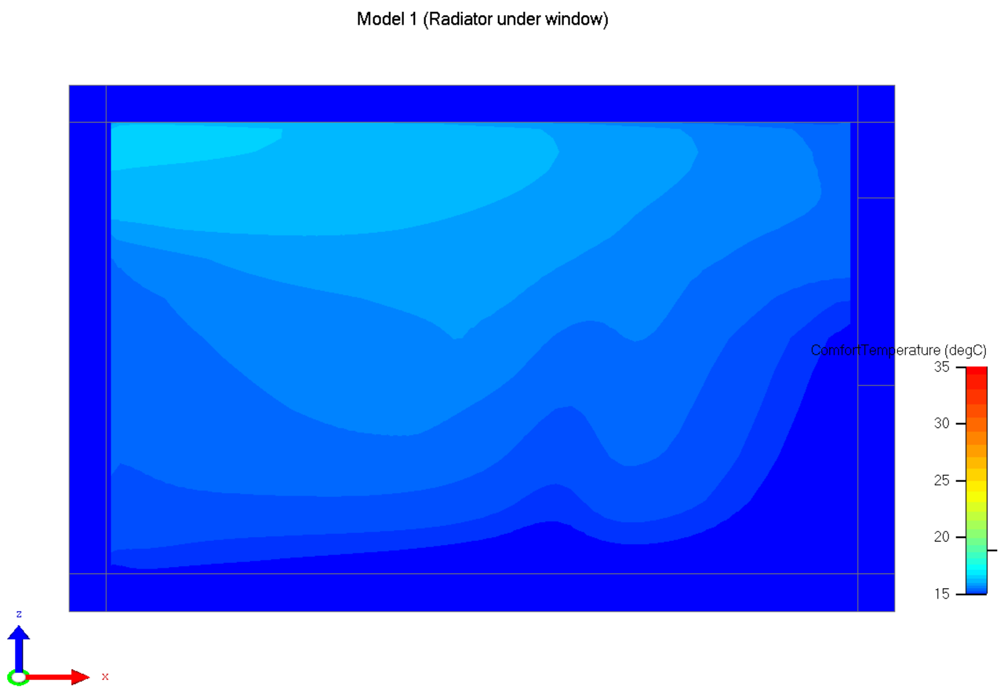


Figure 4 Model 1 Thermal Comfort Temperature Slice 2

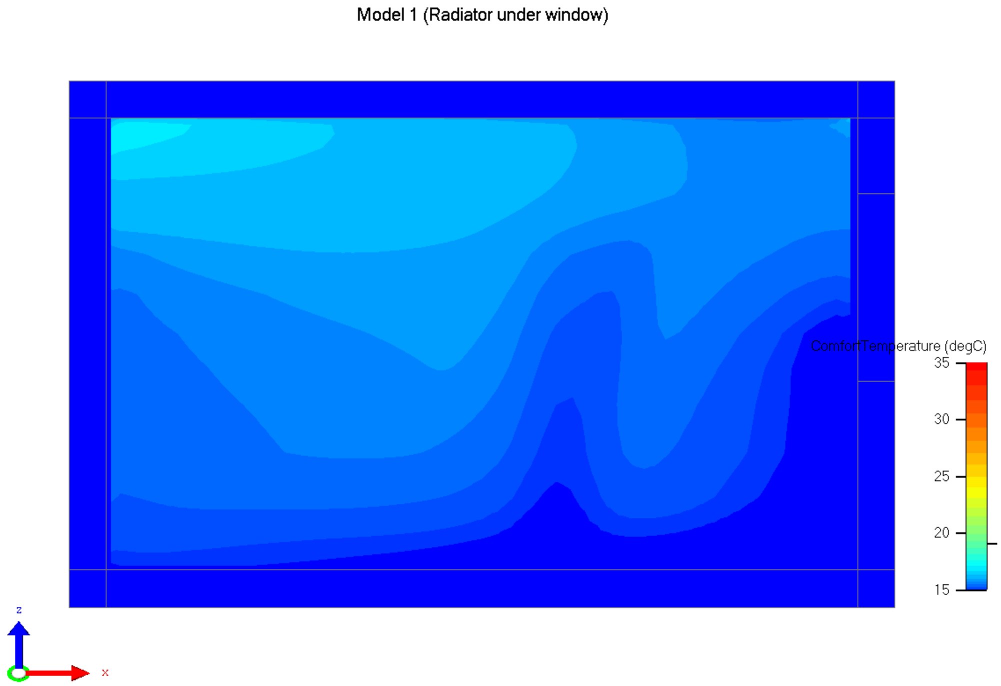


Figure 5 Model 1 Thermal Comfort Temperature Slice 3

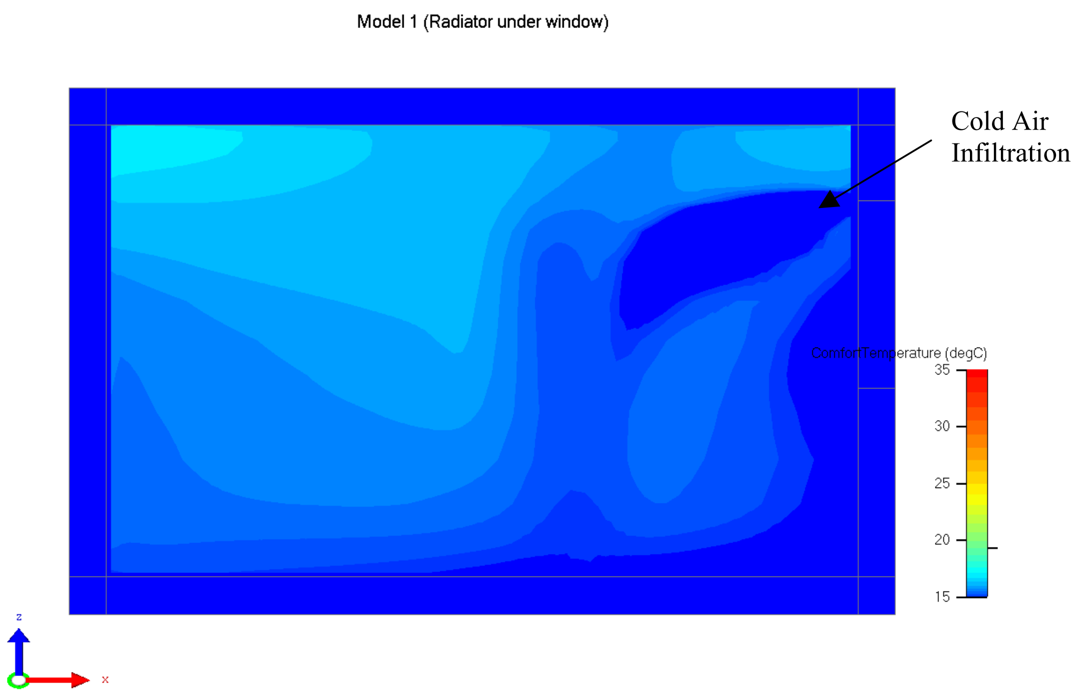


Figure 6 Model 1 Thermal Comfort Temperature Slice 4

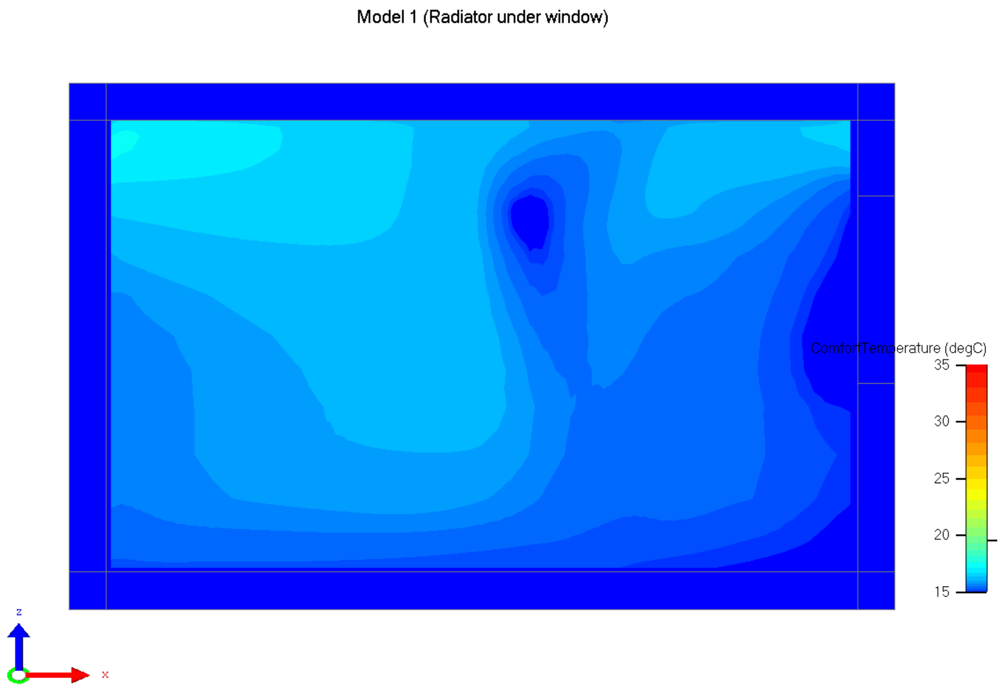


Figure 7 Model 1 Thermal Comfort Temperature Slice 5

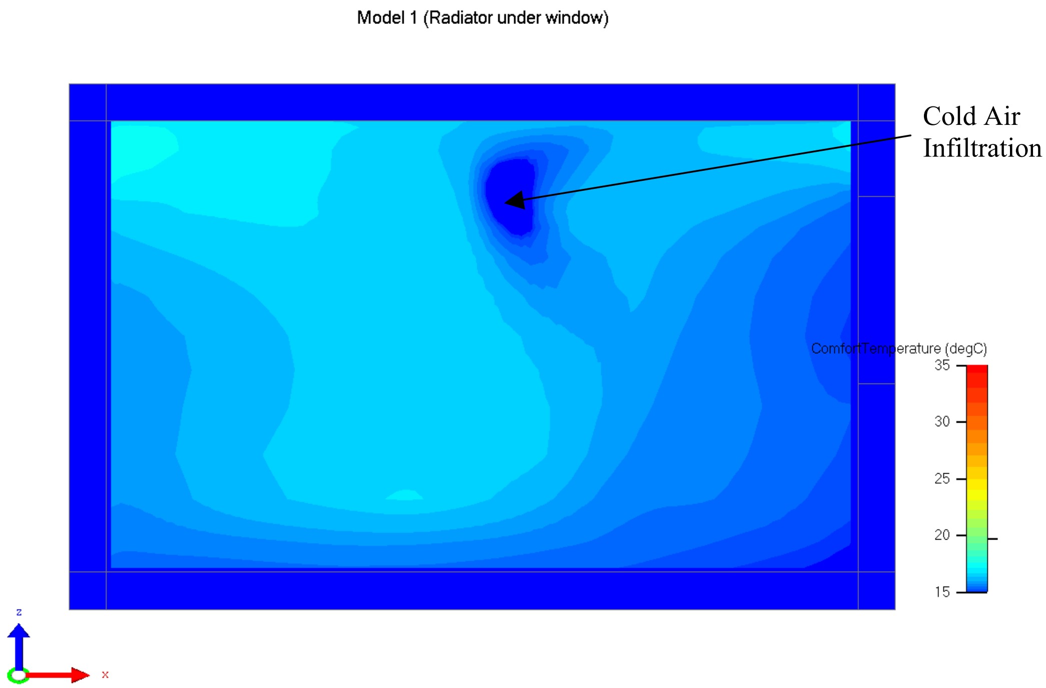


Figure 8 Model 1 Thermal Comfort Temperature Slice 6

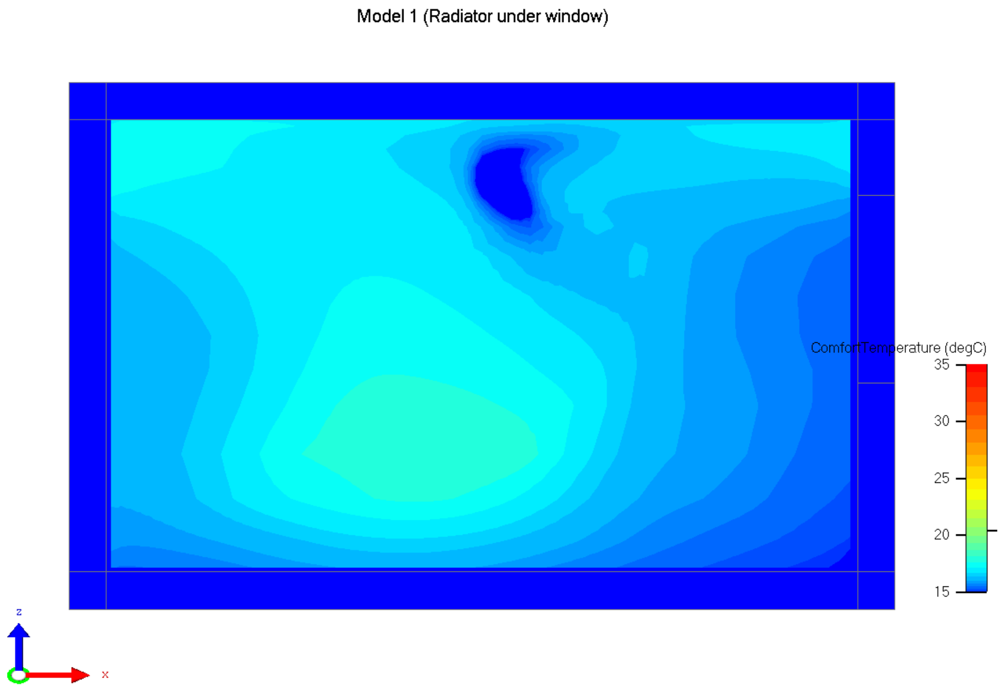


Figure 9 Model 1 Thermal Comfort Temperature Slice 7

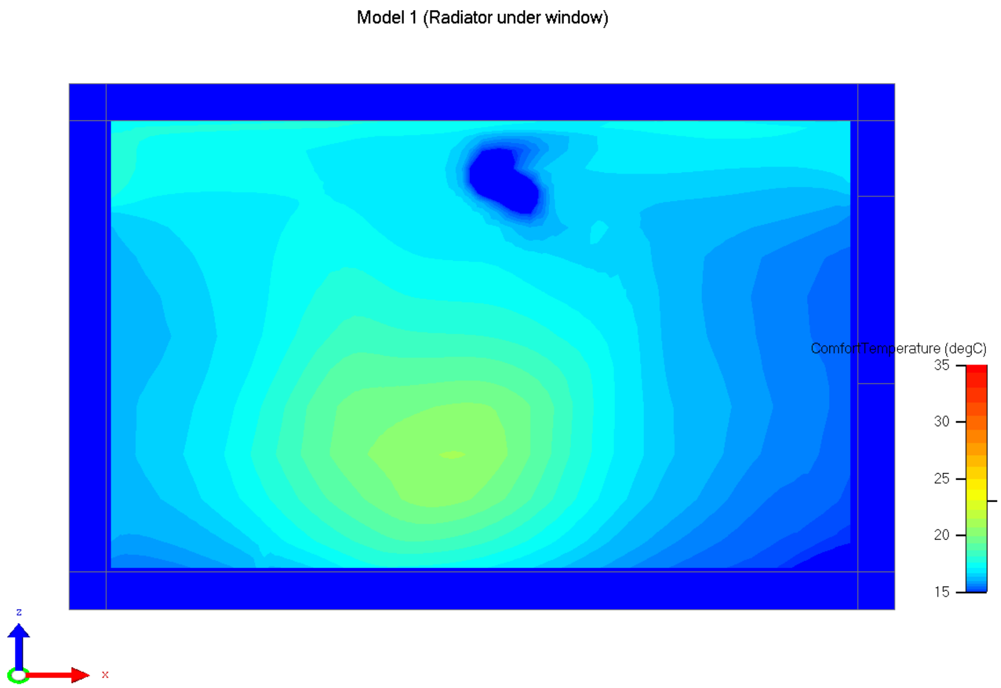


Figure 10 Model 1 Thermal Comfort Temperature Slice 8

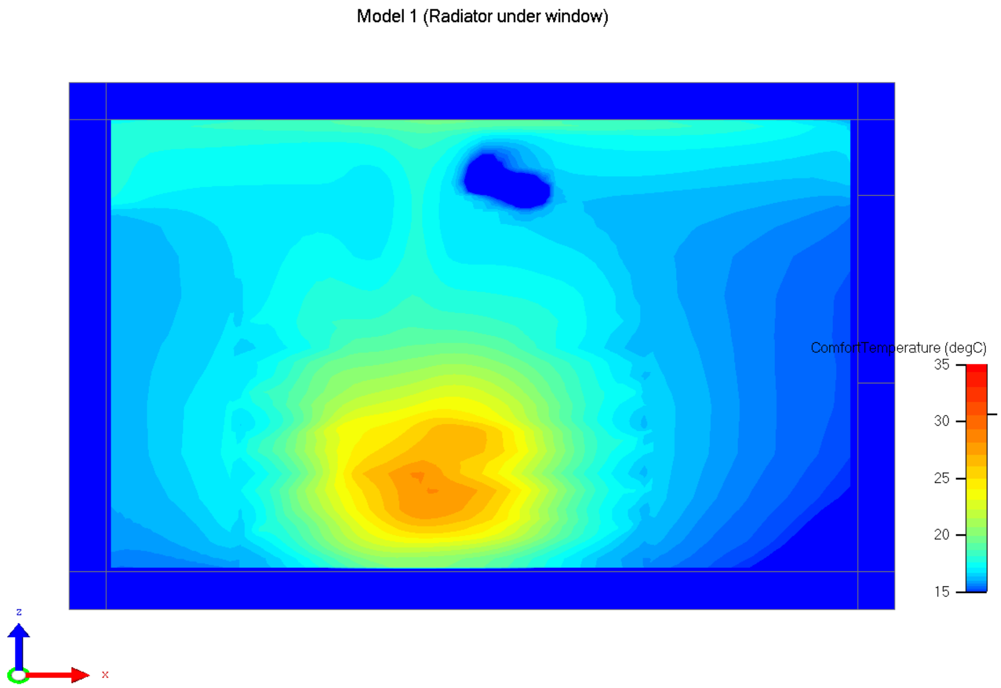


Figure 11 Model 1 Thermal Comfort Temperature Slice 9

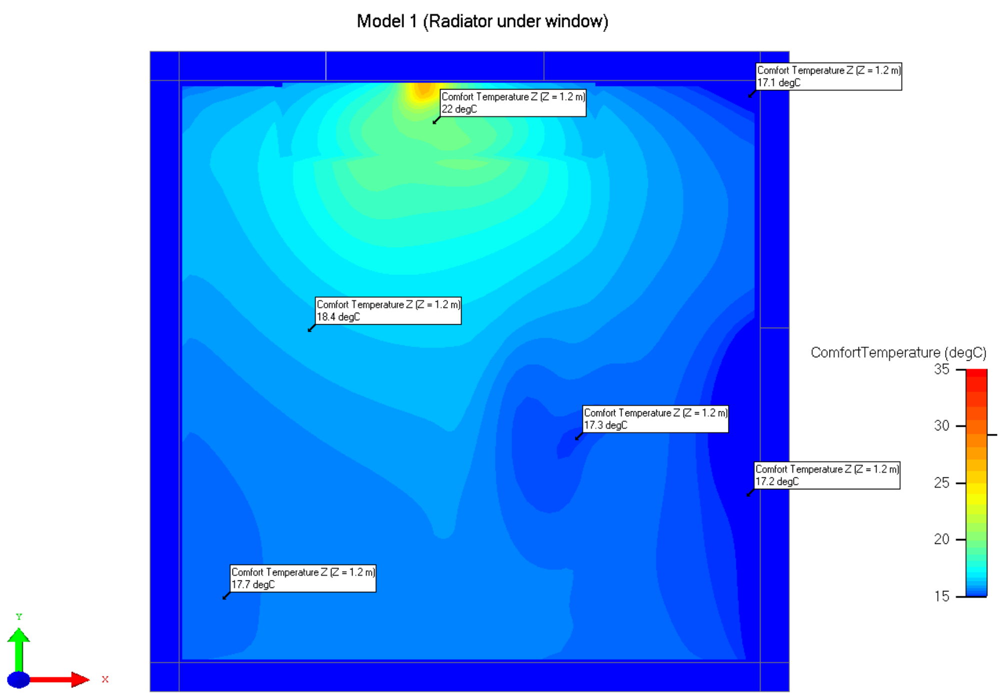


Figure 12 Model 1 Thermal Comfort Temperature at Z=1.2m (1.2 m Above Floor)

4.1.2 TEMPERATURE

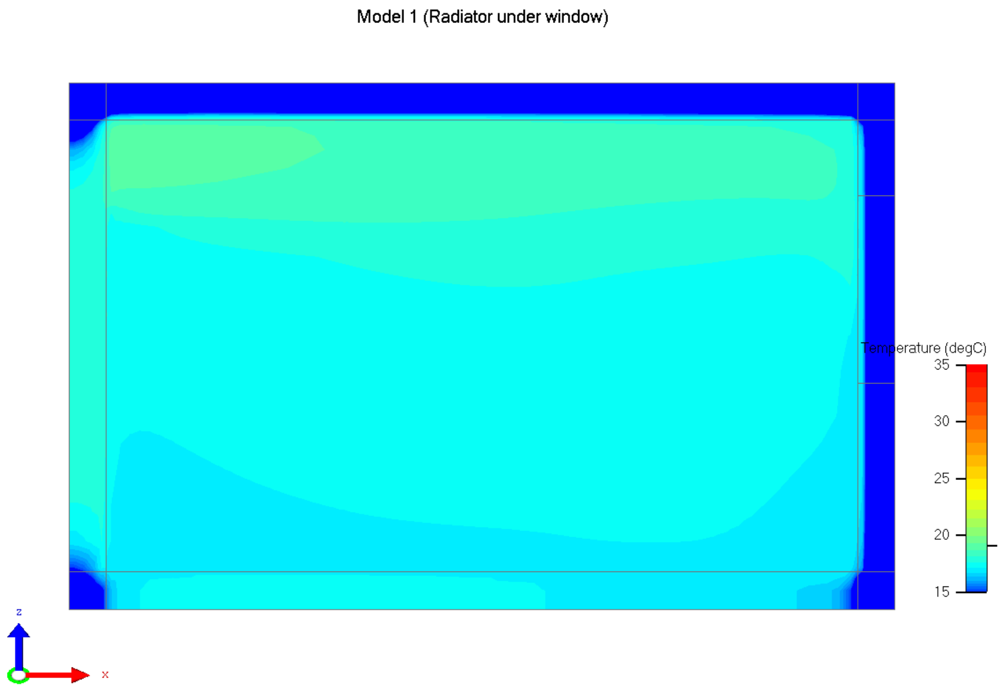


Figure 13 Model 1 Temperature Slice 1

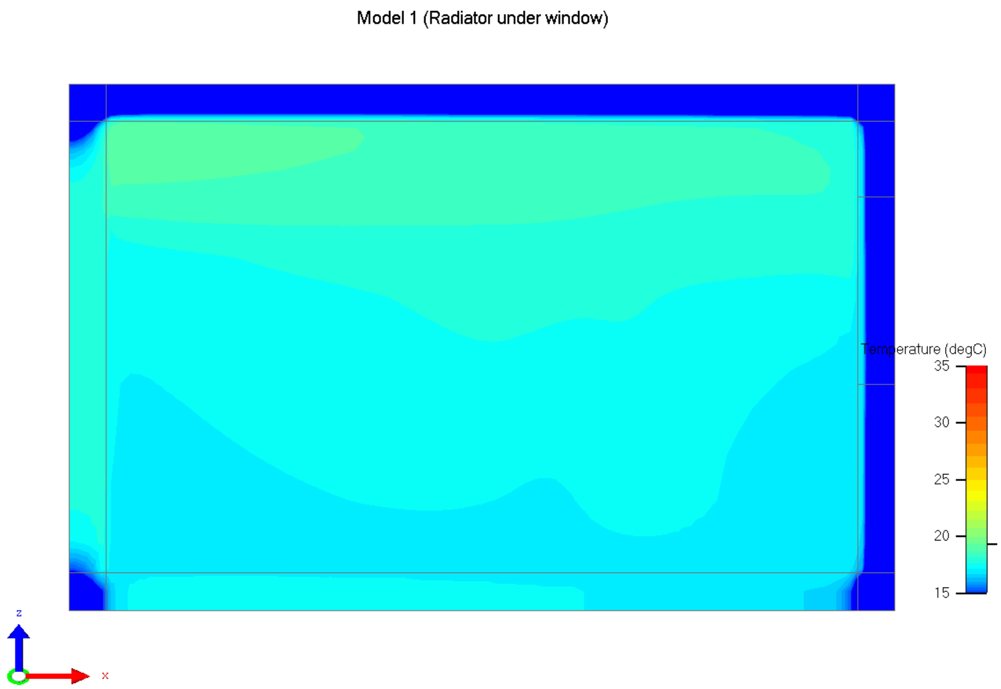


Figure 14 Model 1 Temperature Slice 2

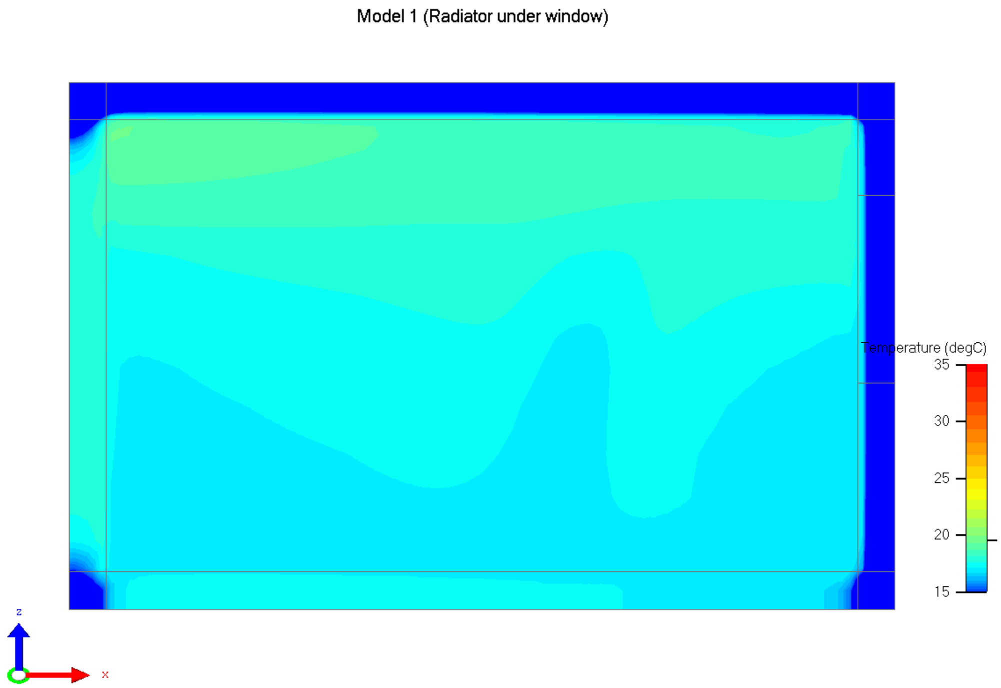


Figure 15 Model 1 Temperature Slice 3

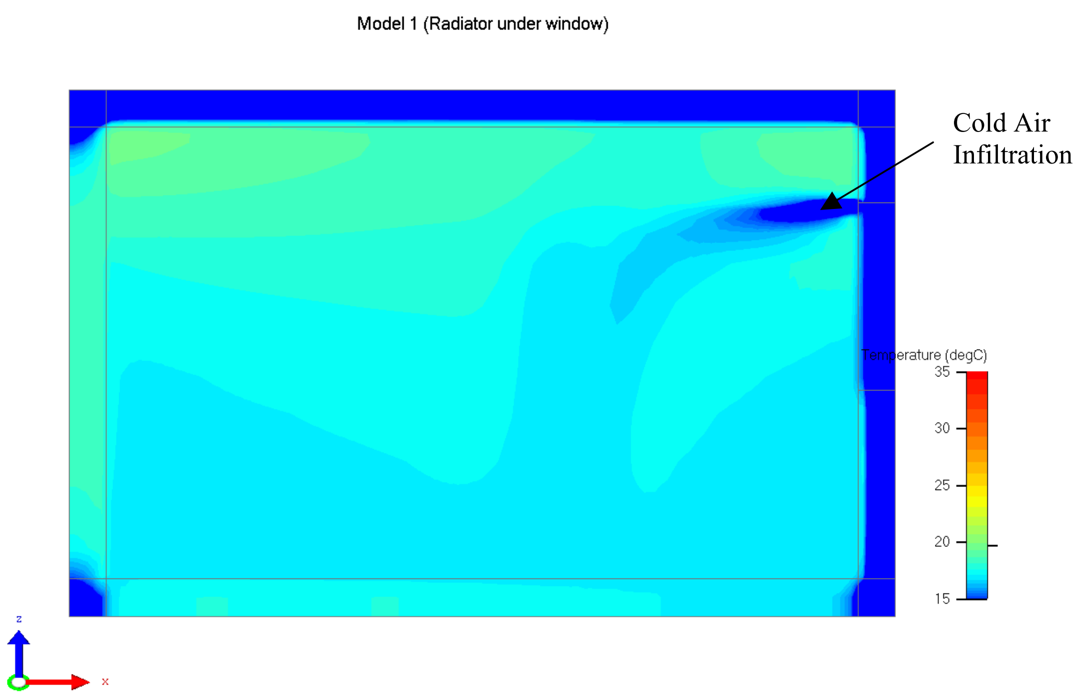


Figure 16 Model 1 Temperature Slice 4

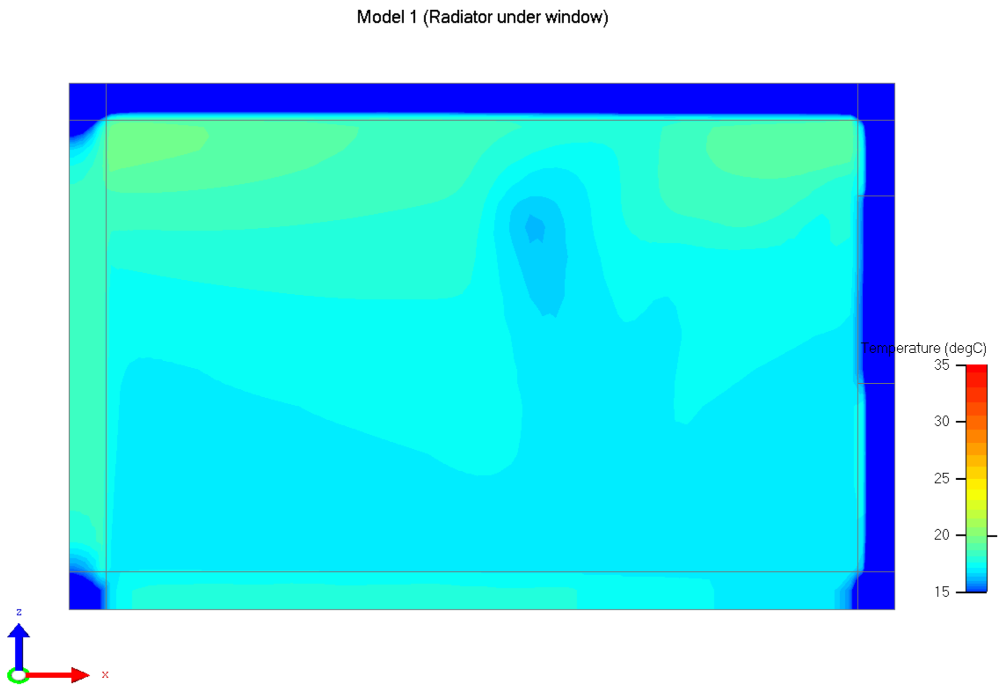


Figure 17 Model 1 Temperature Slice 5

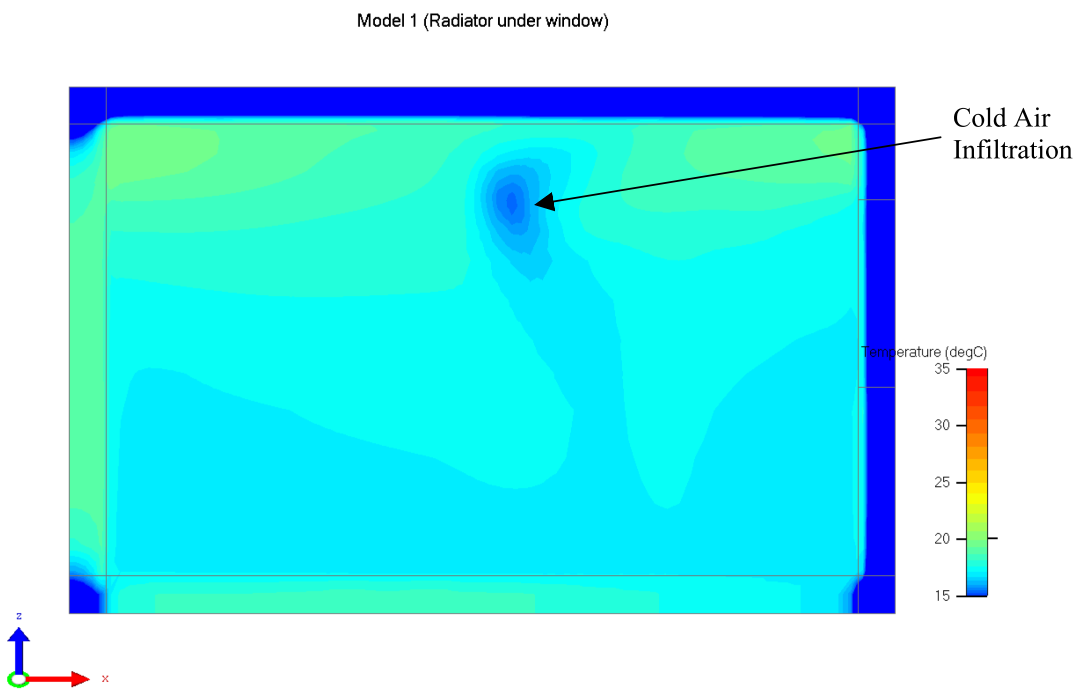


Figure 18 Model 1 Temperature Slice 6

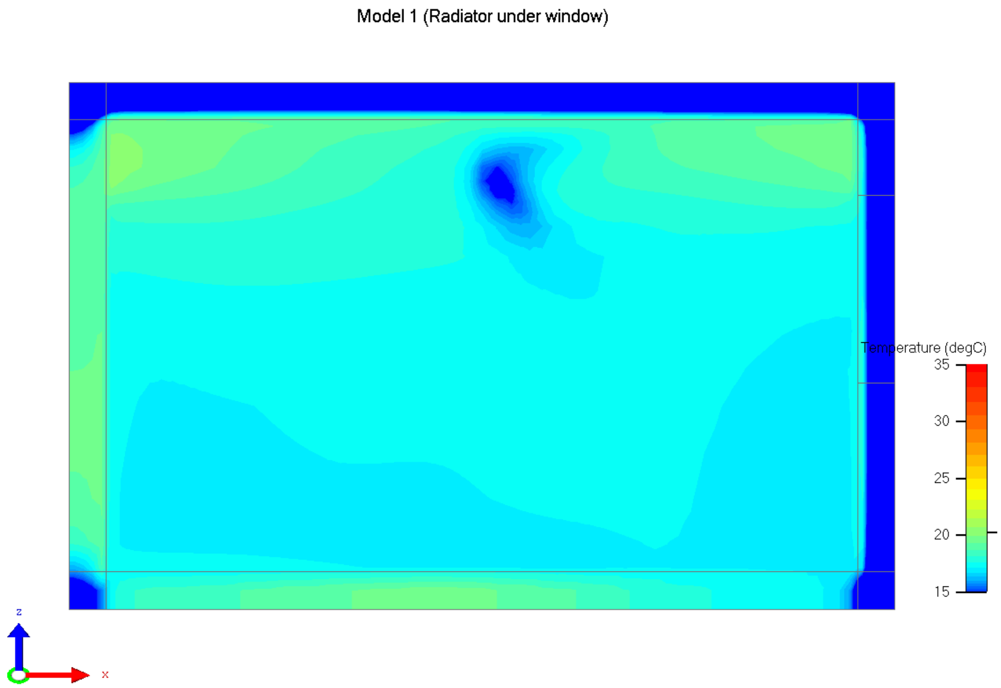


Figure 19 Model 1 Temperature Slice 7

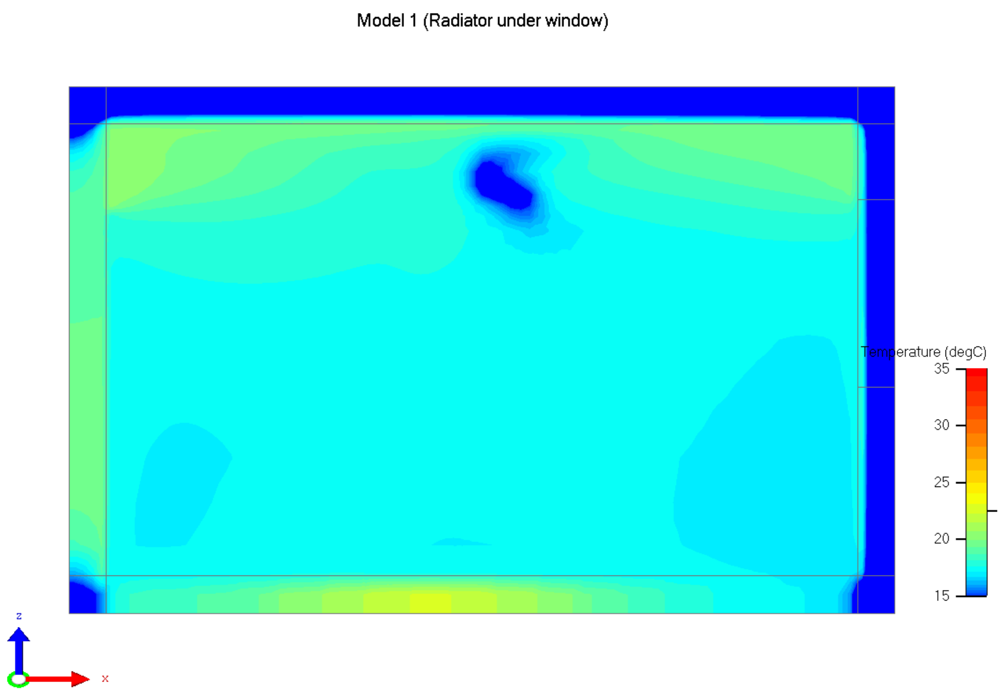


Figure 20 Model 1 Temperature Slice 8

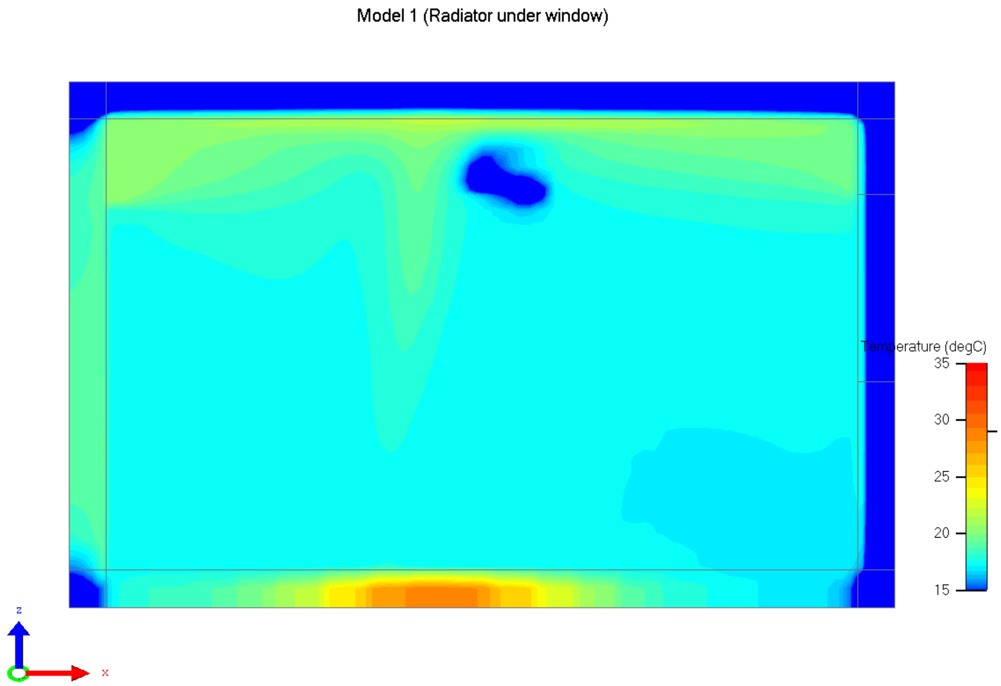


Figure 21 Model 1 Temperature Slice 9

4.1.3 VELOCITY

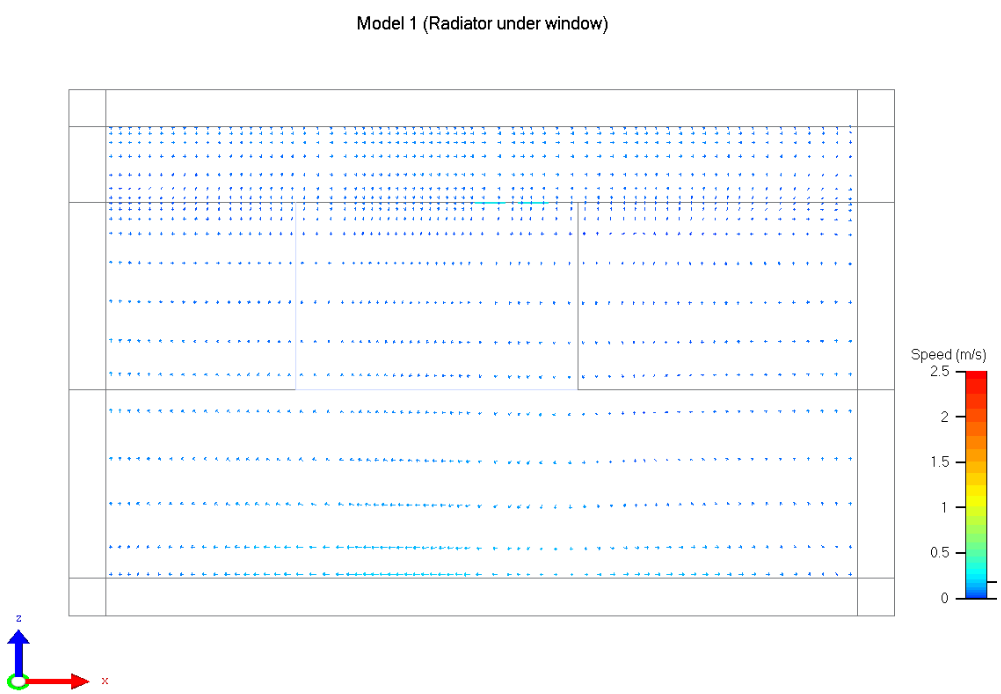


Figure 22 Model 1 Velocity Slice 1

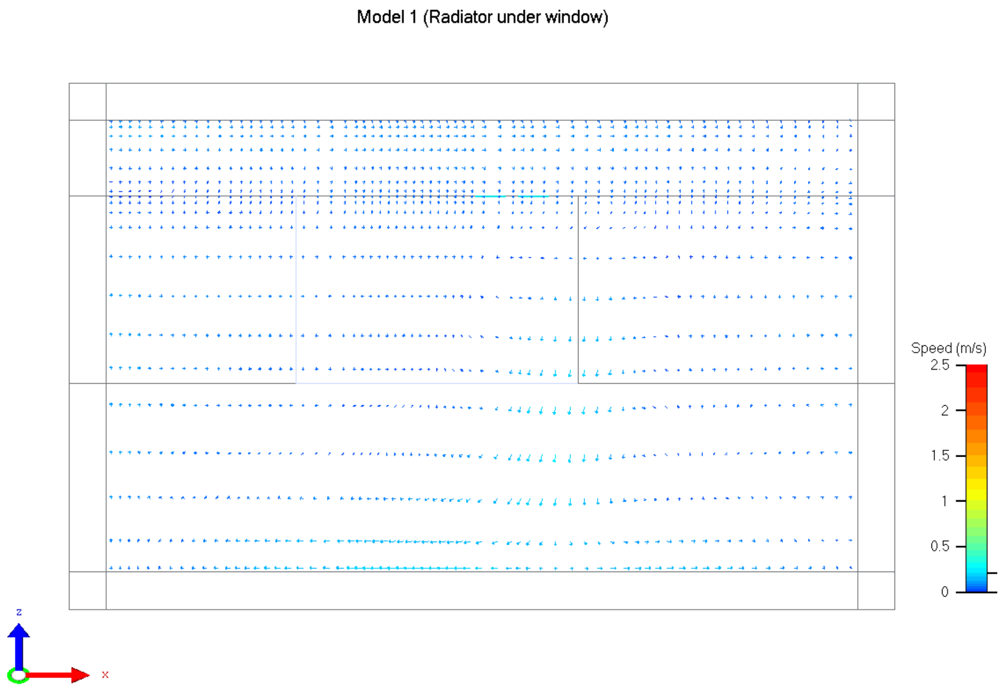


Figure 23 Model 1 Velocity Slice 2

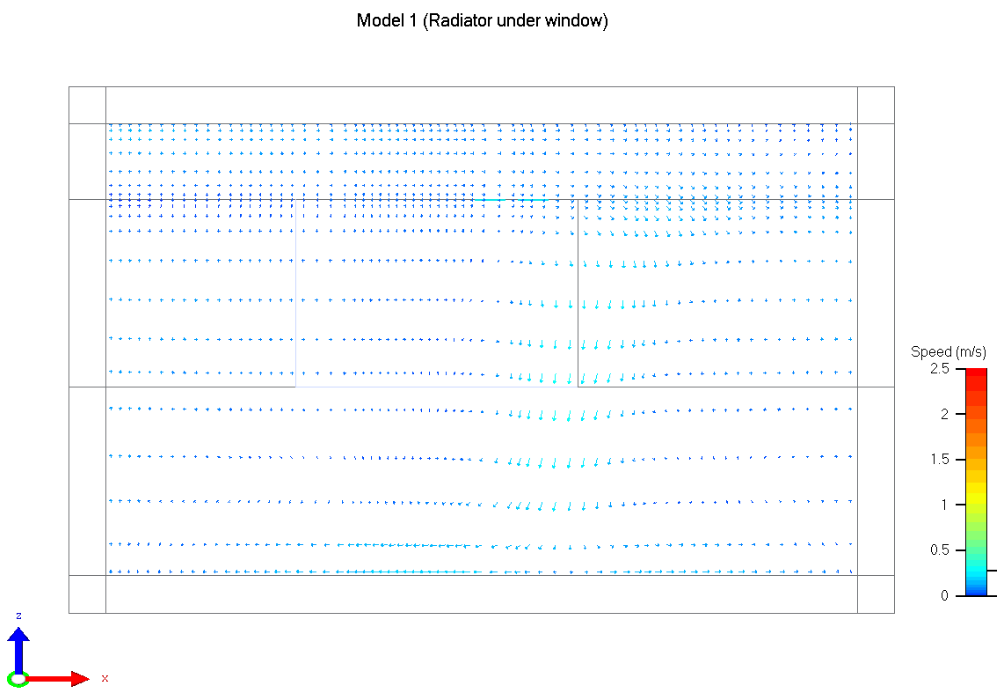


Figure 24 Model 1 Velocity Slice 3

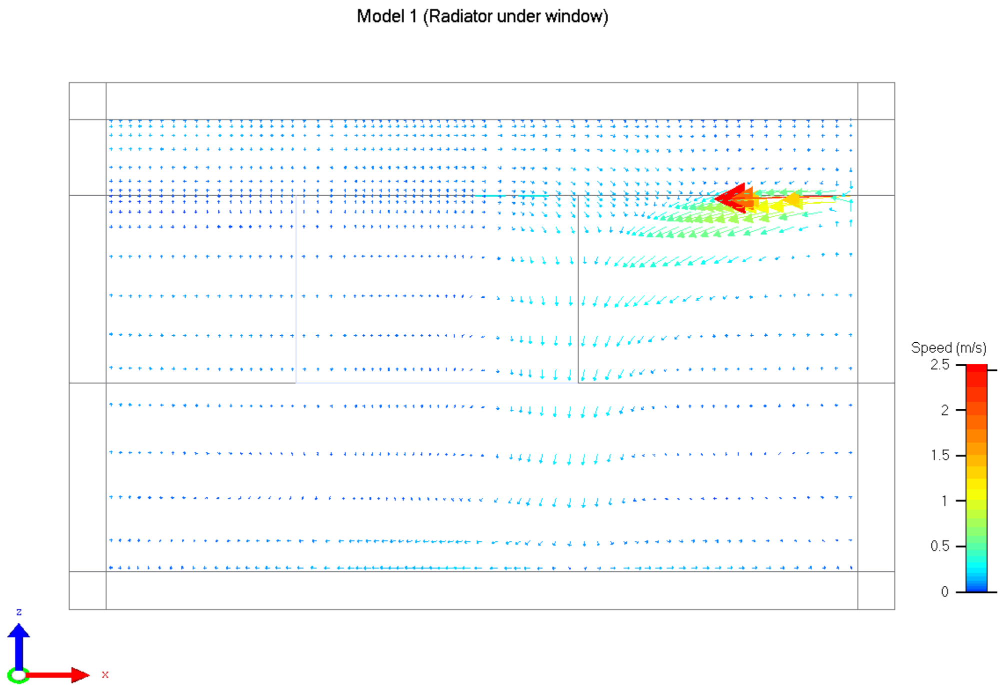


Figure 25 Model 1 Velocity Slice 4

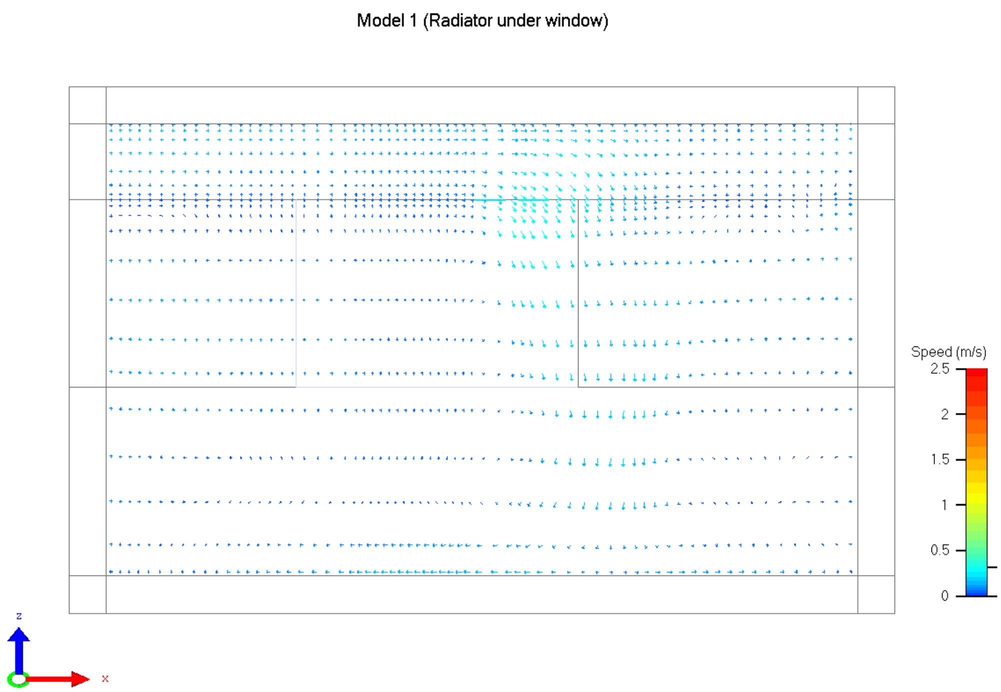


Figure 26 Model 1 Velocity Slice 5

Model 1 (Radiator under window)

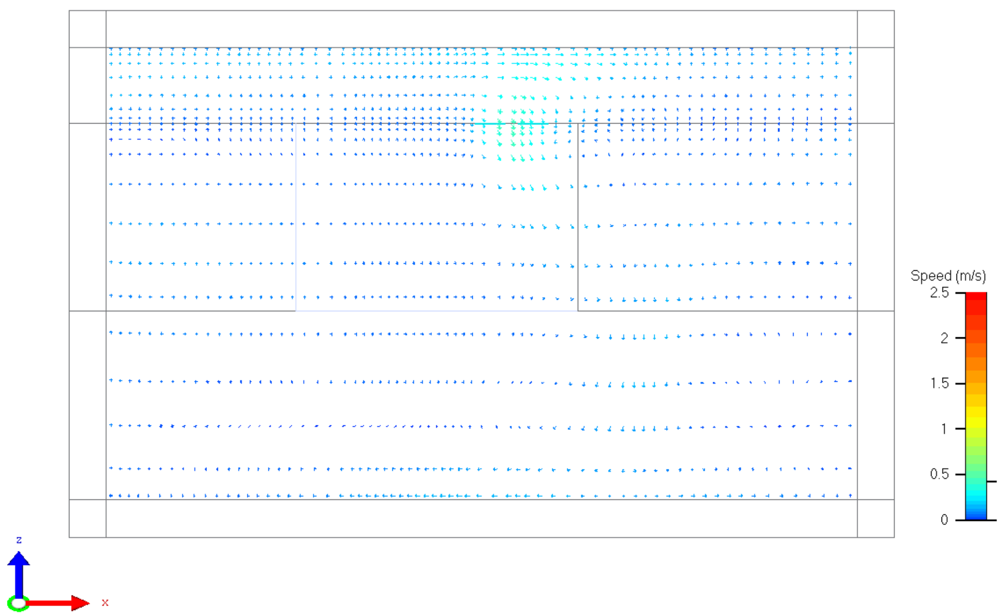


Figure 27 Model 1 Velocity Slice 6

Model 1 (Radiator under window)

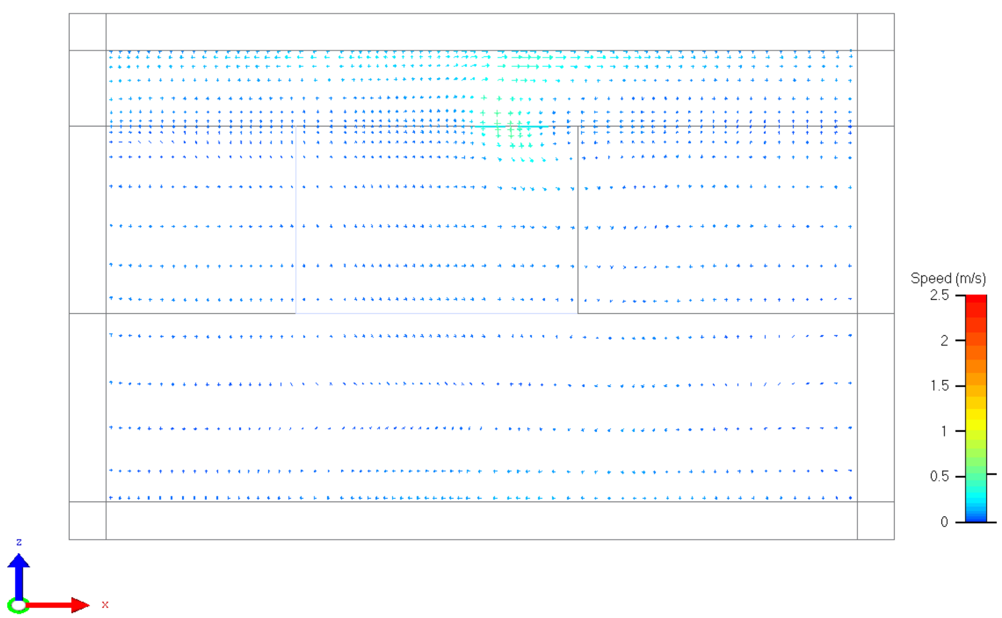


Figure 28 Model 1 Velocity Slice 7

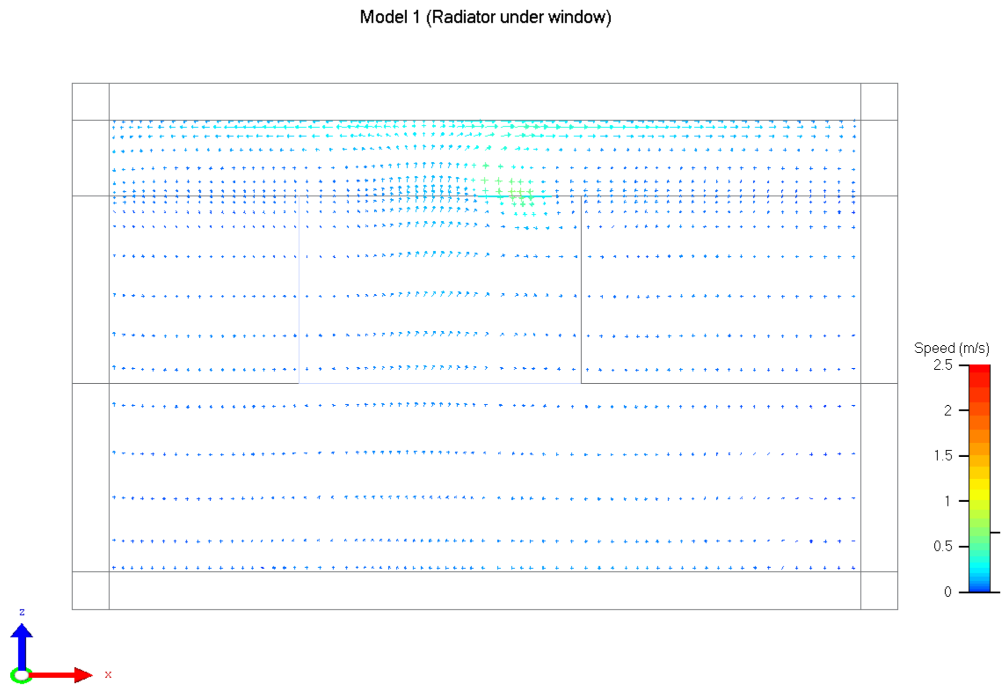


Figure 29 Model 1 Velocity Slice 8

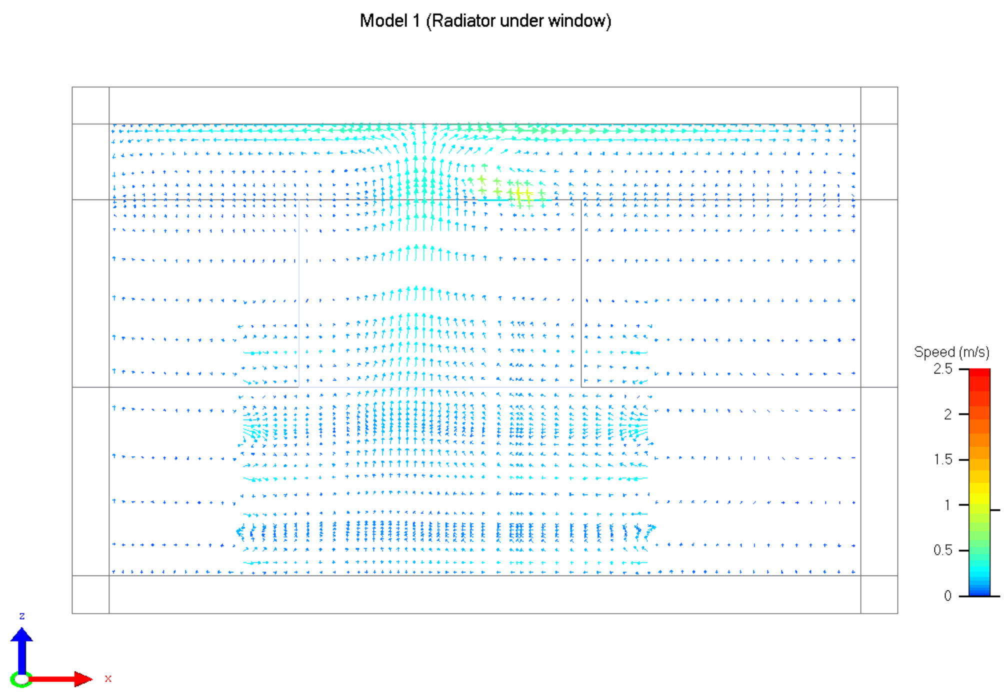


Figure 30 Model 1 Velocity Slice 9

4.2 MODEL 2 (RADIATOR AT INTERNAL WALL)

4.2.1 THERMAL COMFORT TEMPERATURE

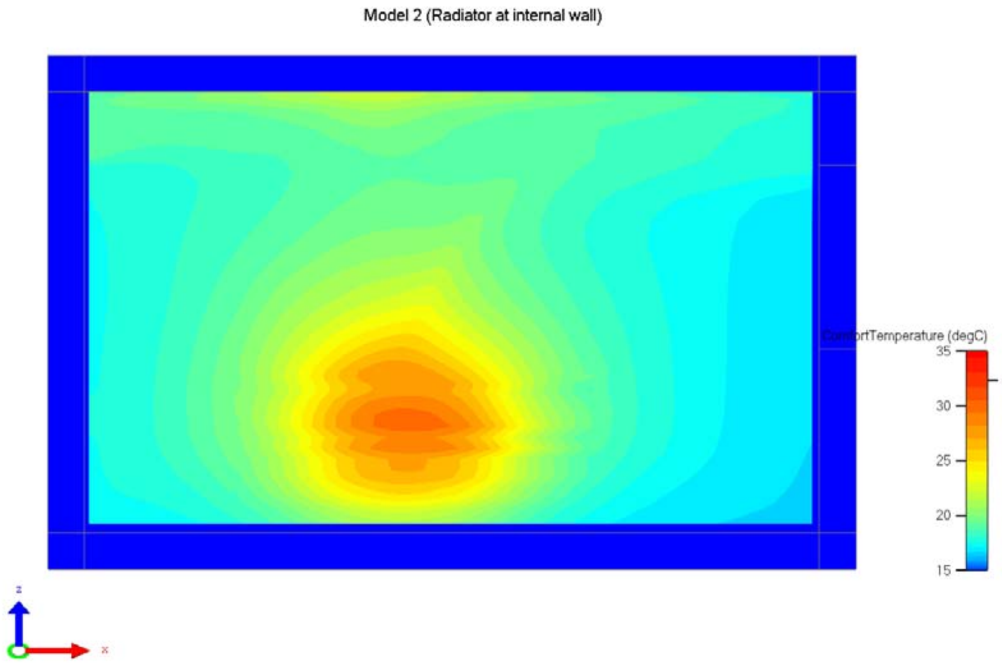


Figure 31 Model 2 Comfort Temperature Slice 1

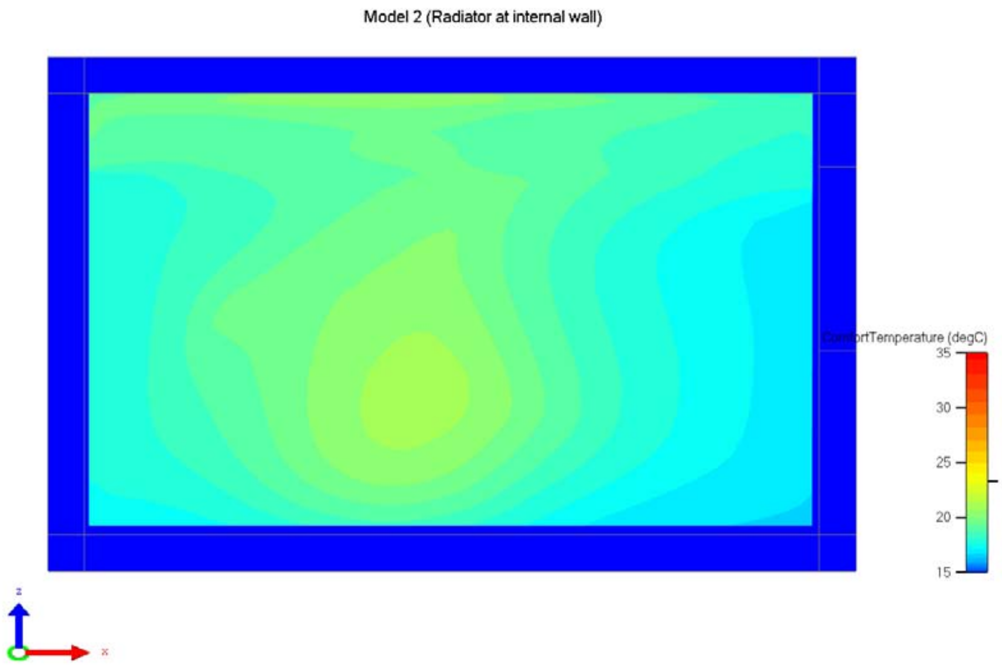


Figure 32 Model 2 Comfort Temperature Slice 2

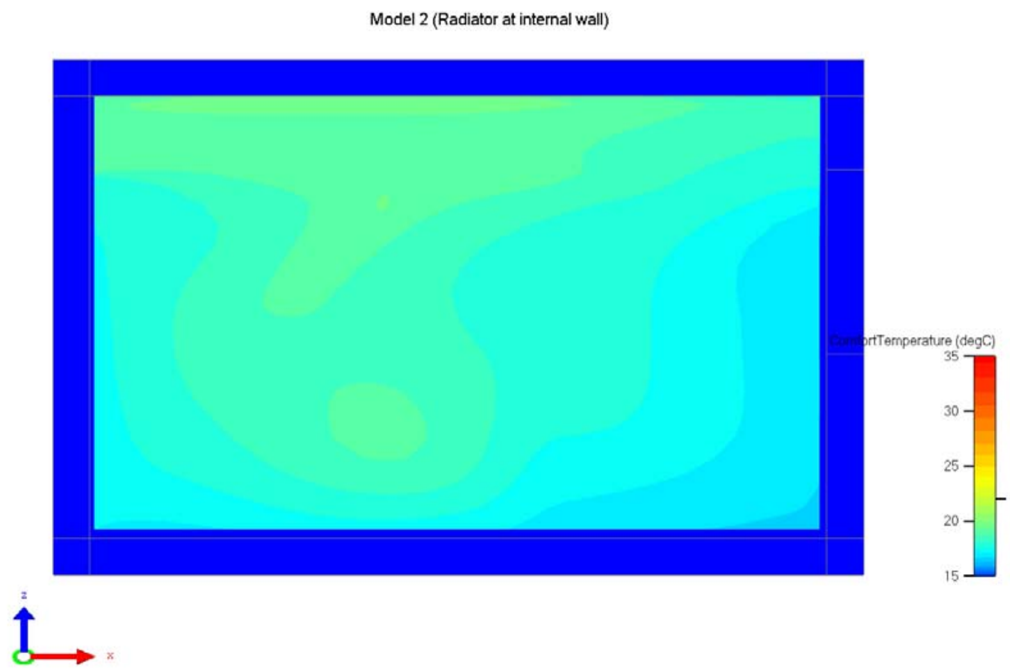


Figure 33 Model 2 Comfort Temperature Slice 3

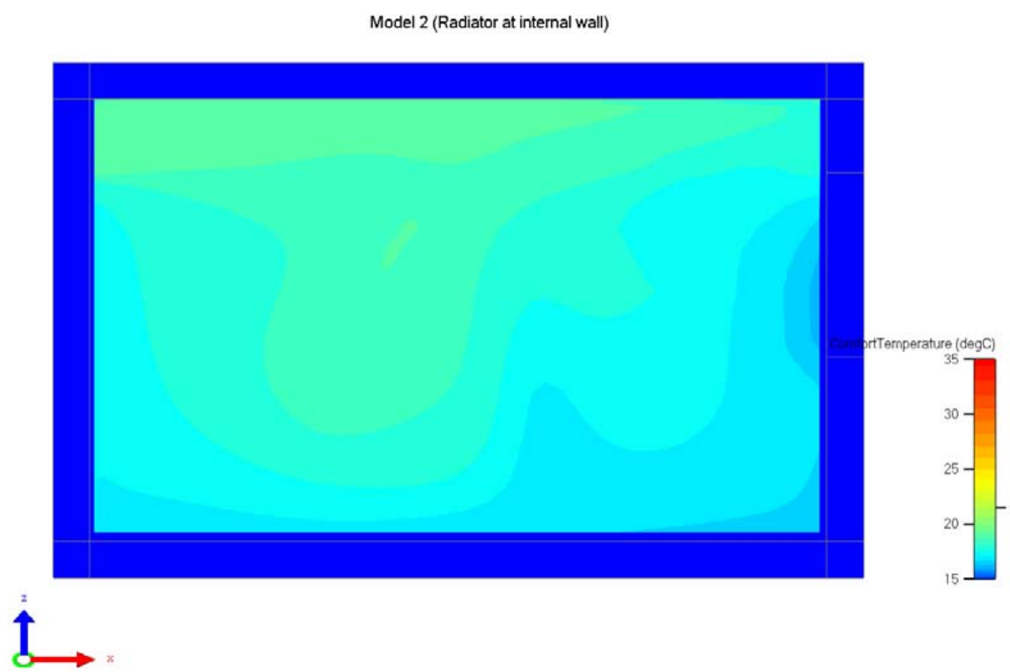


Figure 34 Model 2 Comfort Temperature Slice 4

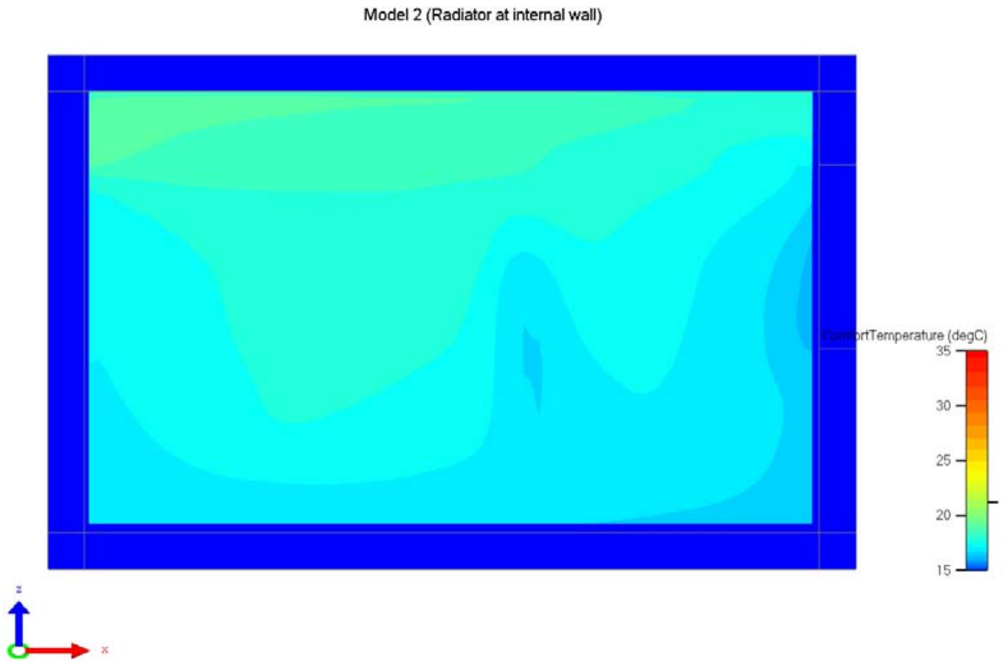


Figure 35 Model 2 Comfort Temperature Slice 5

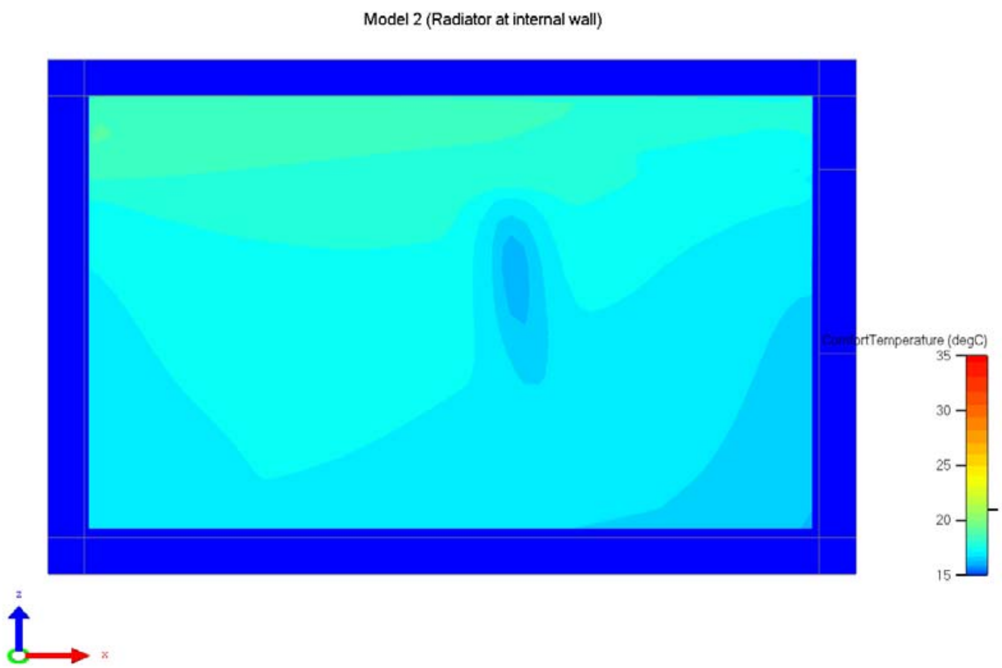


Figure 36 Model 2 Comfort Temperature Slice 6

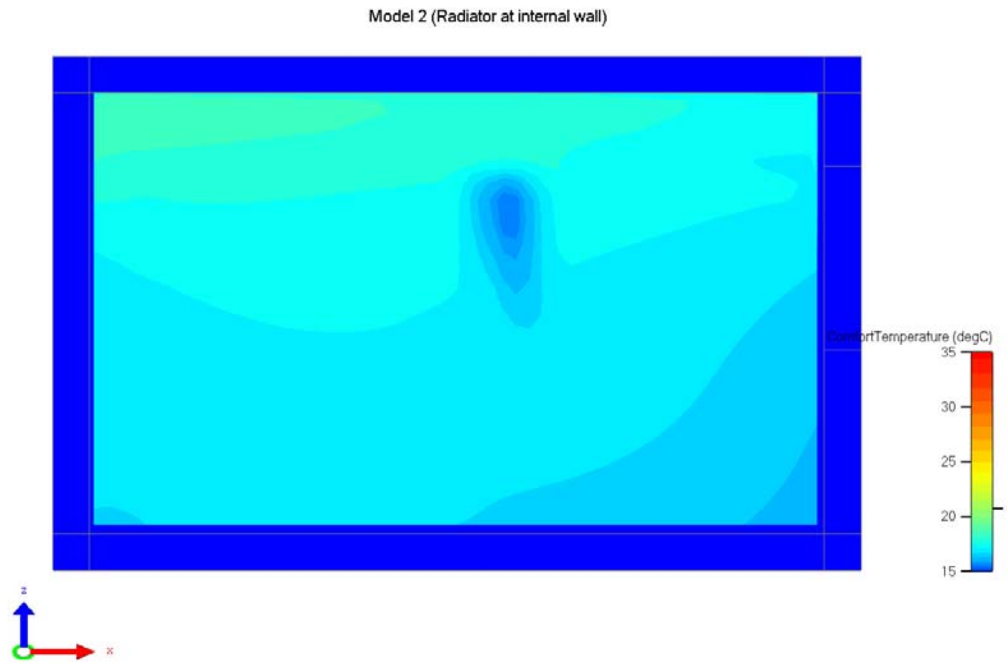


Figure 37 Model 2 Comfort Temperature Slice 7

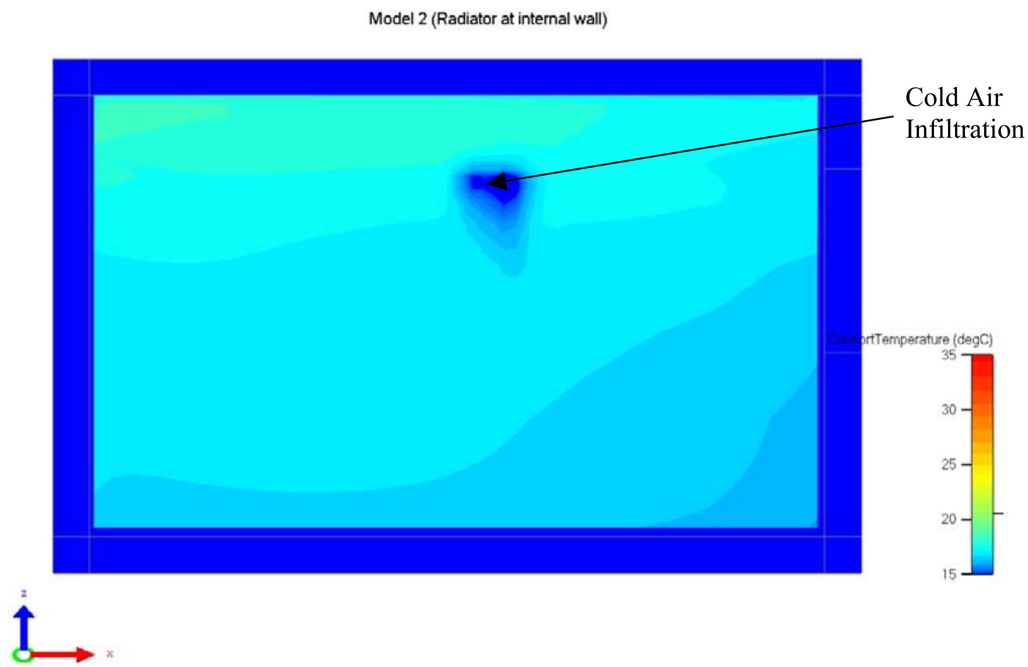


Figure 38 Model 2 Comfort Temperature Slice 8

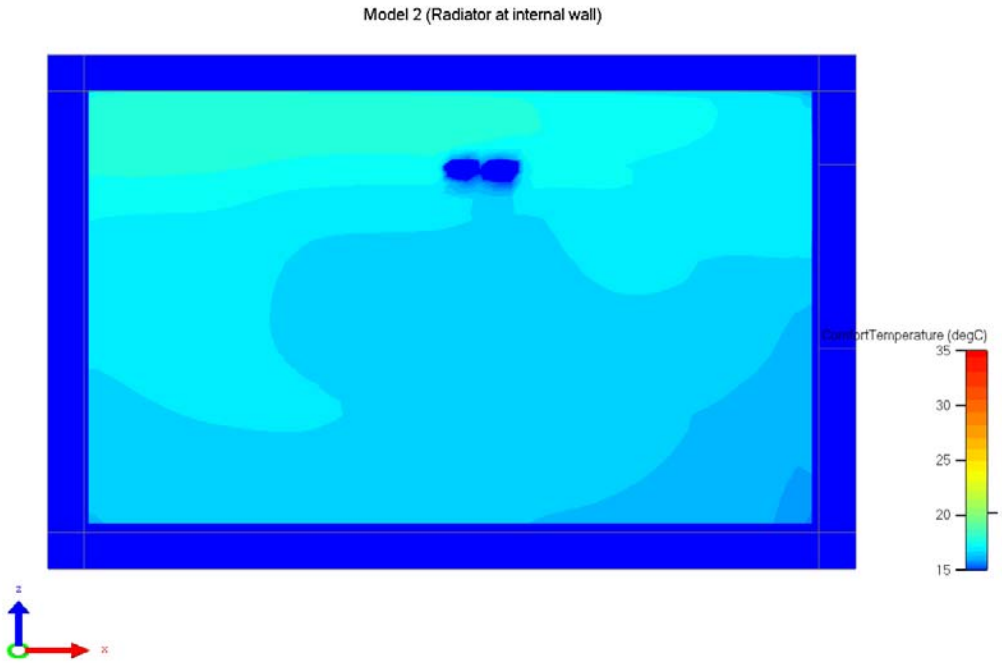


Figure 39 Model 2 Comfort Temperature Slice 9

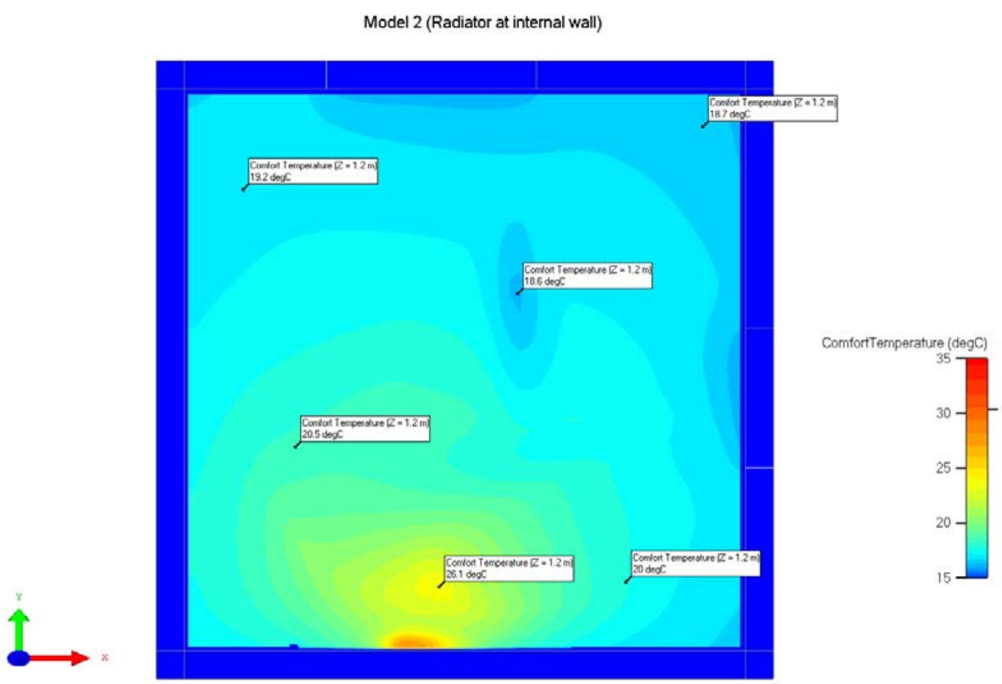


Figure 40 Model 2 Comfort Temperature at Z=1.2m (1.2 m Above Floor)

4.2.2 TEMPERATURE

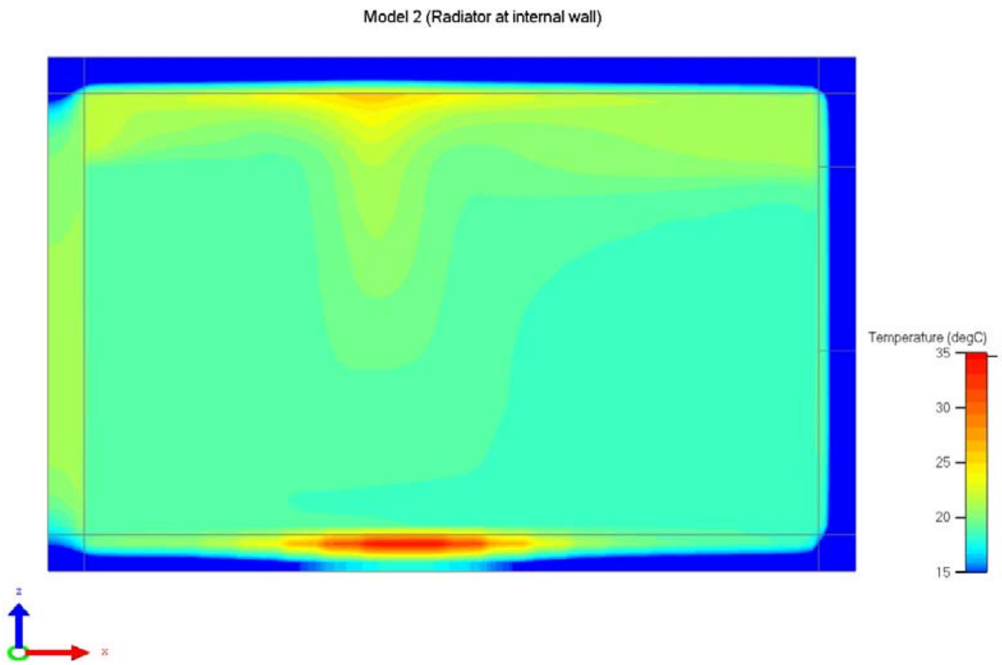


Figure 41 Model 2 Temperature Slice 1

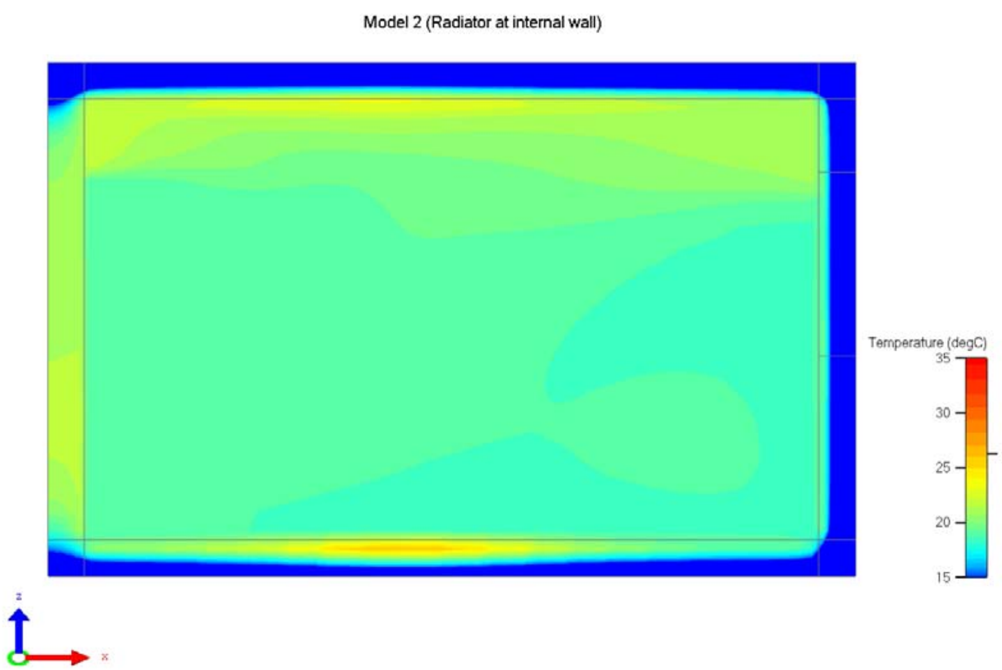


Figure 42 Model 2 Temperature Slice 2

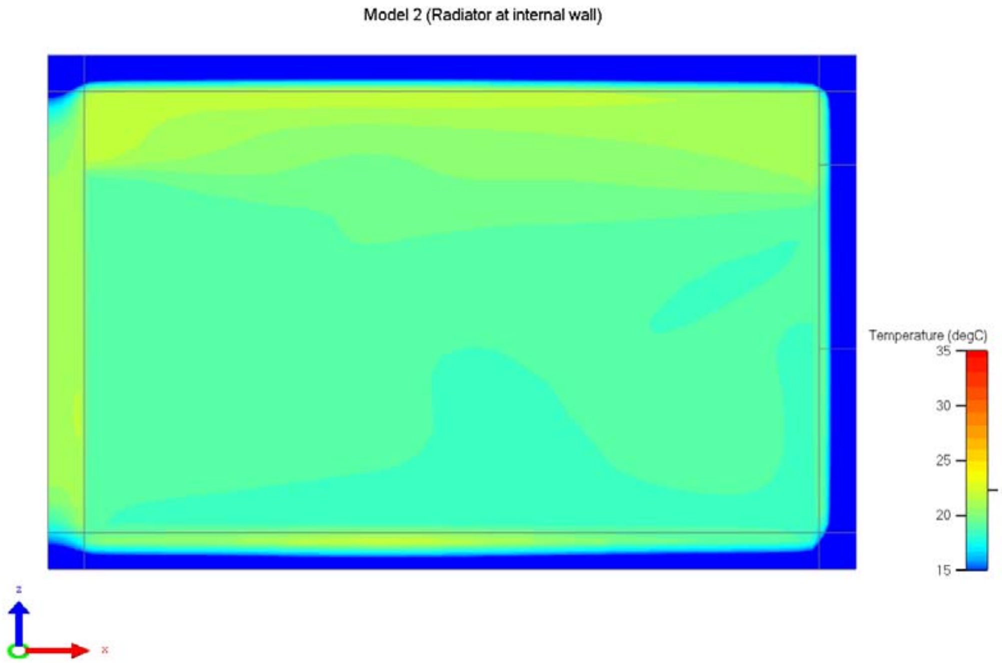


Figure 43 Model 2 Temperature Slice 3

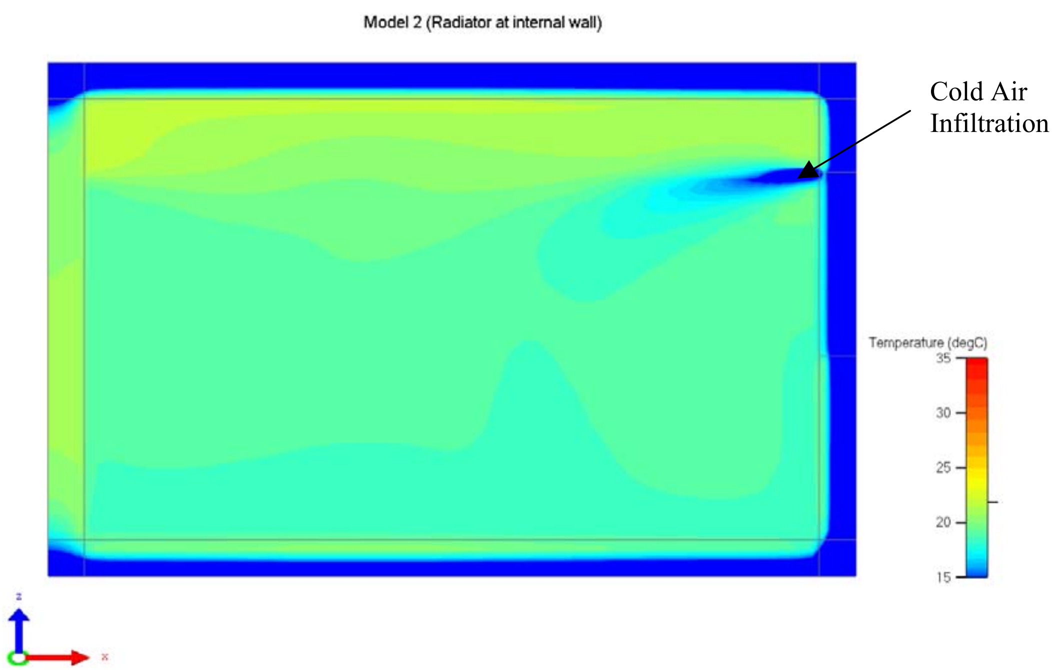


Figure 44 Model 2 Temperature Slice 4

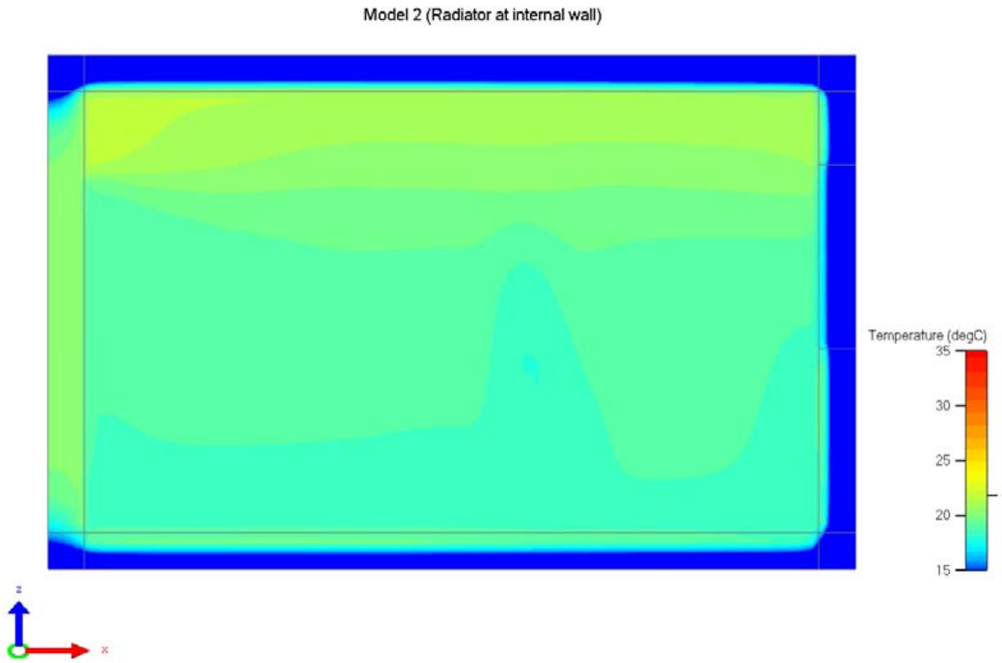


Figure 45 Model 2 Temperature Slice 5

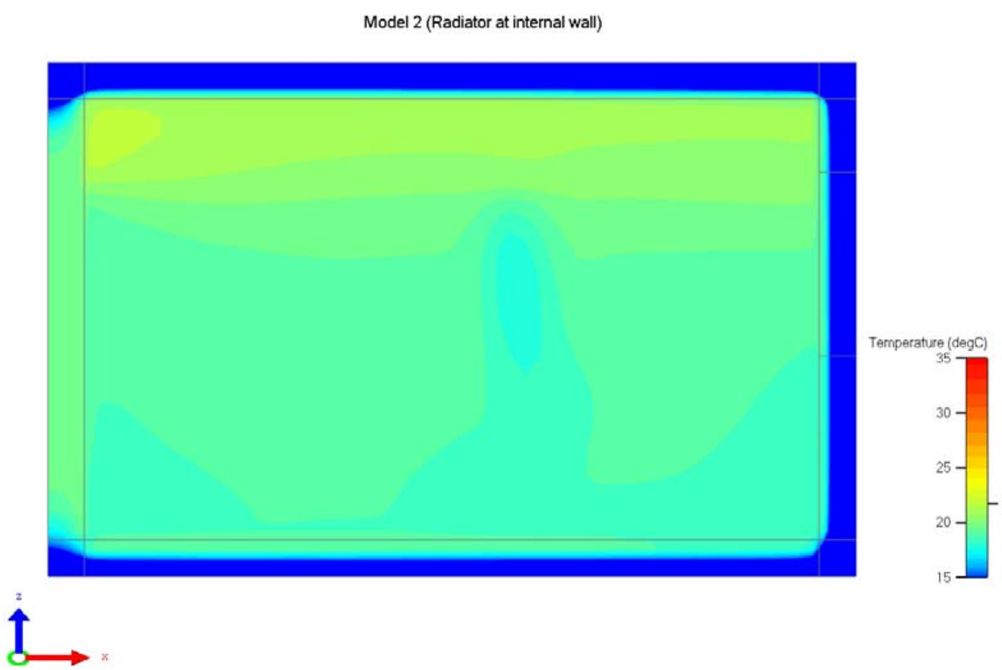


Figure 46 Model 2 Temperature Slice 6

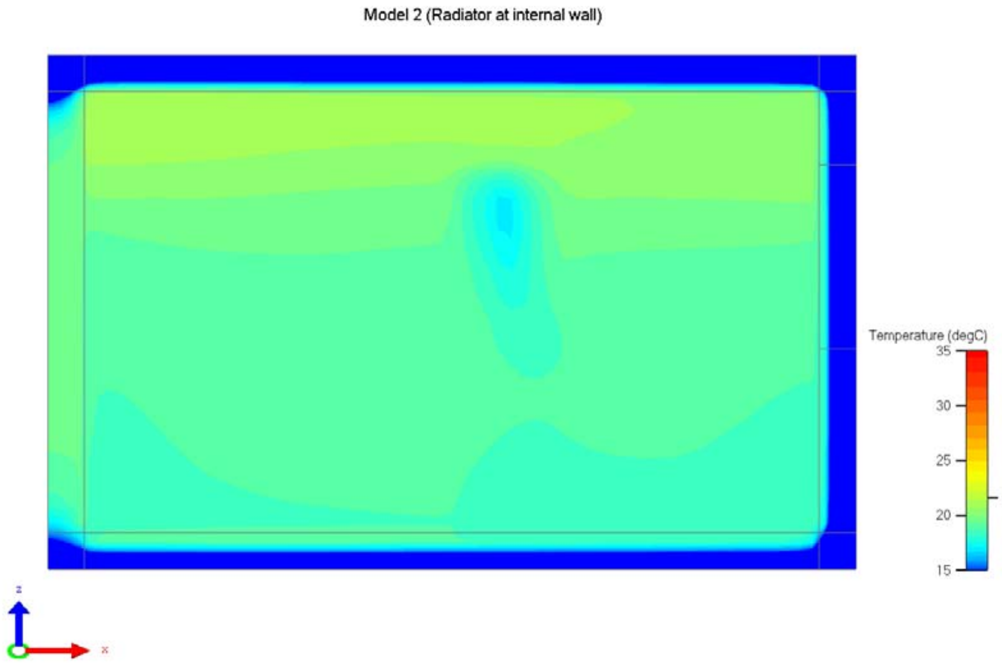


Figure 47 Model 2 Temperature Slice 7

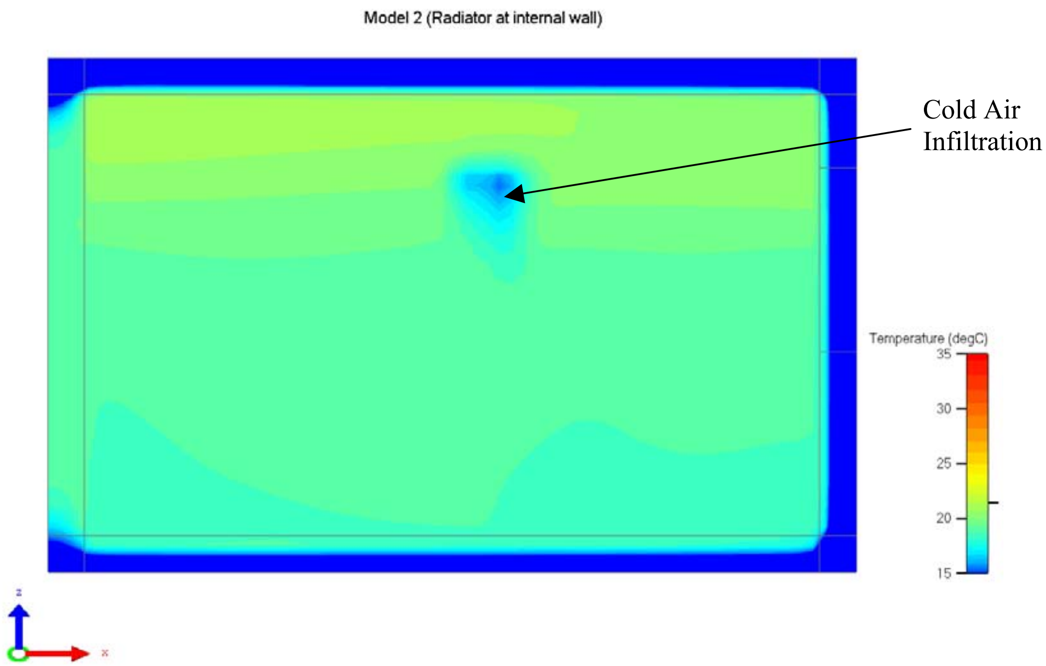


Figure 48 Model 2 Temperature Slice 8

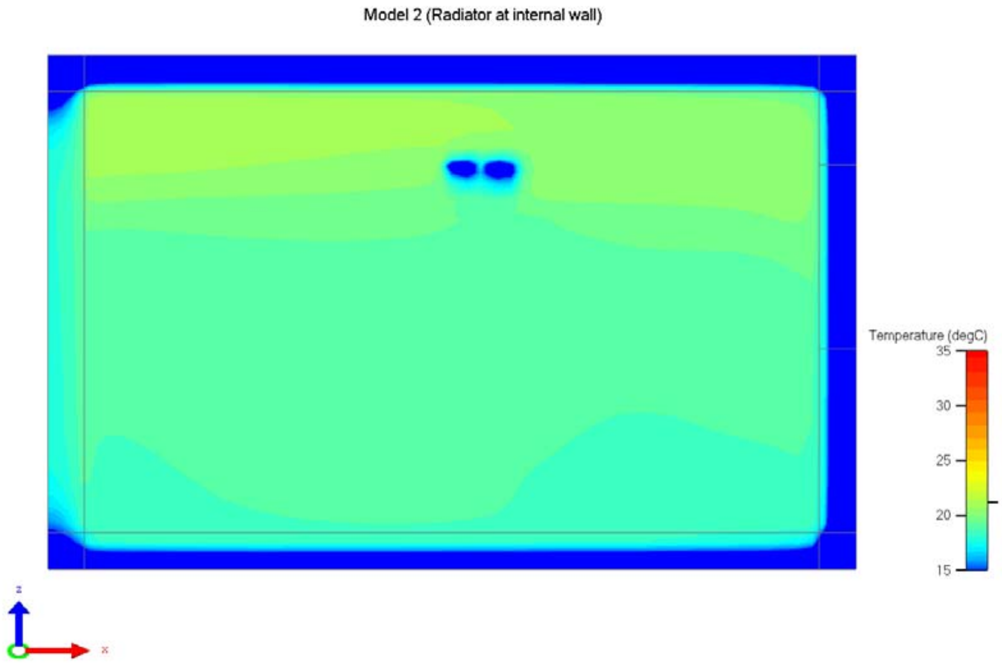


Figure 49 Model 2 Temperature Slice 9

4.2.3 VELOCITY

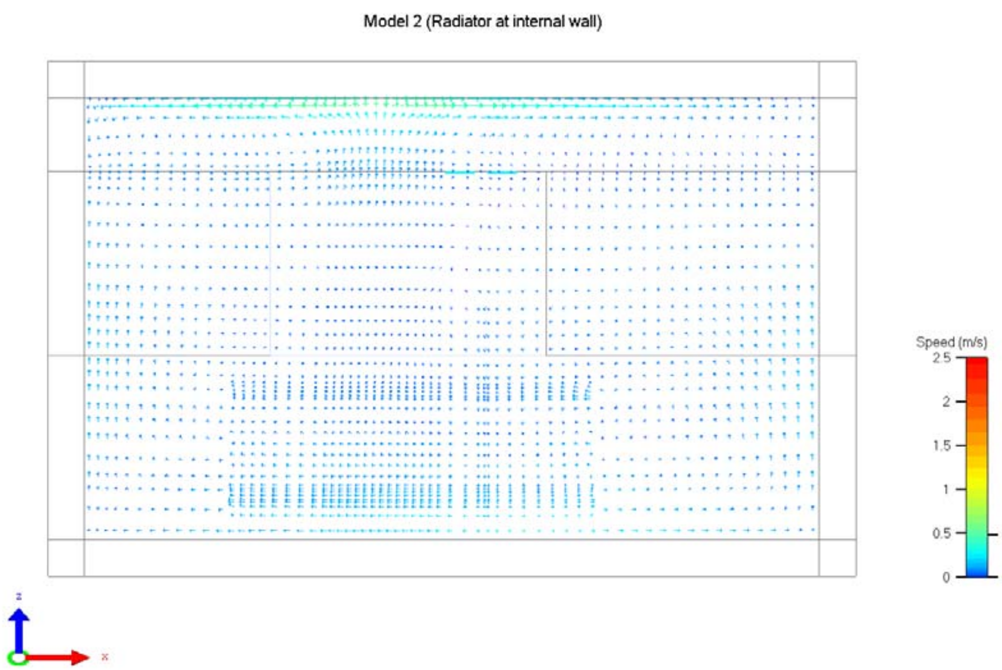


Figure 50 Model 2 Velocity Slice 1

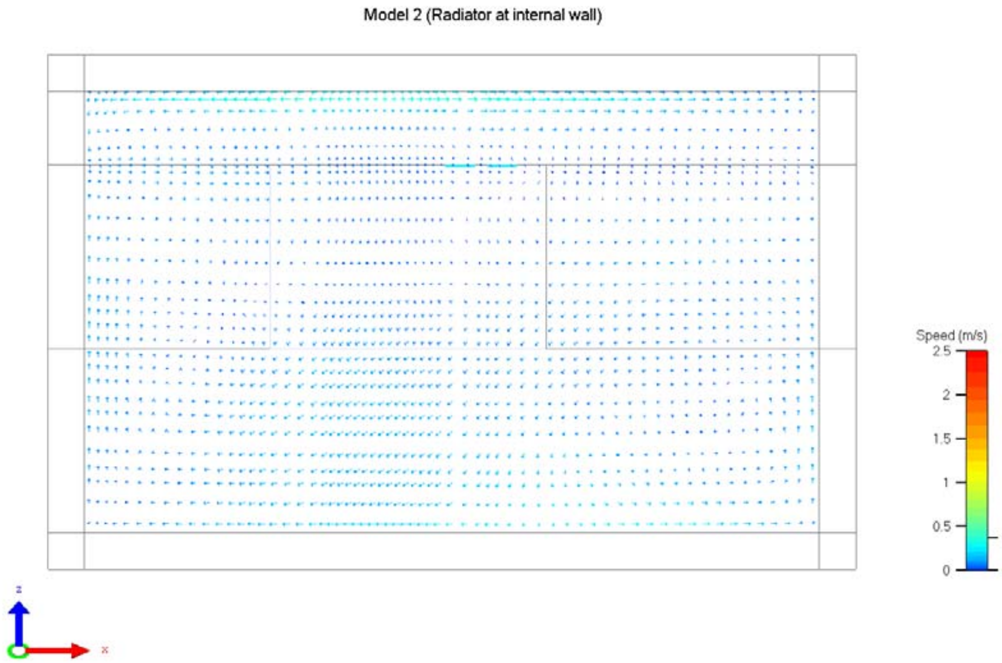


Figure 51 Model 2 Velocity Slice 2

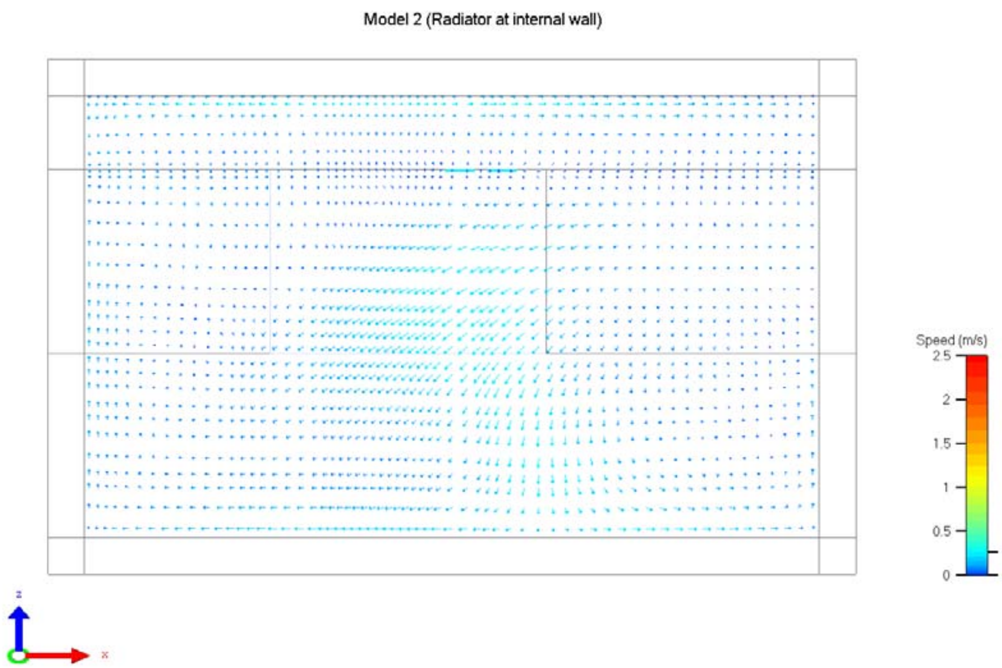


Figure 52 Model 2 Velocity Slice 3

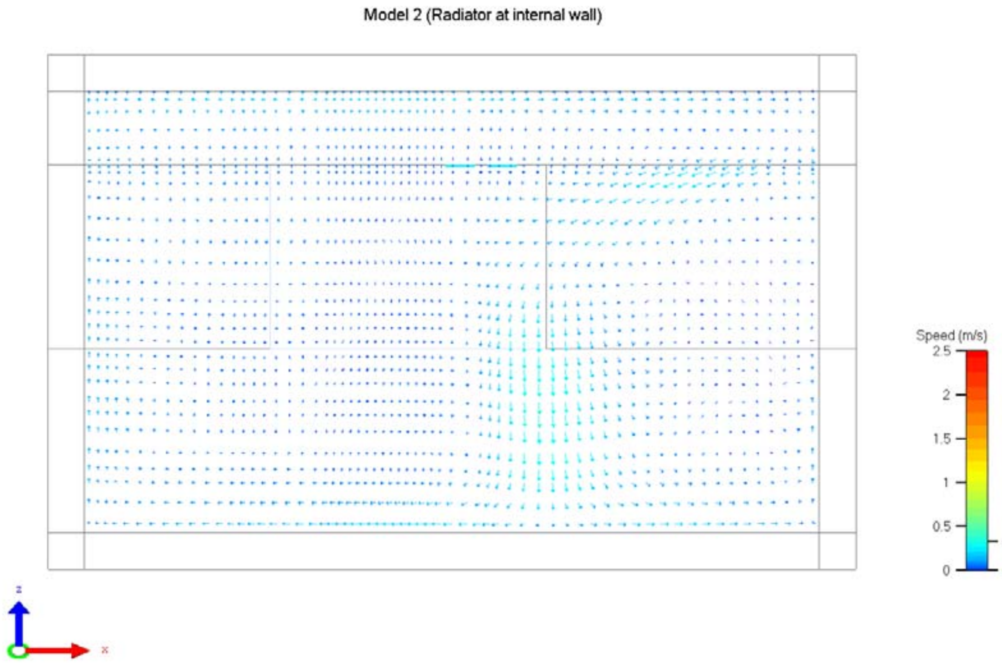


Figure 53 Model 2 Velocity Slice 4

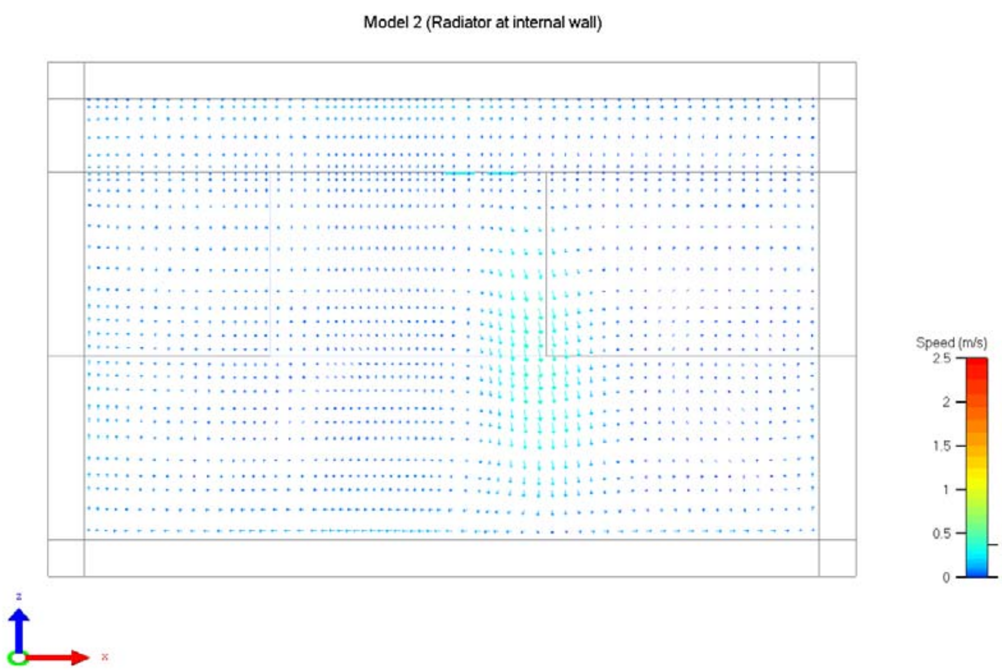


Figure 54 Model 2 Velocity Slice 5

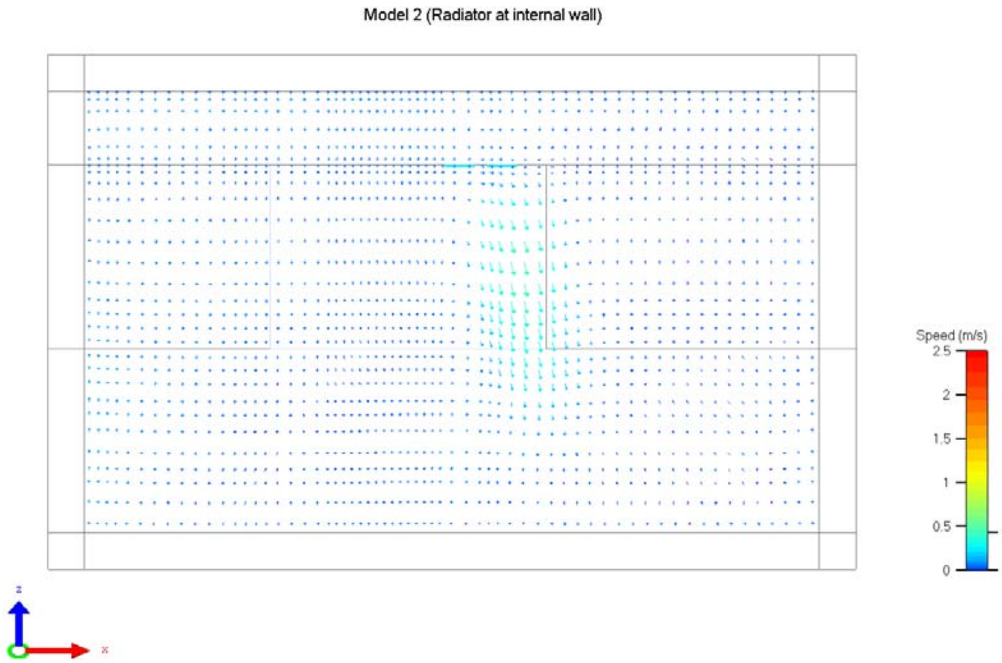


Figure 55 Model 2 Velocity Slice 6

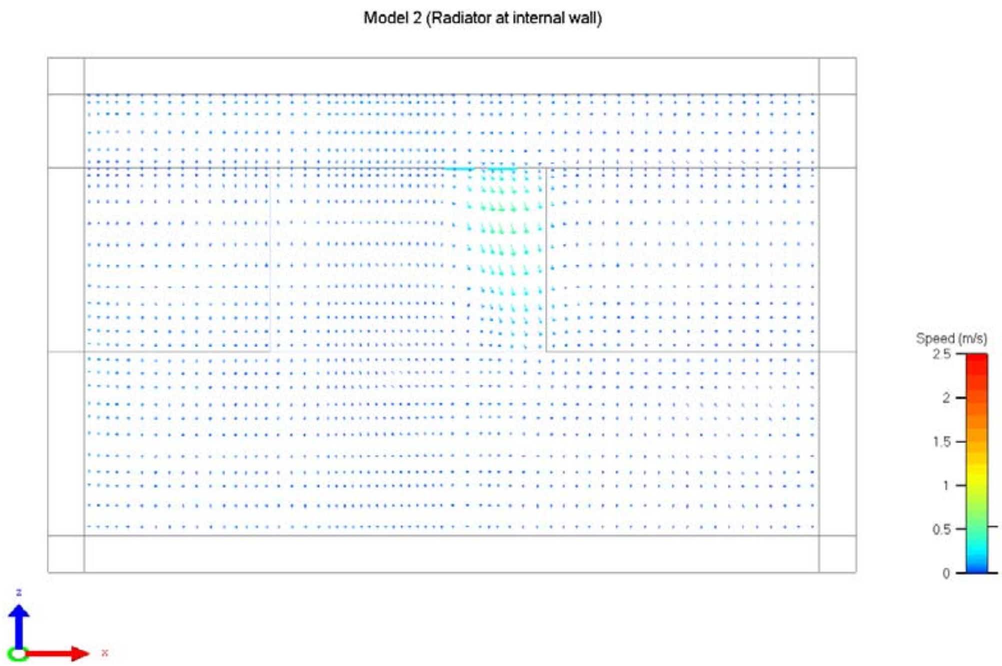


Figure 56 Model 2 Velocity Slice 7

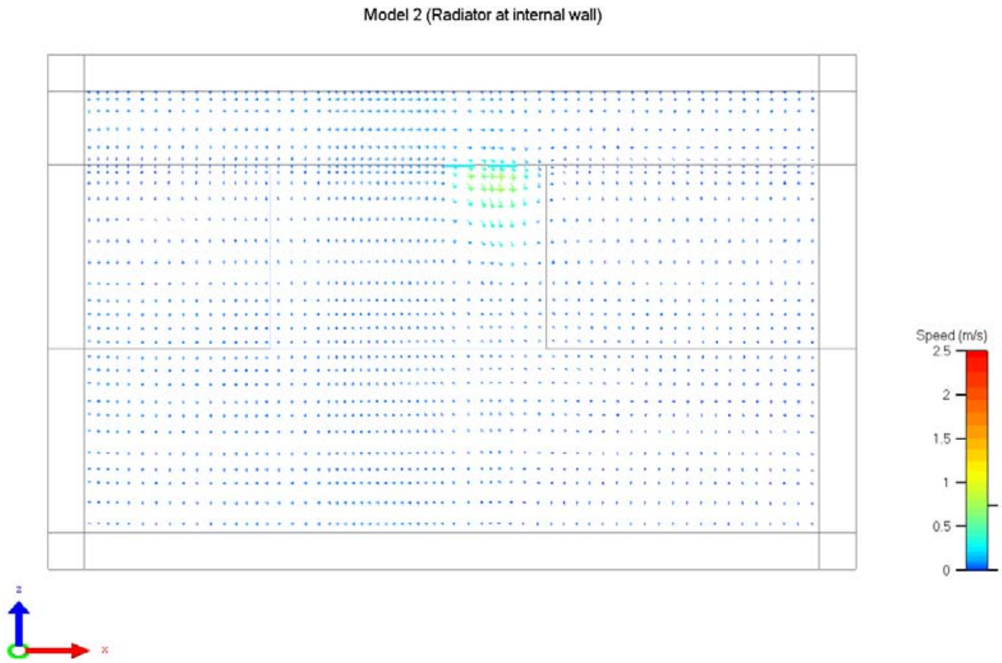


Figure 57 Model 2 Velocity Slice 8

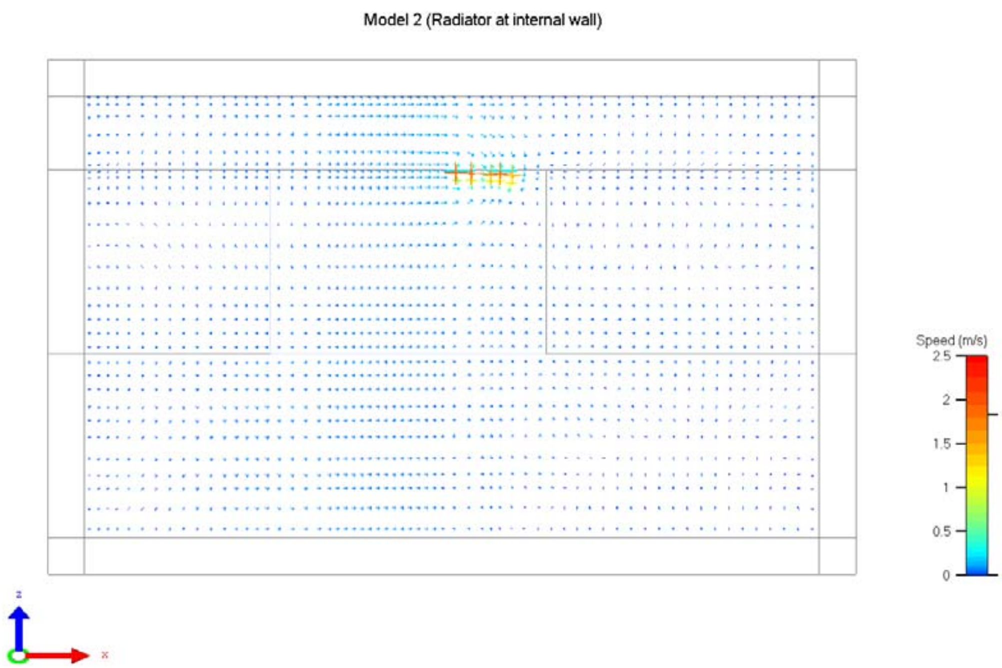


Figure 58 Model 2 Velocity Slice 9

4.3 MODEL 3 (THERMASKIRT)

4.3.1 THERMAL COMFORT TEMPERATURE

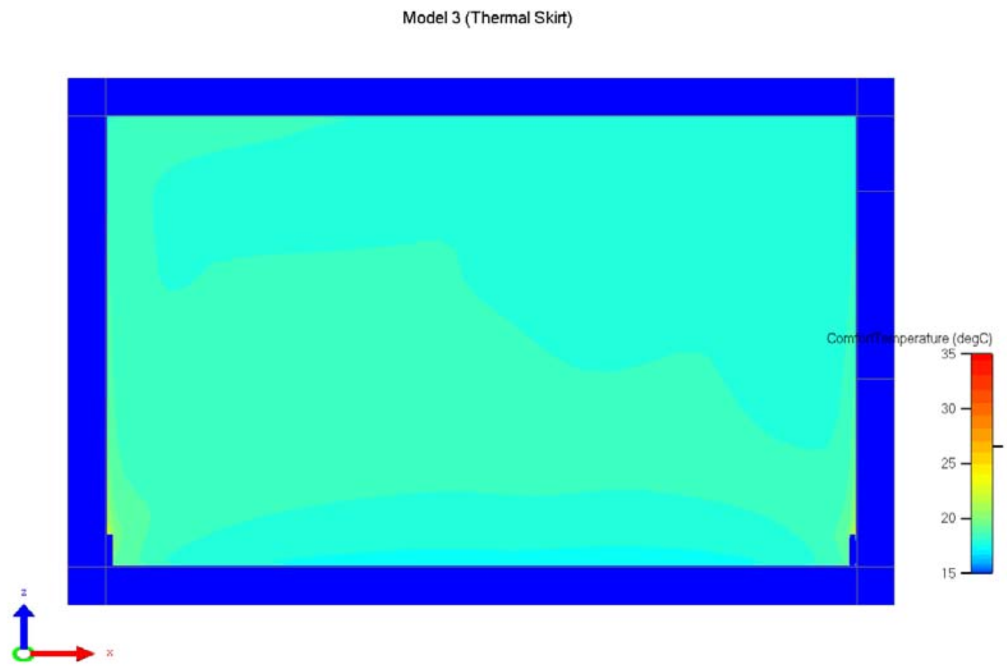


Figure 59 Model 2 Comfort Temperature Slice 1

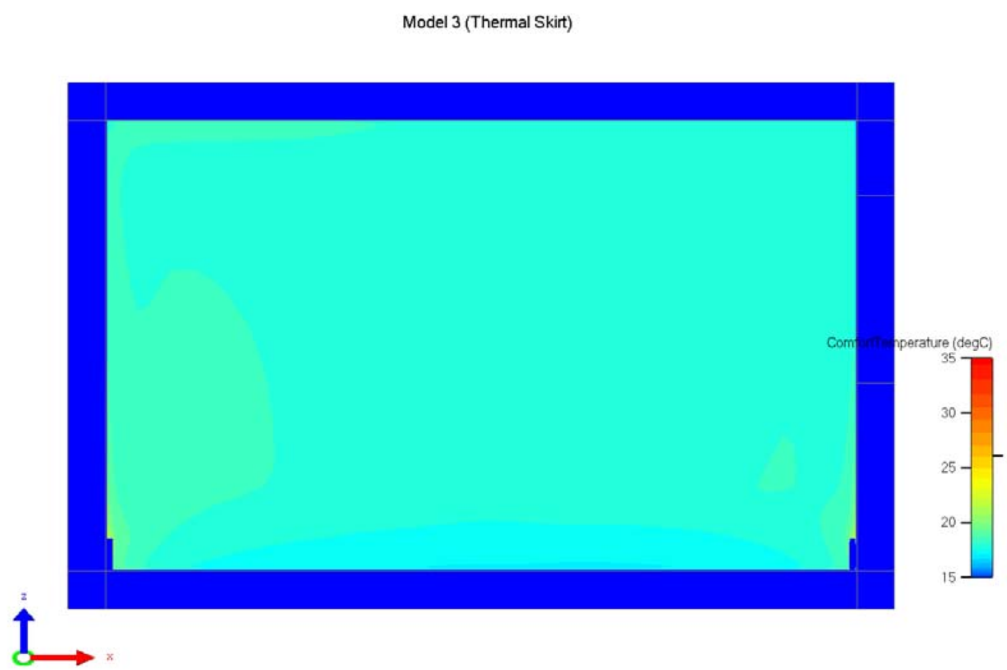


Figure 60 Model 3 Comfort Temperature Slice 2

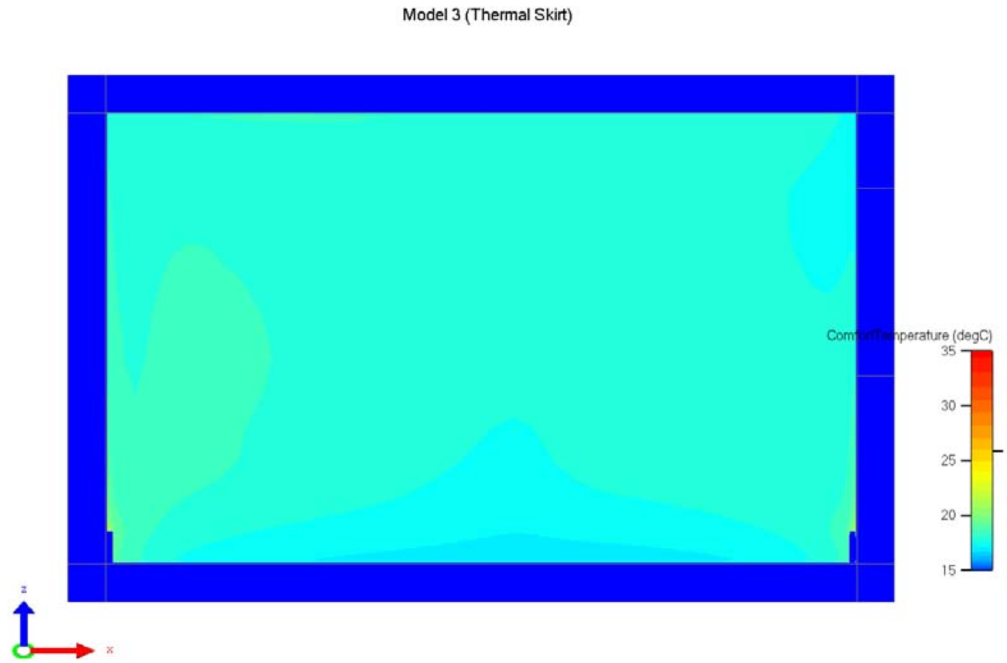


Figure 61 Model 3 Comfort Temperature Slice 3

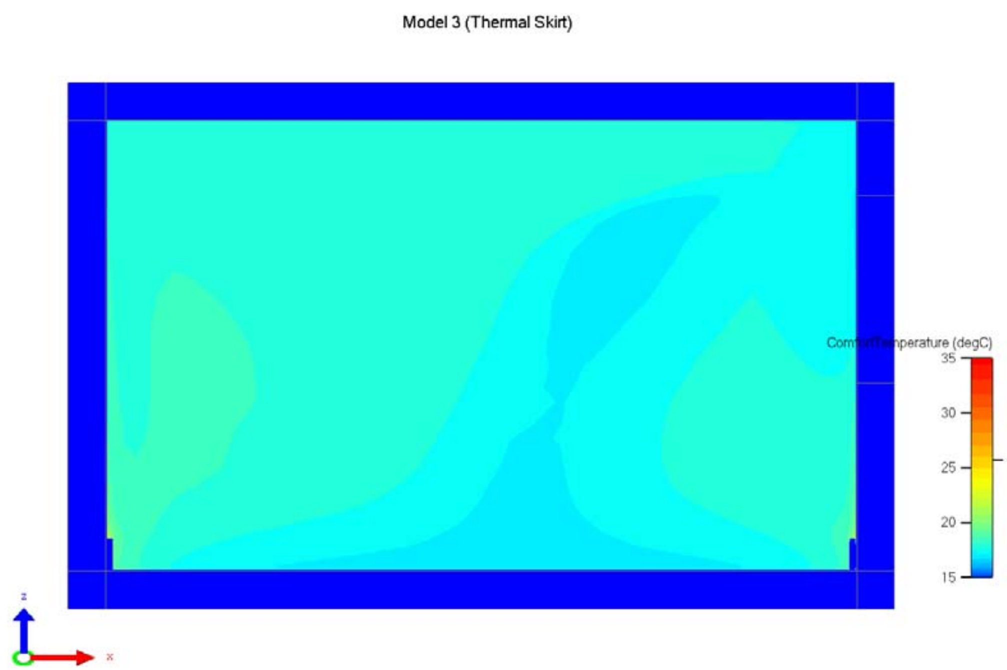


Figure 62 Model 3 Comfort Temperature Slice 4

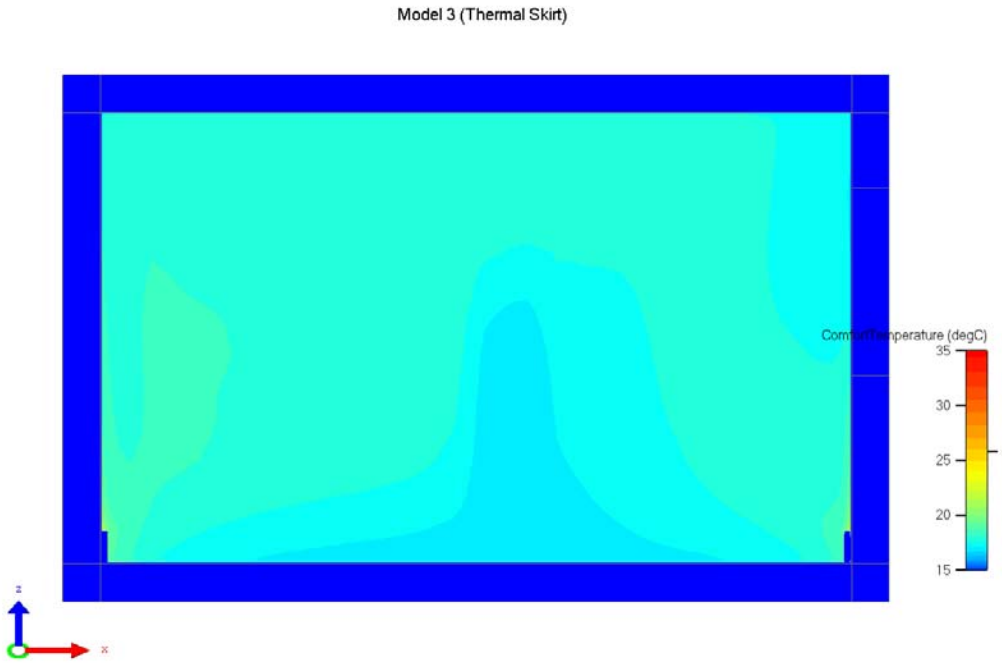


Figure 63 Model 3 Comfort Temperature Slice 5

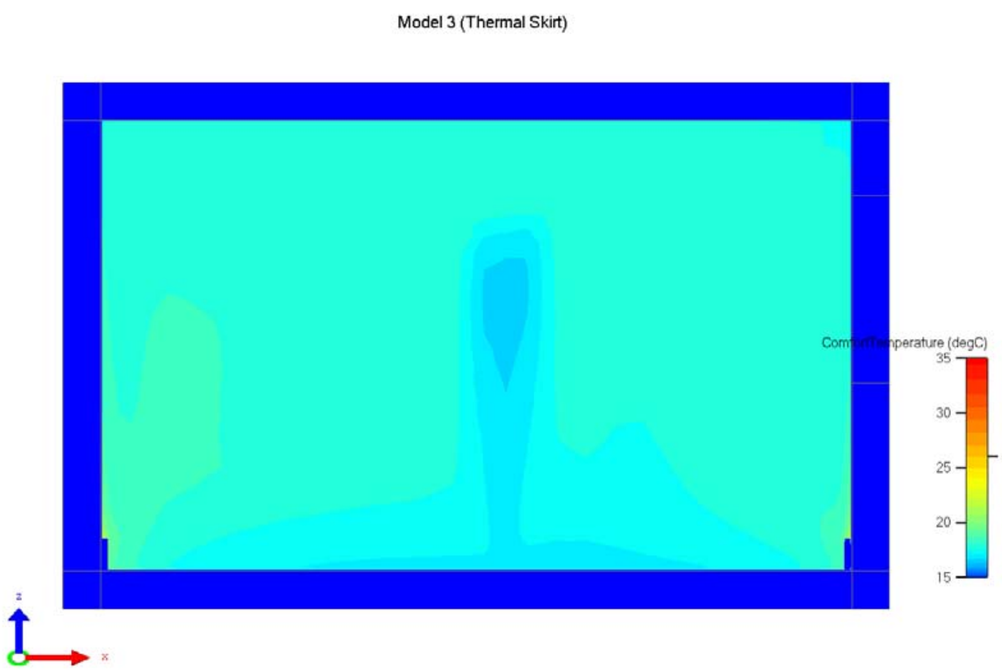


Figure 64 Model 3 Comfort Temperature Slice 6

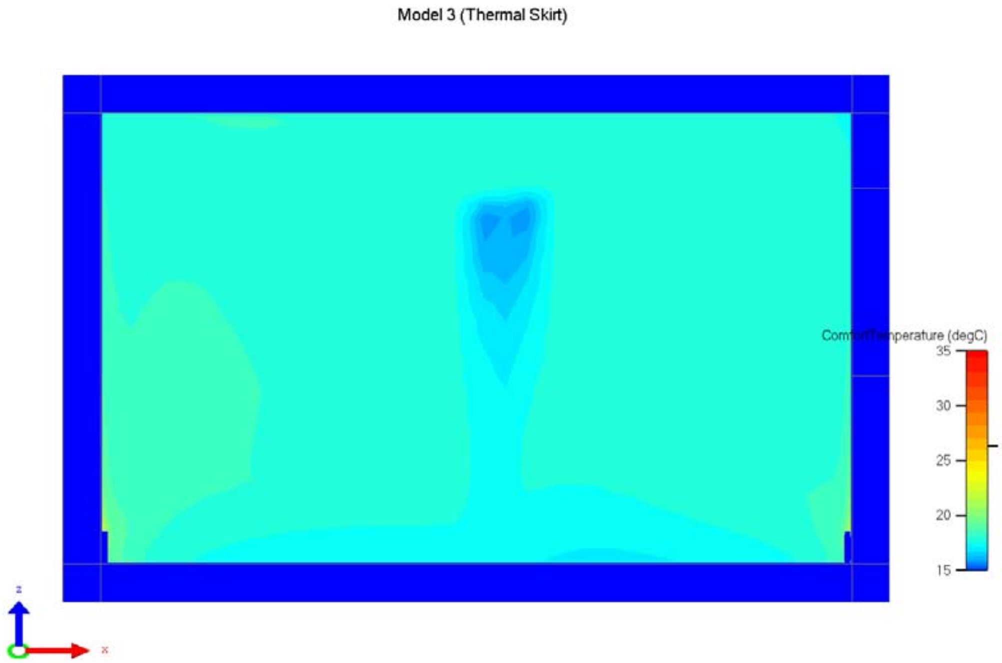


Figure 65 Model 3 Comfort Temperature Slice 7

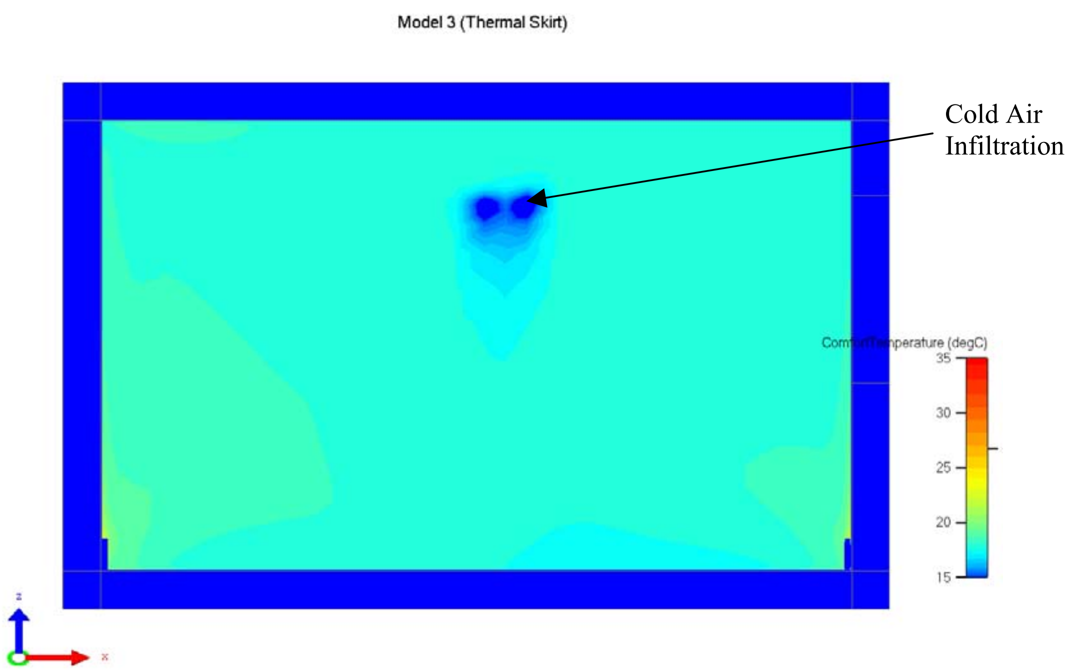


Figure 66 Model 3 Comfort Temperature Slice 8

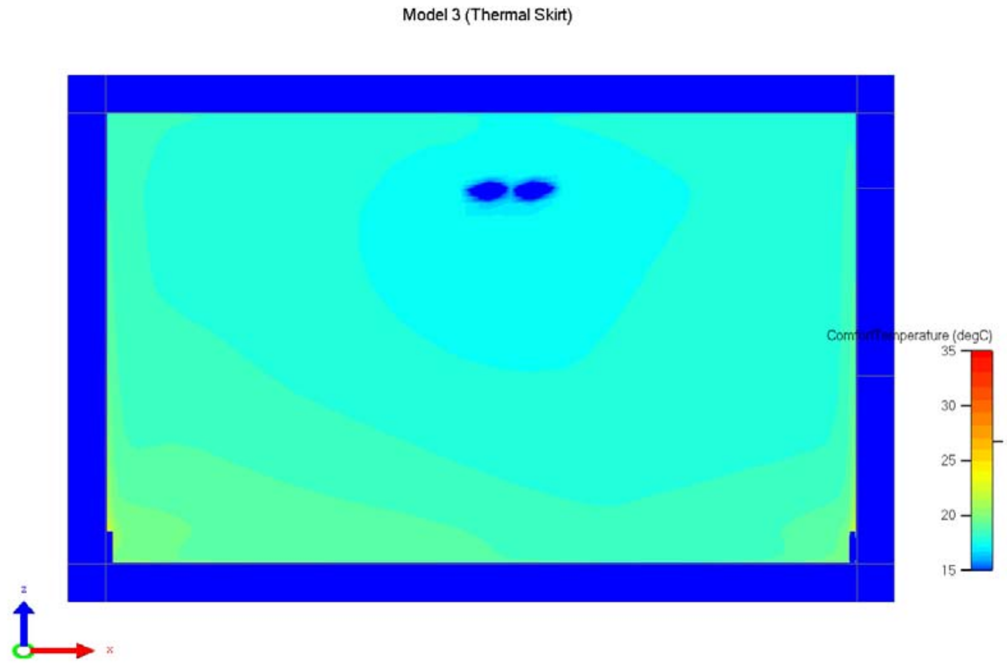


Figure 67 Model 3 Comfort Temperature Slice 9

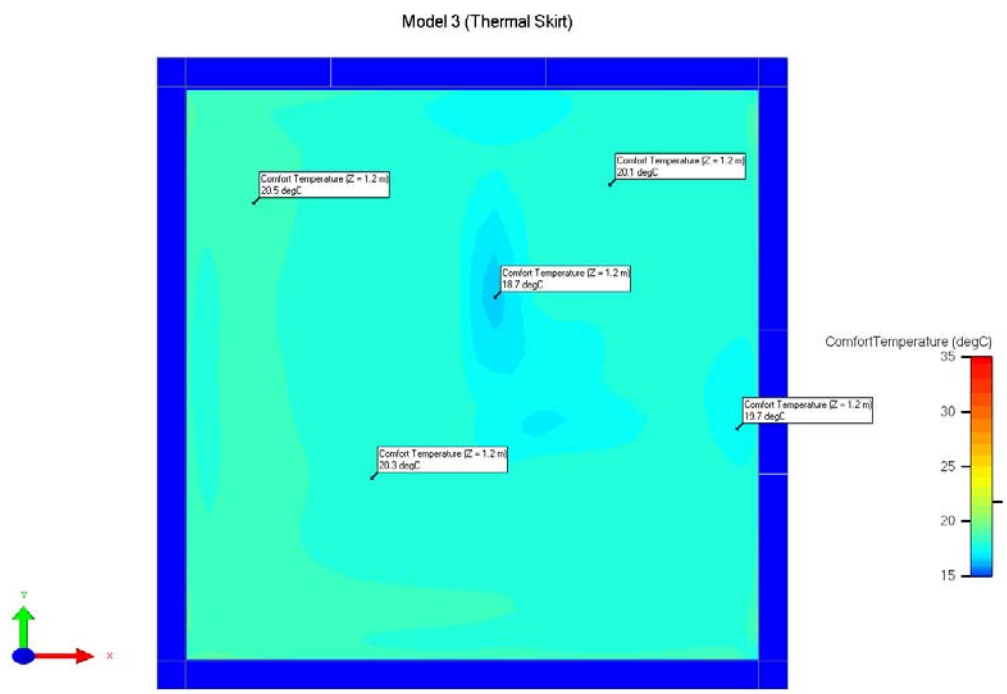


Figure 68 Model 3 Comfort Temperature at Z=1.2m (1.2 m Above Floor)

4.3.2 TEMPERATURE

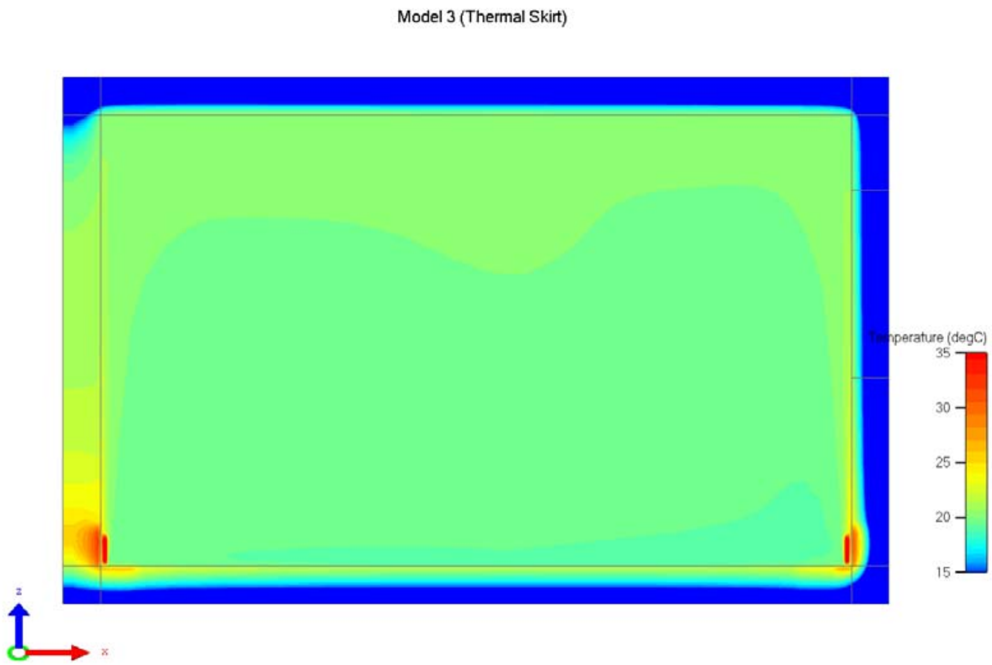


Figure 69 Model 3 Temperature Slice 1

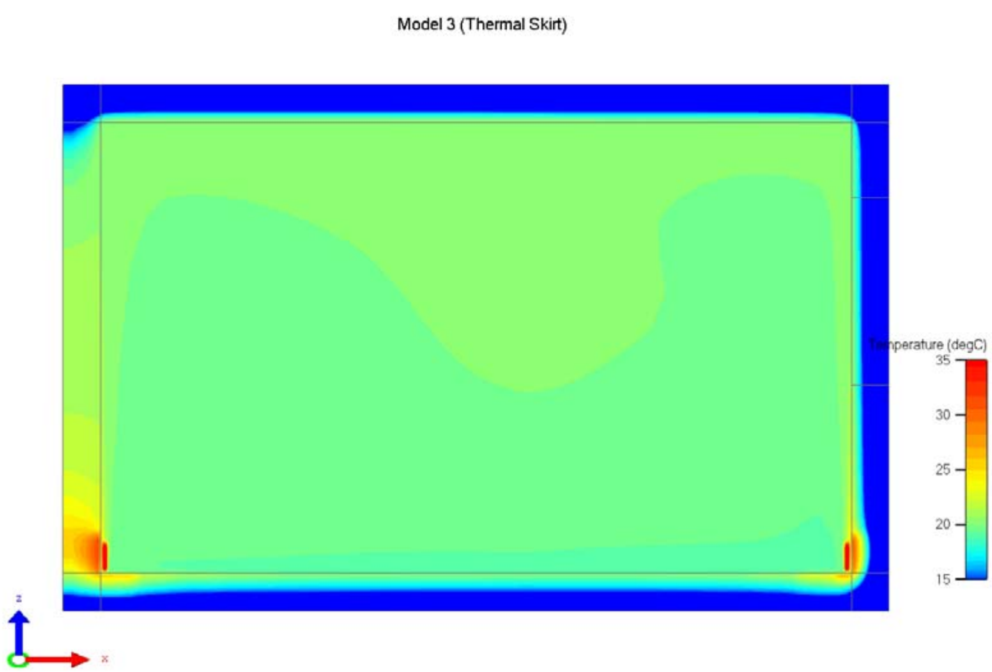


Figure 70 Model 3 Temperature Slice 2

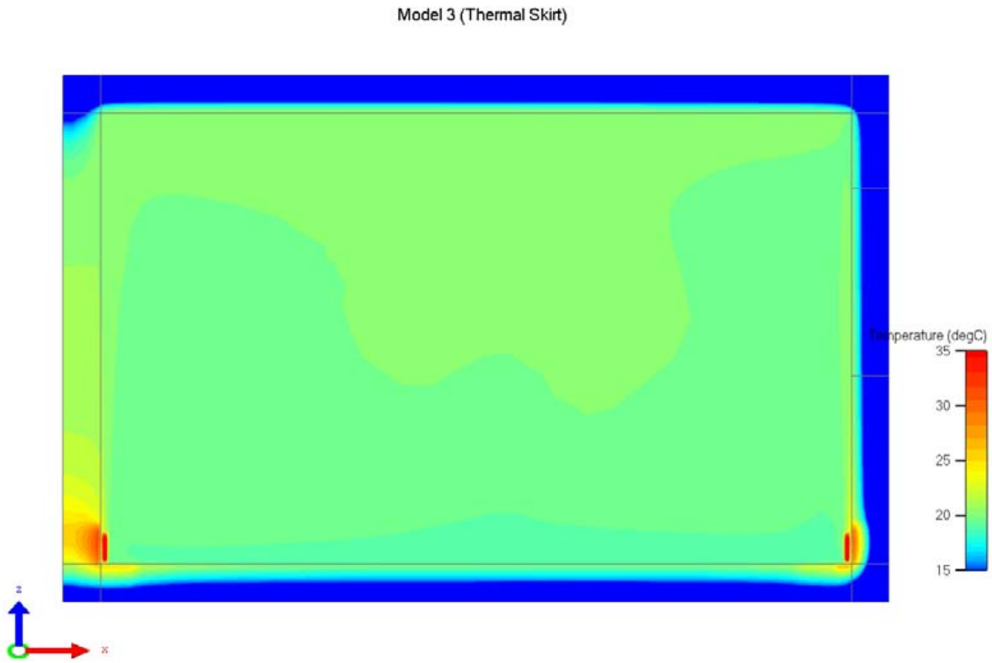


Figure 71 Model 3 Temperature Slice 3

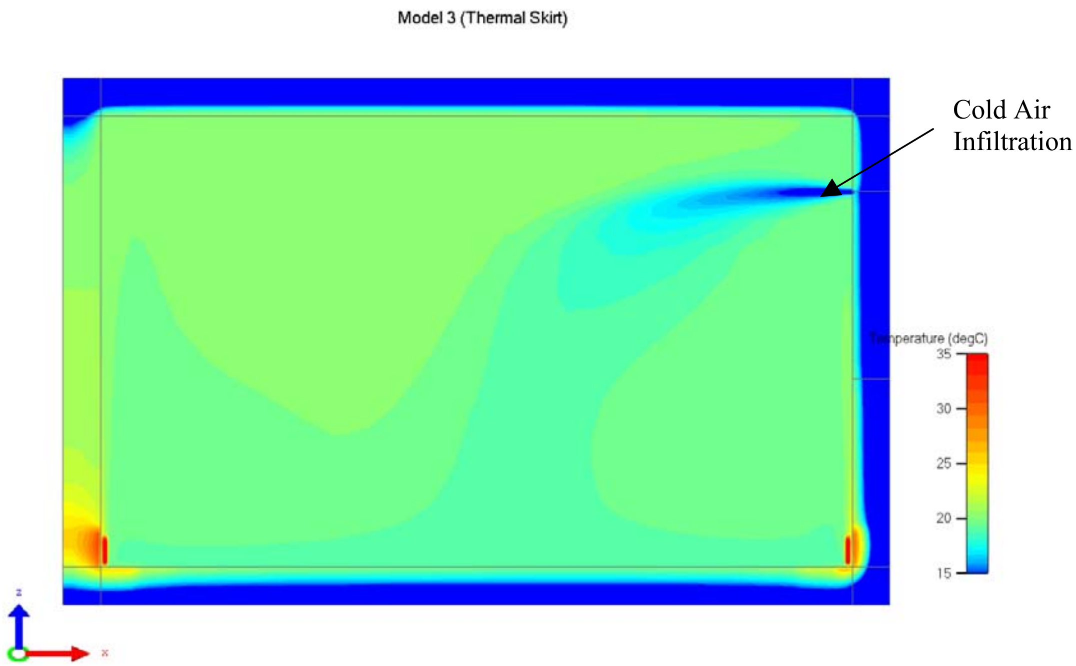


Figure 72 Model 3 Temperature Slice 4

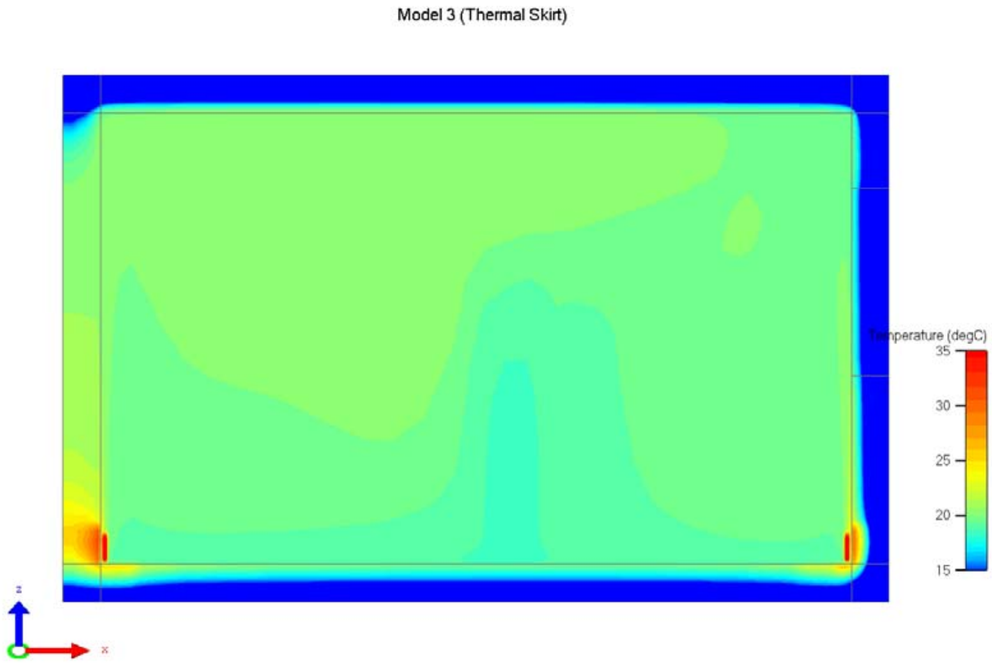


Figure 73 Model 3 Temperature Slice 5

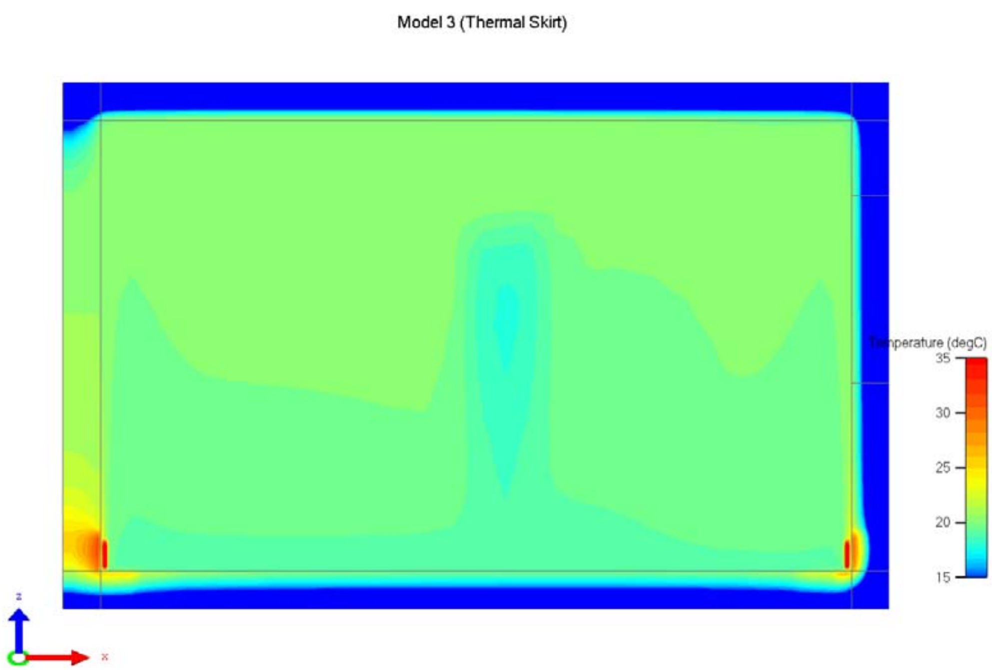


Figure 74 Model 3 Temperature Slice 6

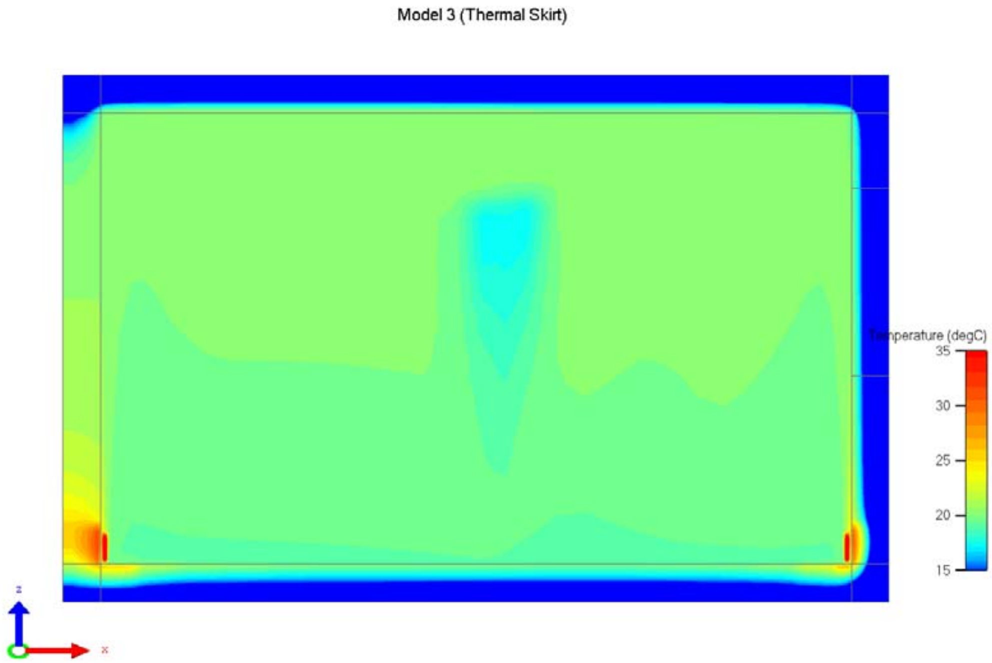


Figure 75 Model 3 Temperature Slice 7

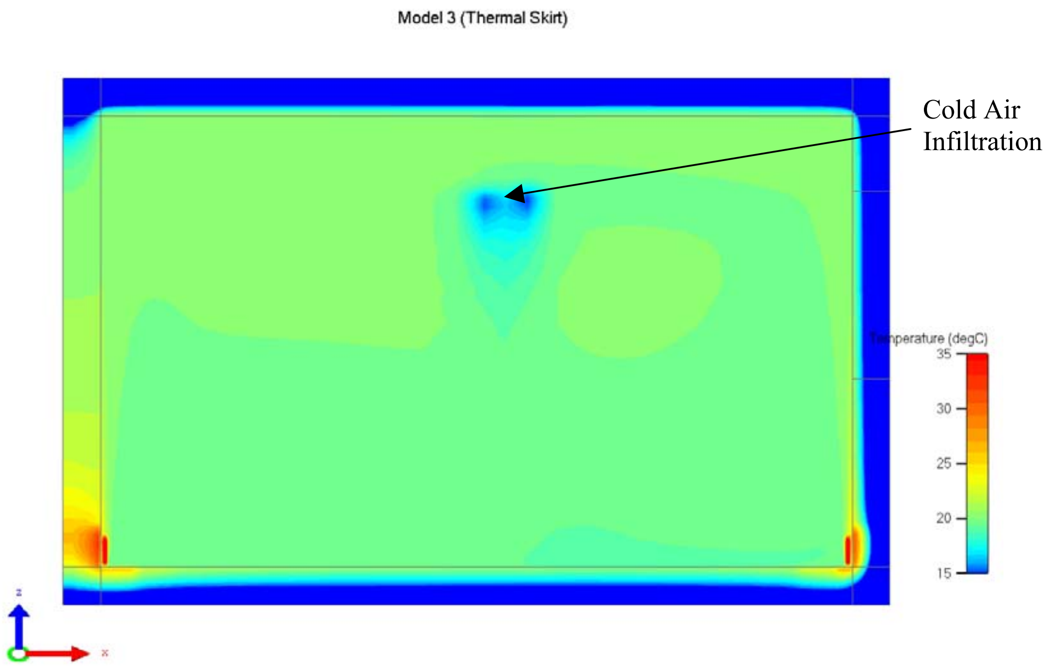


Figure 76 Model 3 Temperature Slice 8

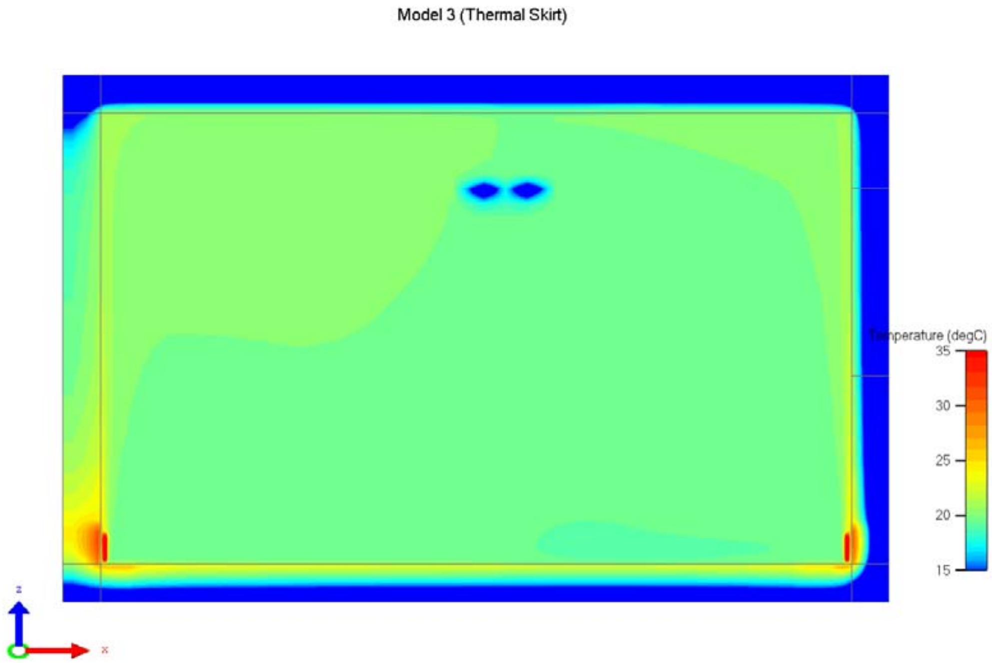


Figure 77 Model 3 Temperature Slice 9

4.3.3 VELOCITY

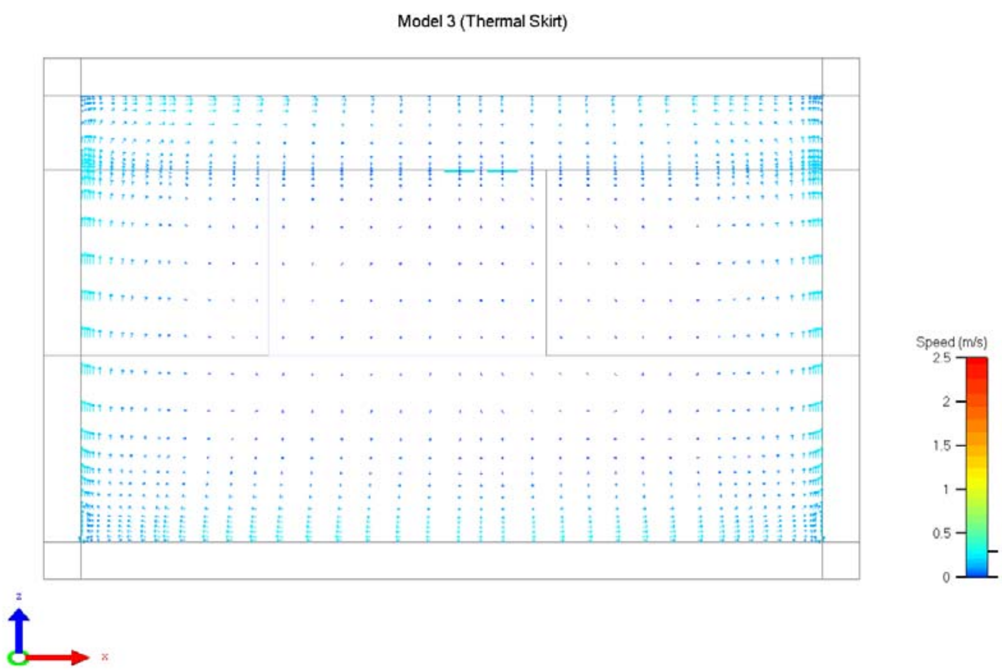


Figure 78 Model 3 Velocity Slice 1

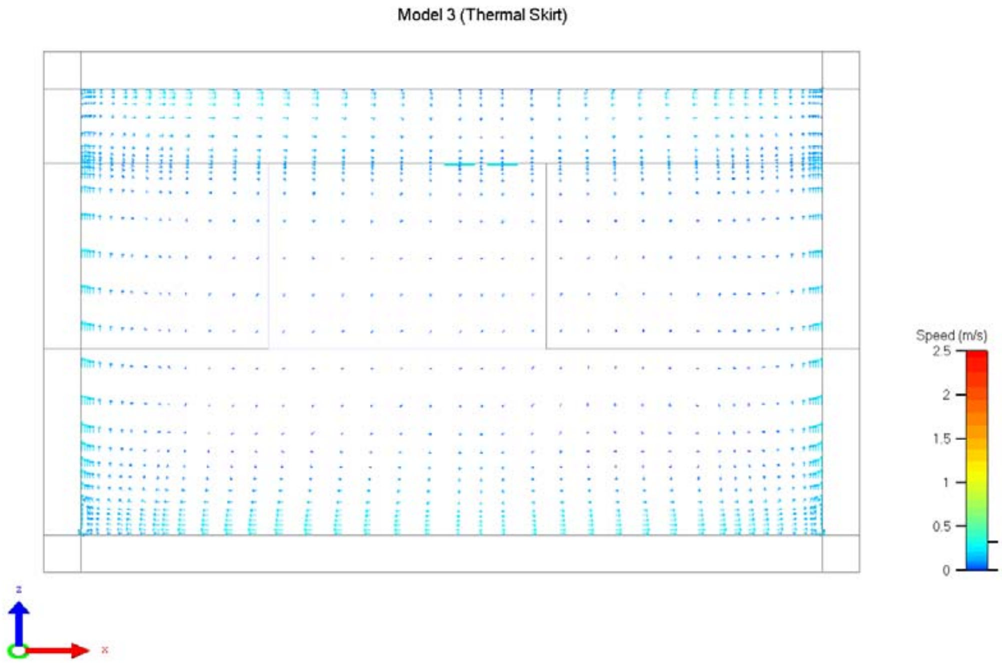


Figure 79 Model 3 Velocity Slice 2

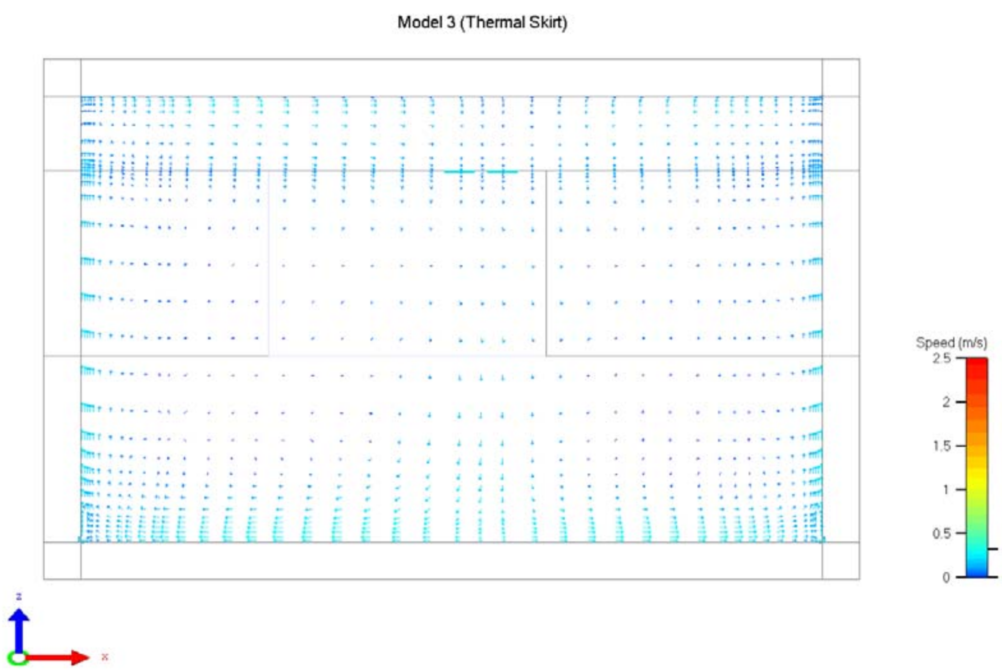


Figure 80 Model 3 Velocity Slice 3

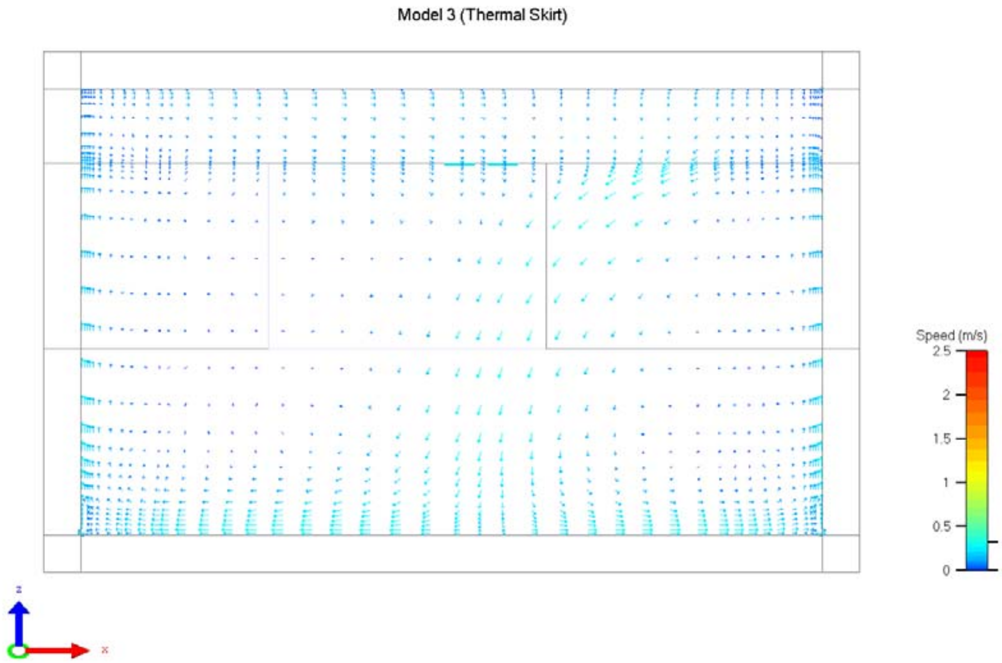


Figure 81 Model 3 Velocity Slice 4

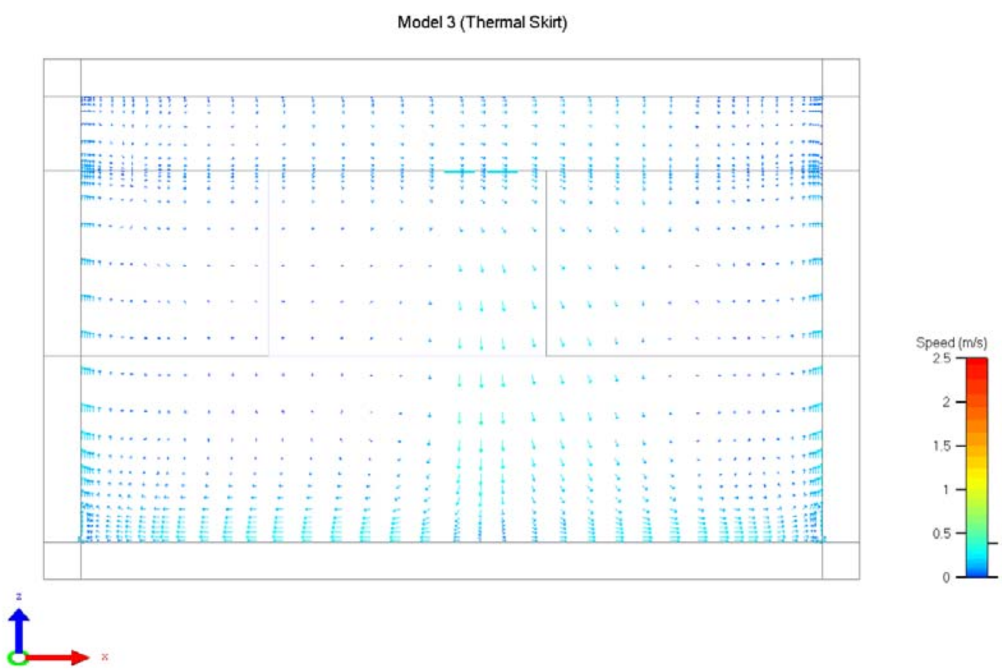


Figure 82 Model 3 Velocity Slice 5

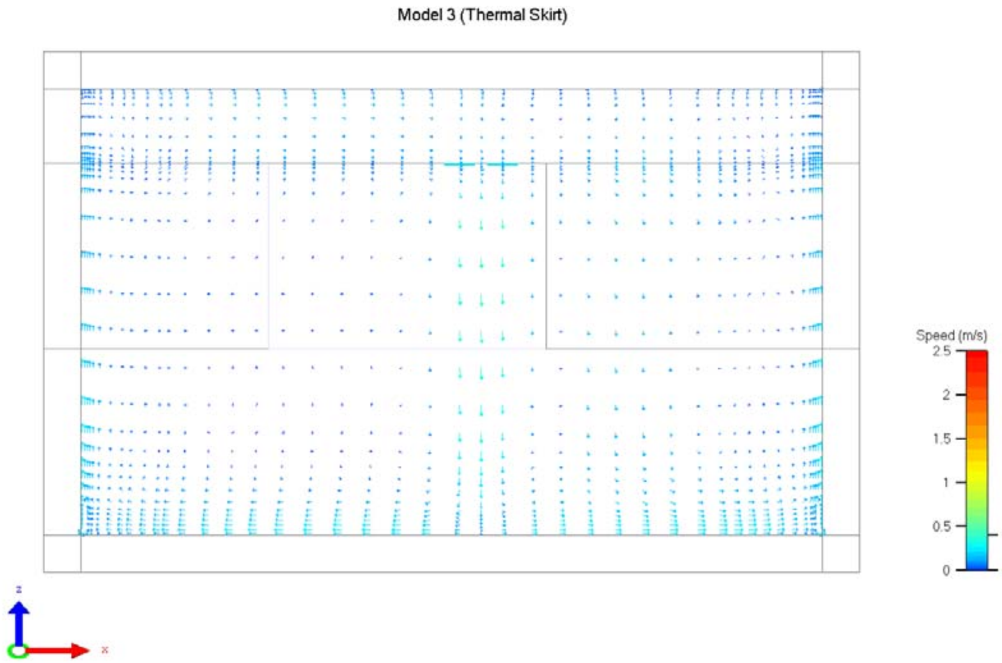


Figure 83 Model 3 Velocity Slice 6

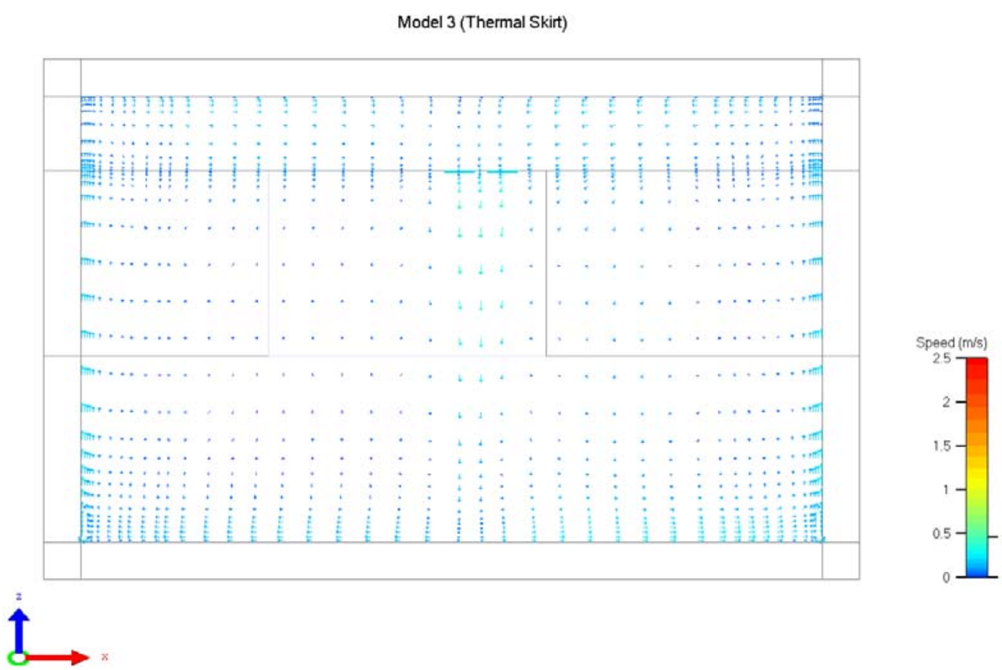


Figure 84 Model 3 Velocity Slice 7

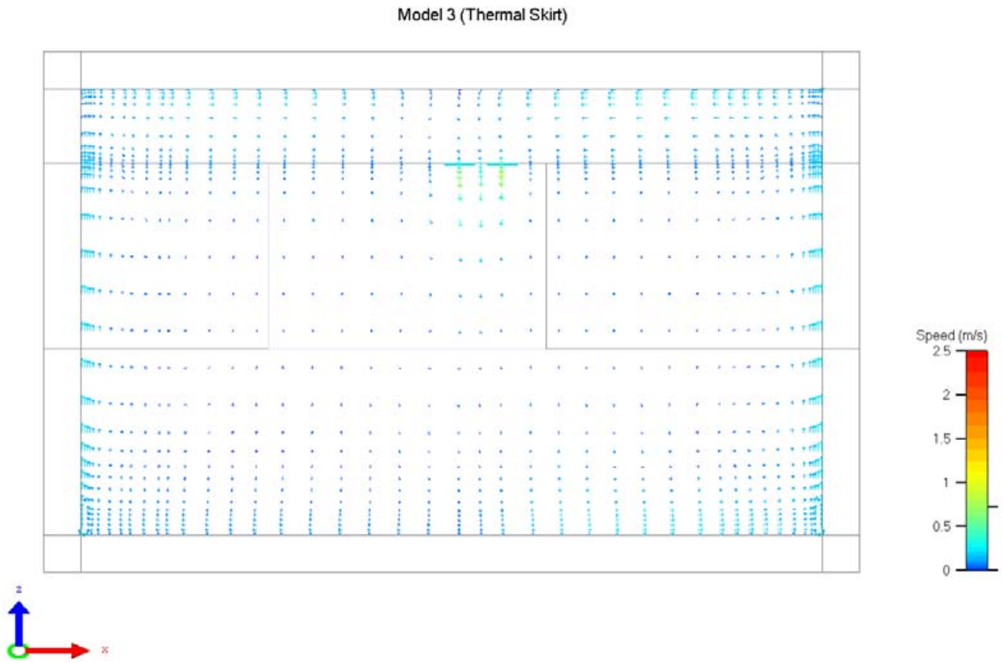


Figure 85 Model 3 Velocity Slice 8

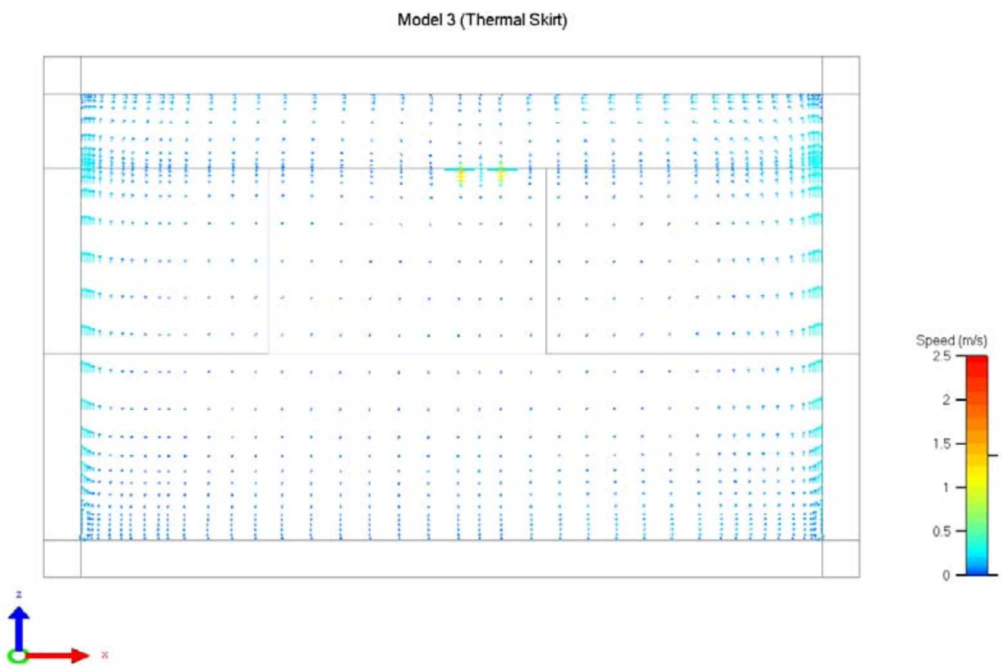


Figure 86 Model 3 Velocity Slice 9

5 CONCLUSION

The conclusions drawn in here are for the particular model setup of this study only (see Section 3.1.1 for detailed information).

The thermal comfort temperature pictures for models show that model 3 (ThermaSkirt) has the most uniform distribution and the most acceptable level among all simulations, see Figure 12, Figure 40 and Figure 67 for the contours at Z=1.2 m with annotations. For the model 1 (radiator under windows), the comfort temperatures are as low as 16.8°C in some places (e.g., the corner between two windows).

The minimum, maximum and mean value of comfort temperature has been calculated at the plane located at 1.2 m above floor (Z=1.2 m), which is shown in the table below. Model 3 has 2 °C higher mean comfort temperature than Model 1 at the same heating load (800 W). Although Model 2 has quite similar mean as model 3, but the standard deviation suggests that the uniformity of model 2 is quite poor.

Table 3 Thermal Comfort Temperature at Z=1.2 m (1.2 m above floor)

Model No.	Min (°C)	Max (°C)	Mean (°C)	Stand. Dev
Model 1 (Radiator under window)	16.8	29.3	18.2	0.89
Model 2 (Radiator at internal wall)	18.4	30.4	19.9	1.37
Model 3 (ThermaSkirt)	18.7	21.7	20.2	0.32

The air movement pictures for all the models show that air infiltrated in through the trickle vent and is being drawn up at low level, pushed upwards from the heater and heated. The warm air at the top of the room is being drawn out at the top.

The thermal comfort temperature, temperature and velocity animations are supplied in the Power Point file accompanying this report.