Make-Up Air Performance CFD Study

October 30, 2003

PURPOSE

CFD models are useful tools in visualizing airflow and temperature gradients and flow. This CFD (computational fluid dynamics) study was performed on an exhaust only kitchen hood with a front, perforated make-up air system. The exhaust rate of the hood was held constant to determine how changes in velocity and temperature of the make-up air effect the kitchen.

CFD MODEL PARAMETERS

Two CFD models were analyzed in this study. Model number 1 represents a make-up air system that introduces ambient outdoor air into the kitchen space. Model number 2 represents a make-up air system with two plenums on the front of the hood. The plenum closest to the hood (SP1) introduces 95°F ambient outdoor air into the space and the second plenum (SP2) introduces 72°F air conditioned air into the system.

Exhaust Hood Parameters:
Model 5424ND, 8 ft. Long
16” Tall Baffle Filters
6’6” Hanging Height
2400 CFM Exhaust (300 CFM/Ft)
6” Left and Right Overhang
24” Front Overhang

Cooking Equipment Parameters:
600°F Char broilers
6 Burner, 96,000 BTU/Hr Each
22.75” Deep x 32” Wide Cooking Surface Each
36” Tall

Supply Plenem Paramaters:
8 ft. Long
6” Tall
12” Wide

Room Parameters:
72°F Ambient Temperature
4 ft. Space on Both Sides of Hood
No Wall Opposite Hood Wall

The following figures show the CFD model setups. Figures 1 and 3 illustrate the 3-D models used for the analysis and figures 2 and 4 show the plan view of the hood, plenums and the cooking equipment, along with the general space layout.

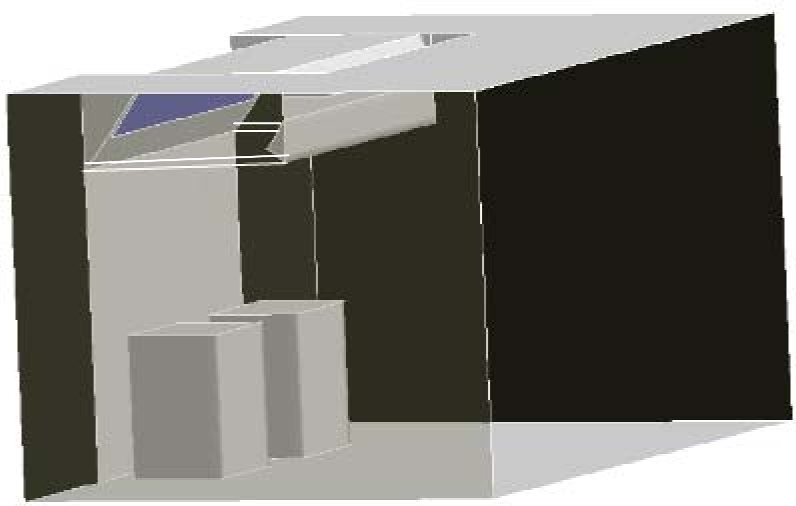


Figure 1. Model Number 1 – Ambient Outdoor Air Supply Plenum

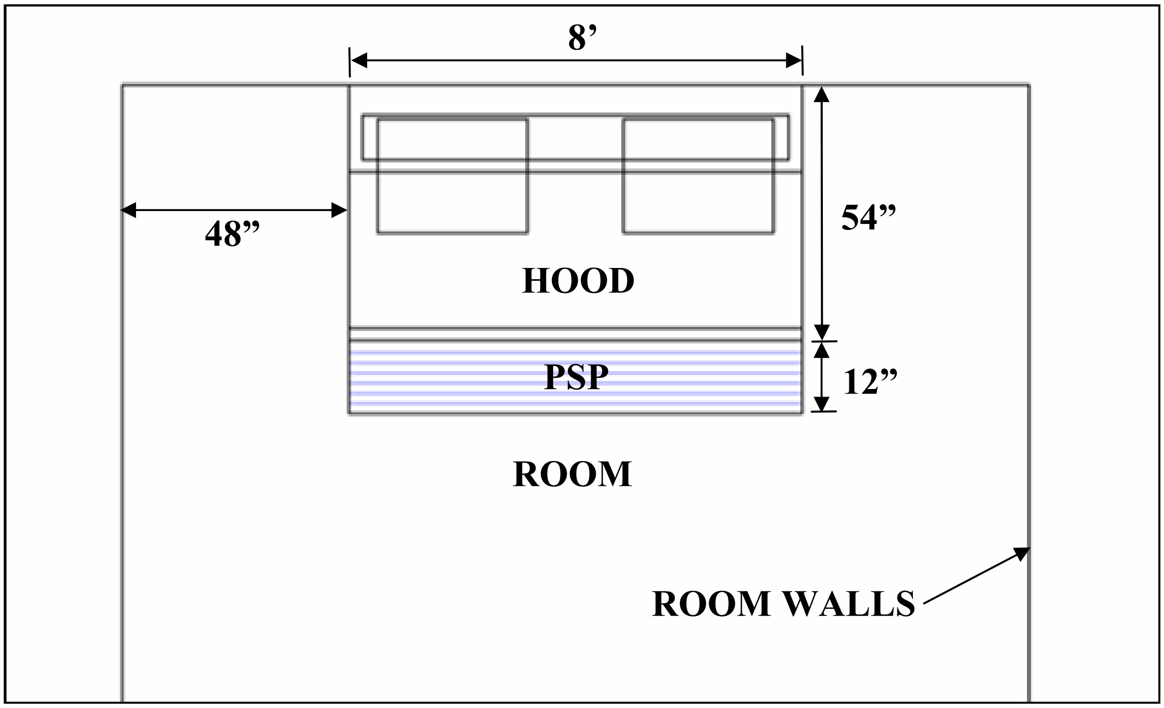


Figure 2. Plan View of Model Number 1

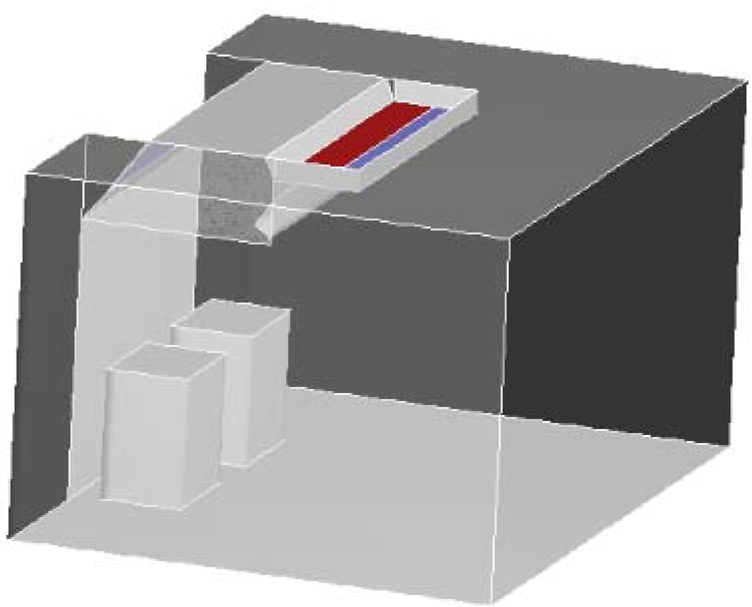


Figure 3. Model Number 2 – Ambient Outdoor Air Supply and AC Plenum

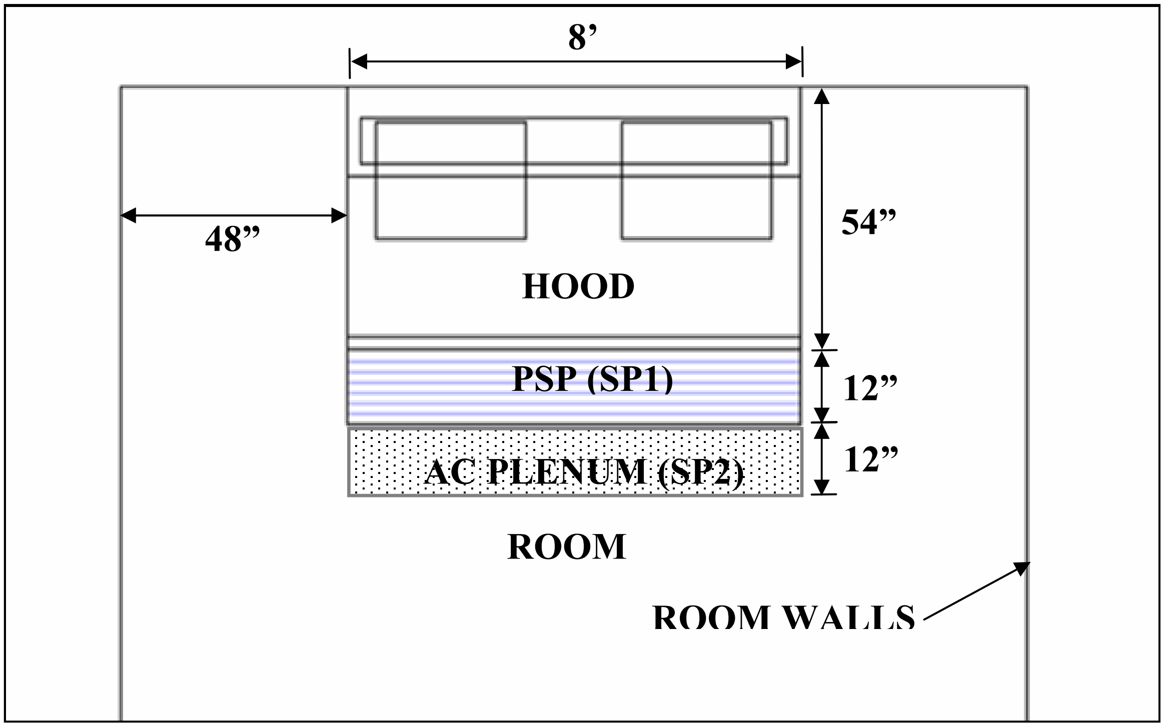


Figure 4. Plan View of Model Number 2

RESULTS
The CFD analysis results are illustrated on the following four pages. The first two pages illustrate the results of the model 1 analysis and the last two pages illustrate the results of the model 2 analysis. Again, model number 1 represents a single supply plenum on the front of the hood and model number 2 refers to an untempered supply plenum (SP1) along with an air conditioned plenum (SP2), both on the front of the hood.

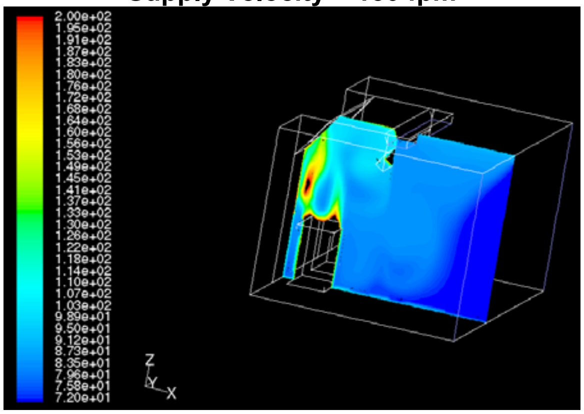
The first set of results for model number 1 show the supply air-stream being introduced at 85°F with a side-by-side comparison of 150 fpm and 200 fpm supply velocity. The second set of results for model number 1 show the supply air-stream being introduced at 95°F with a side-by-side comparison of 150 fpm and 200 fpm supply velocity.

The results for model number 2 on the third and fourth page show four scenarios. All scenarios show untempered supply air (SP1) being delivered at 95°F, and conditioned supply air (SP2) being delivered at 72°F. There are four cases for each of these sets of results showing combinations of 150 fpm and 200 fpm air velocities for each of the plenums.

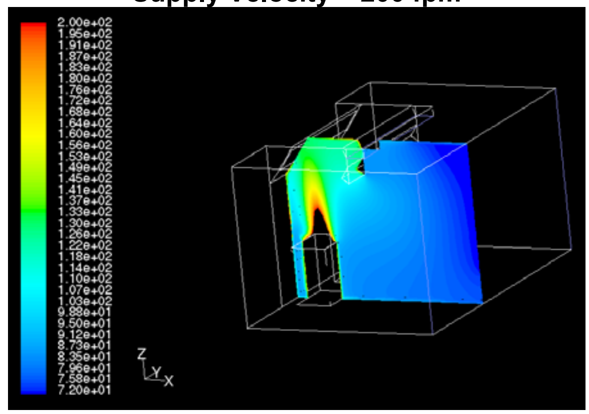
The CFD results are displayed as cross sections of temperature contours in the space (°F), supply temperature pathlines (°F), velocity flow pathlines (fpm), and velocity profiles (fpm). The results of model number 2 are also represented by an **82°F** temperature contour showing the location of this constant temperature contour in the space.

Model Number 1: Supply Air Temperature = 85°F

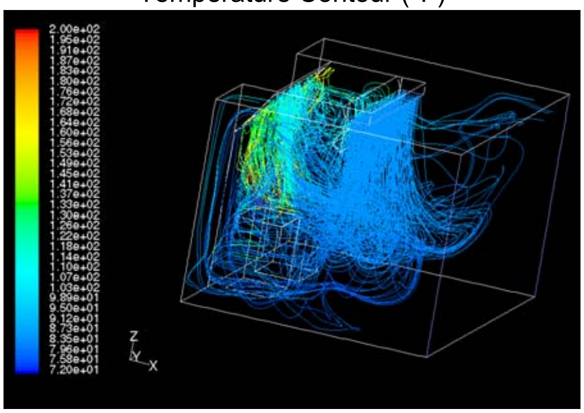
Supply Velocity = 150 fpm | **Supply Velocity = 200 fpm**



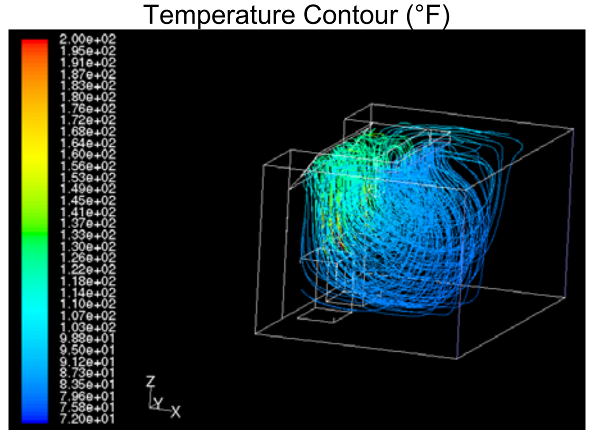
Temperature Contour (°F)



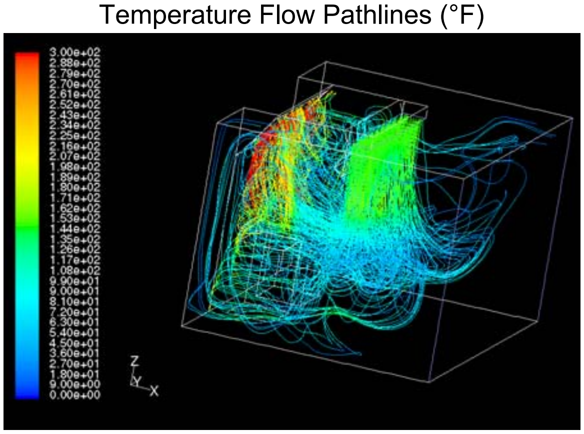
Temperature Contour (°F)



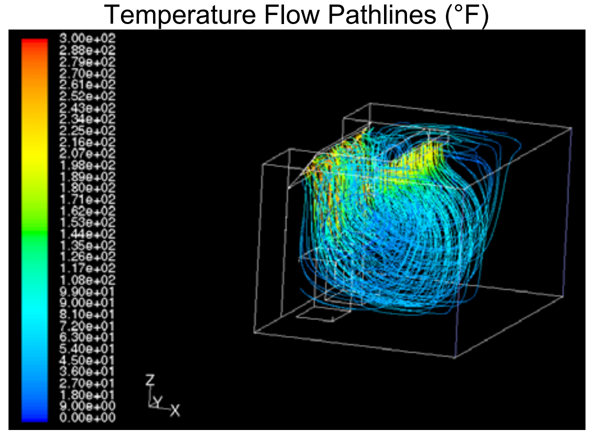
Temperature Flow Pathlines (°F)



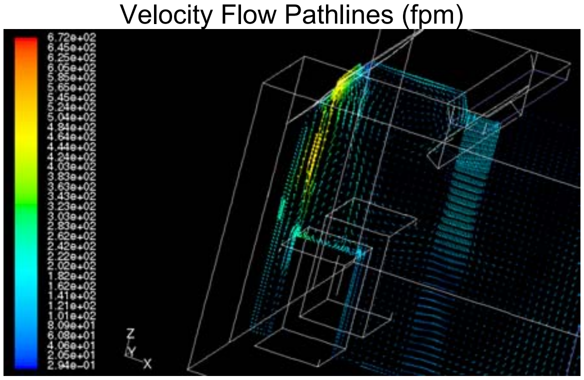
Temperature Flow Pathlines (°F)



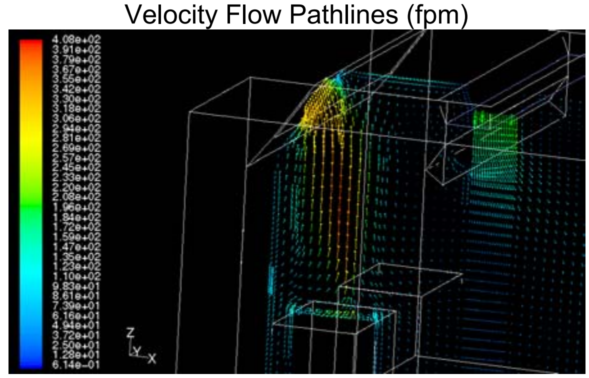
Velocity Flow Pathlines (fpm)



Velocity Flow Pathlines (fpm)



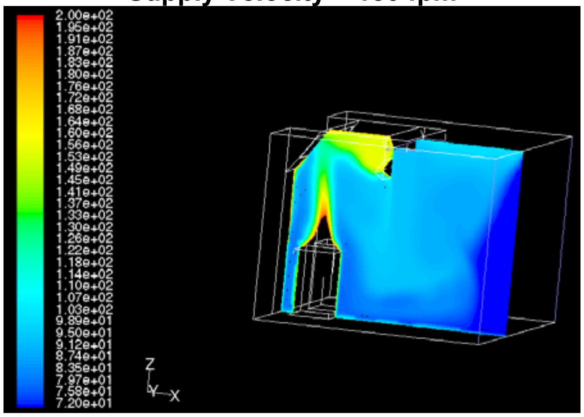
Velocity Profile (fpm)



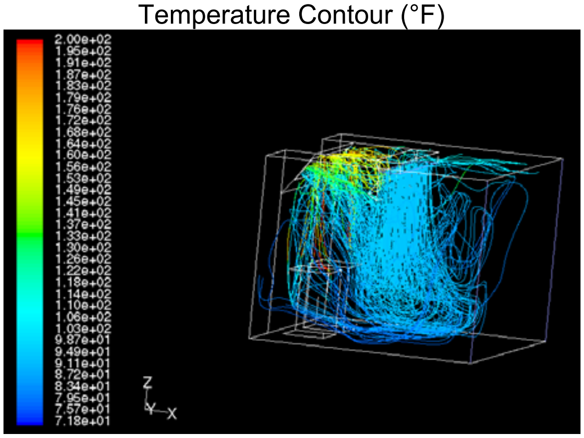
Velocity Profile (fpm)

Model Number 1: Supply Air Temperature = 95°F

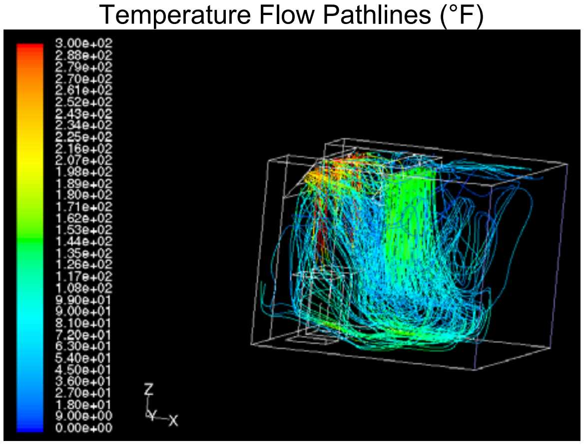
Supply Velocity = 150 fpm



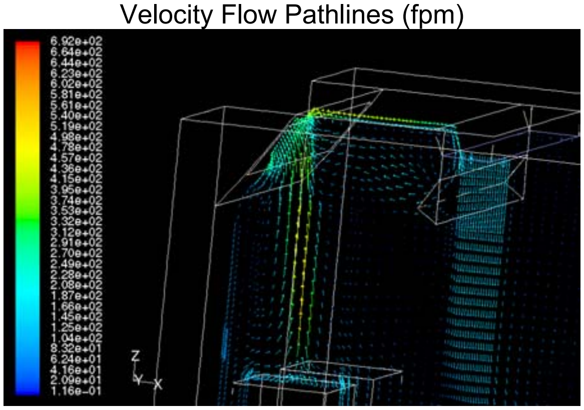
Temperature Contour (°F)



Temperature Flow Pathlines (°F)

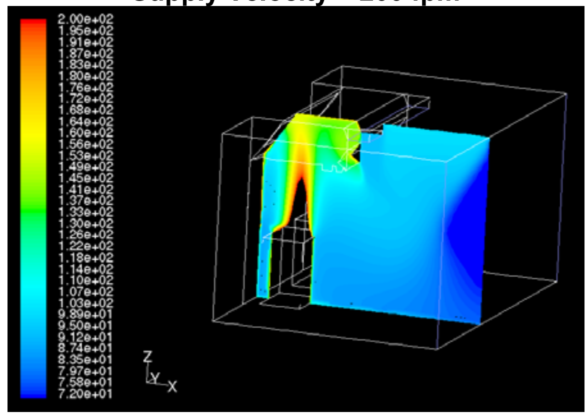


Velocity Flow Pathlines (fpm)

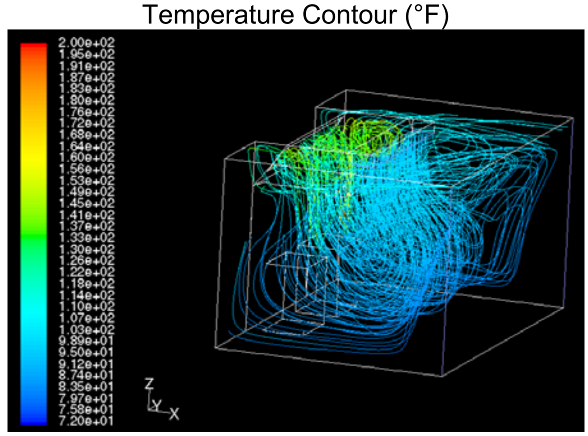


Velocity Profile (fpm)

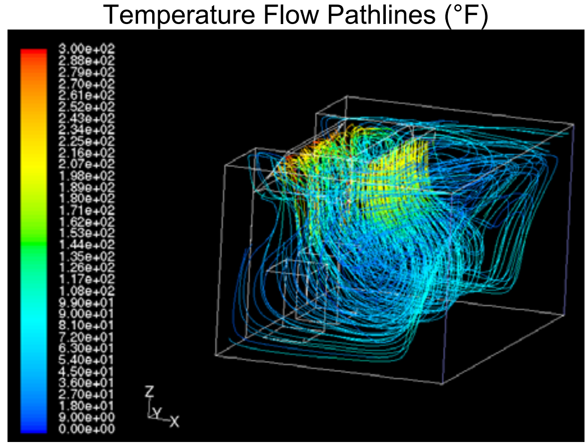
Supply Velocity = 200 fpm



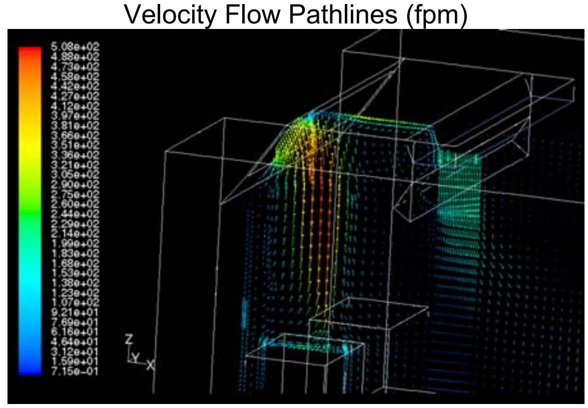
Temperature Contour (°F)



Temperature Flow Pathlines (°F)

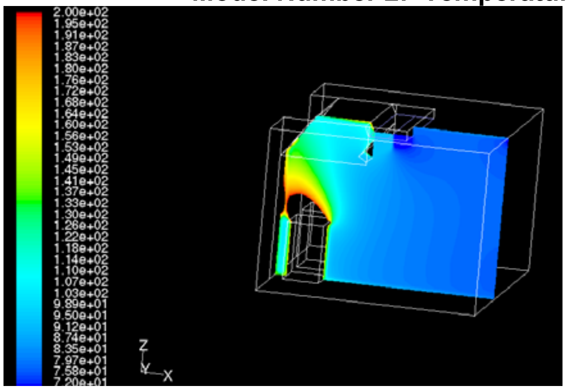


Velocity Flow Pathlines (fpm)

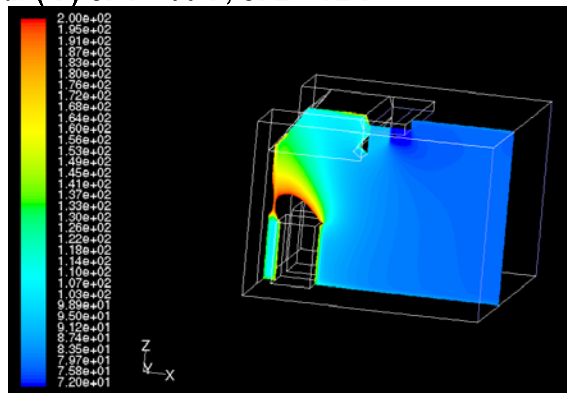


Velocity Profile (fpm)

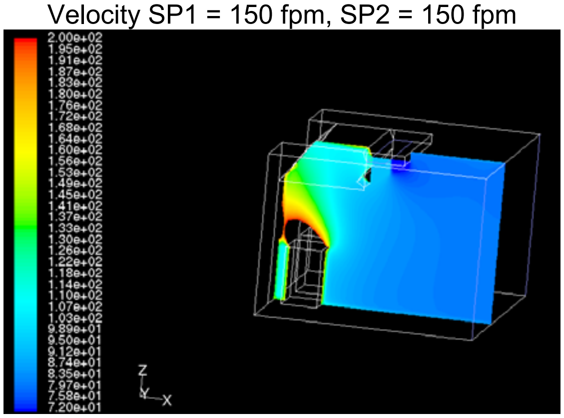
Model Number 2: Temperature Contour (°F) SP1 = 95°F, SP2 = 72°F



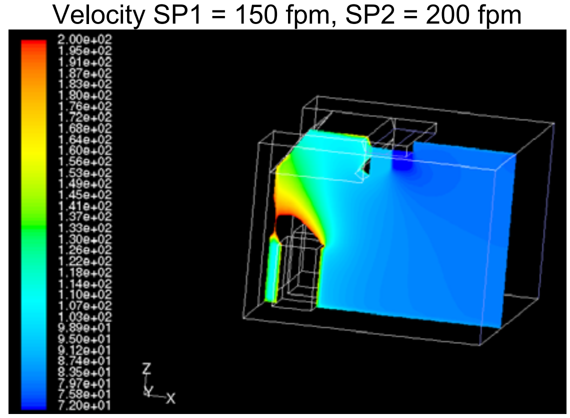
Velocity SP1 = 150 fpm, SP2 = 150 fpm



Velocity SP1 = 150 fpm, SP2 = 200 fpm

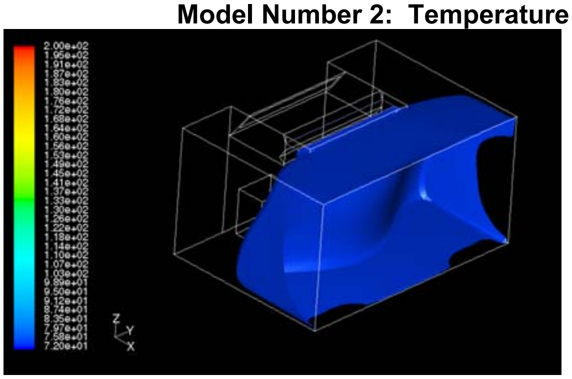


Velocity SP1 = 200 fpm, SP2 = 150 fpm

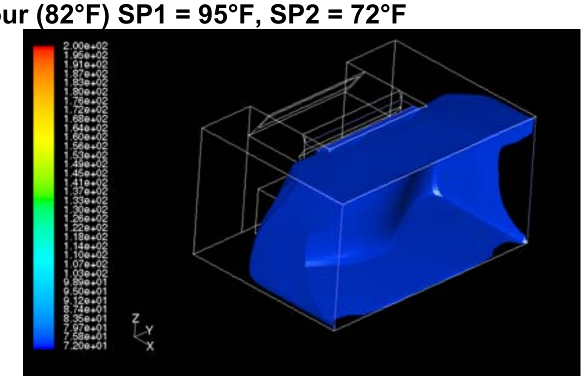


Velocity SP1 = 200 fpm, SP2 = 200 fpm

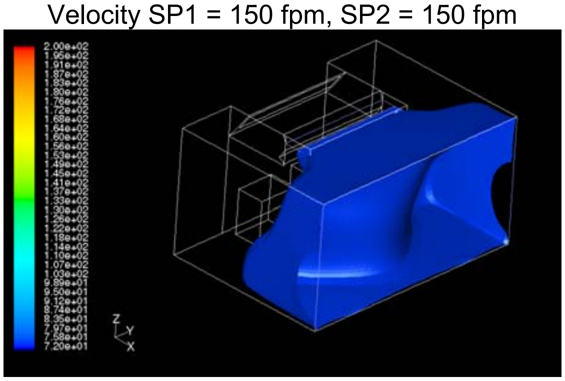
Model Number 2: Temperature Contour (82°F) SP1 = 95°F, SP2 = 72°F



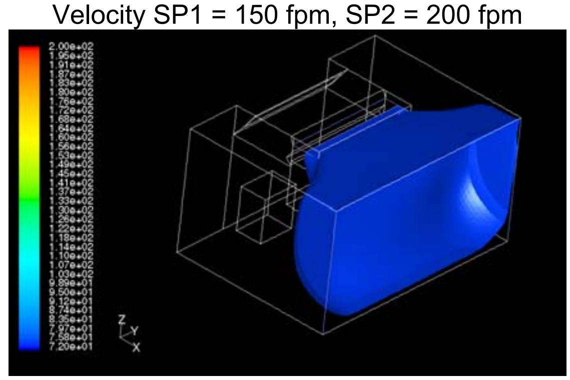
Velocity SP1 = 150 fpm, SP2 = 150 fpm



Velocity SP1 = 150 fpm, SP2 = 200 fpm

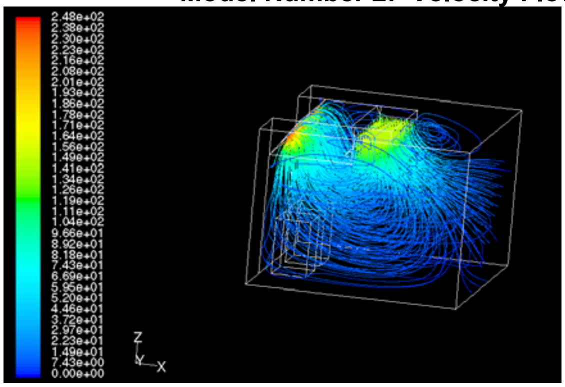


Velocity SP1 = 200 fpm, SP2 = 150 fpm

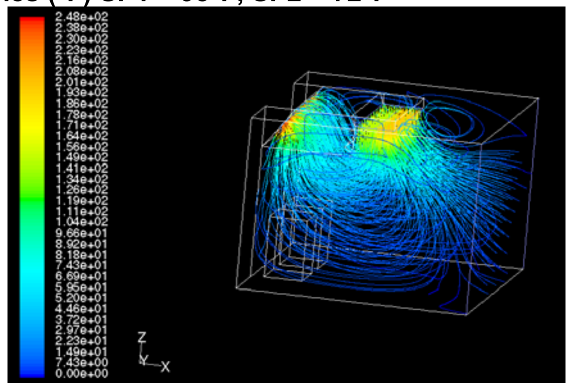


Velocity SP1 = 200 fpm, SP2 = 200 fpm

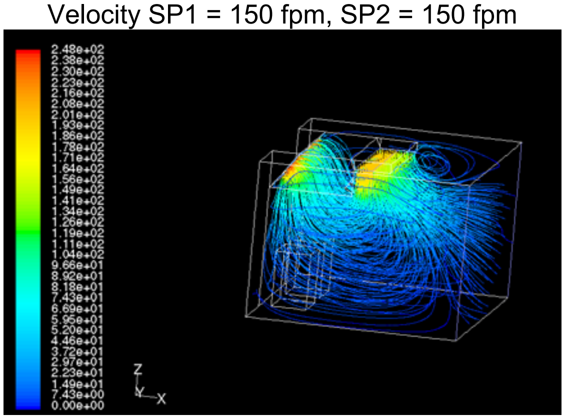
Model Number 2: Velocity Flow Pathlines (°F) SP1 = 95°F, SP2 = 72°F



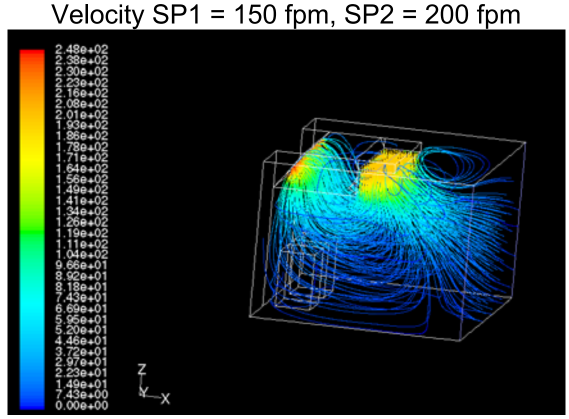
Velocity SP1 = 150 fpm, SP2 = 150 fpm



Velocity SP1 = 150 fpm, SP2 = 200 fpm

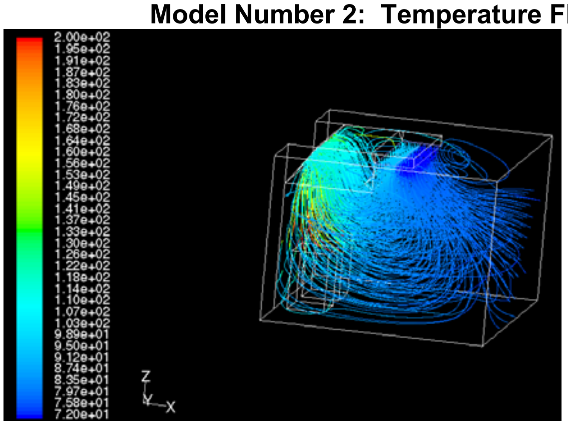


Velocity SP1 = 200 fpm, SP2 = 150 fpm

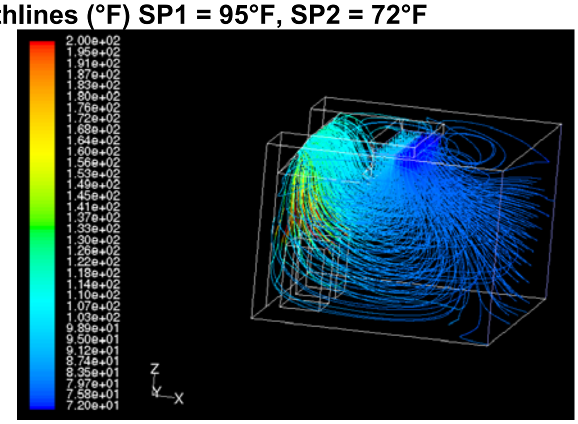


Velocity SP1 = 200 fpm, SP2 = 200 fpm

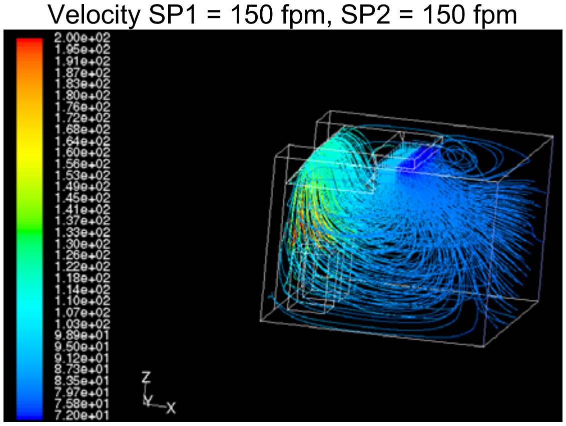
Model Number 2: Temperature Flow Pathlines (°F) SP1 = 95°F, SP2 = 72°F



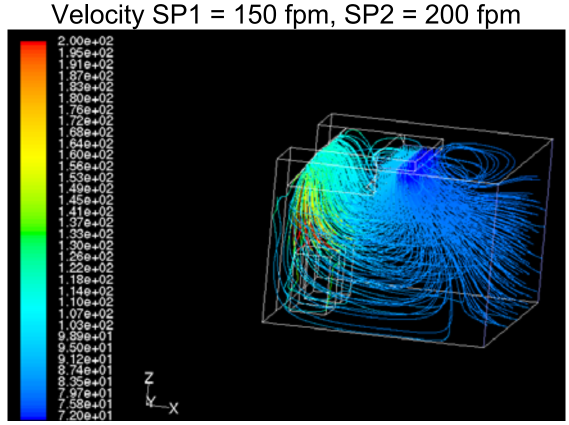
Velocity SP1 = 150 fpm, SP2 = 150 fpm



Velocity SP1 = 150 fpm, SP2 = 200 fpm



Velocity SP1 = 200 fpm, SP2 = 150 fpm



Velocity SP1 = 200 fpm, SP2 = 200 fpm

CONCLUSION

The CFD analysis shows that kitchen comfort is dependent on the temperature and velocity of the supply air. In reference to model number 1, these results show that by introducing hot air (95°F) through the supply plenum at velocities greater than 150 fpm, the circulation of the supply air is promoted back into the exhaust hood. This is due to the lower density of hot air. Hot air is less dense than cool air and thus has a tendency to rise in the cooler kitchen environment. Hot air must have a greater discharge velocity to reach the lower edge of the exhaust hood and thus enter the hood instead of the kitchen.

There are also noticeable results between 95°F supply air and 85°F supply air. The cooler 85°F supply air stream results in a much tighter air circulation back into the exhaust hood with less supply air entering the kitchen. As a matter of fact, for model number 1, the single supply plenum, the best results occur when the air is introduced at **85°F and 200 fpm** discharge velocity. Supply air can be felt by the cook at velocities greater that 150 fpm. Given all of these parameters, the following table illustrates the ideal supply plenum velocities at certain temperature ranges.

Supply Air Temperature (°F)	Min. Air Velocity (fpm)	Max. Air Velocity (fpm)
<50	0	140
50 to 75	140	160
75 to 85	160	180
85 to 95	180	200
>95	200	220

Based on these results, heating the supply air in cold climates will allow the plenum to supply more make-up air and cooling the make-up air in hot climates will allow for the plenum to discharge the air at the optimal velocity and have a minimal impact on the kitchen environment.

In reference to model number 2, the kitchen environment is effected the least by introducing the air conditioned air at a velocity equal to or greater than the untempered supply air. The best results in this analysis occur when the untempered air is delivered at 150 fpm and the air conditioned air is delivered at 200 fpm. The air conditioned air completely pressurizes the untempered air toward the exhaust hood, thus preventing the hot air from entering the kitchen. The hot air is forced into the exhaust hood to be exhausted and the cool, air conditioned air is free to mix with the air in the conditioned kitchen.