The Design Evolution of an Energy Efficient Low – Flow Fumehood

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Objectives

- Design a high performance, low-flow fumehood with excellent containment.
- Address the shortfalls of conventional hoods and apply the changes to the low-flow hood design.
- Use the latest state-of-the art computational and experimental tools to assess performance.
- Combine both computational and experimental techniques to optimize the hood design.

Computational Techniques

- Computational Fluid Dynamics (CFD)
- Models every important aspect of airflow
- Most accurate and comprehensive technique to assess:
  - airflow speed and direction
  - temperature and buoyancy
  - pressure
  - particulate and species gas loading
  - turbulence

Computational Techniques (continued)

- Highly visual and intuitive graphic output.
  - Speed and direction
  - temperature and buoyancy
  - pressure
  - particulate and species gas loading
- Capable of importing complex 3-D solid CAD models.
- Allows rapid “what-if” scenarios and sequential design optimization.

Mixed Reviews of CFD

- Older models
  - usually poorly descretized 3-D or 2-D models
  - usually highly approximated geometry
  - usually ignored important boundary conditions
  - worst of all, usually performed by “dabblers”
- Newer Models
  - Extensively meshed using tetrahedral cells and grid adaption in critical areas
  - very close representation of the solid geometry
  - great efforts to account for all boundary conditions and to benchmark against experimental results

How CFD Works in the Nutshell

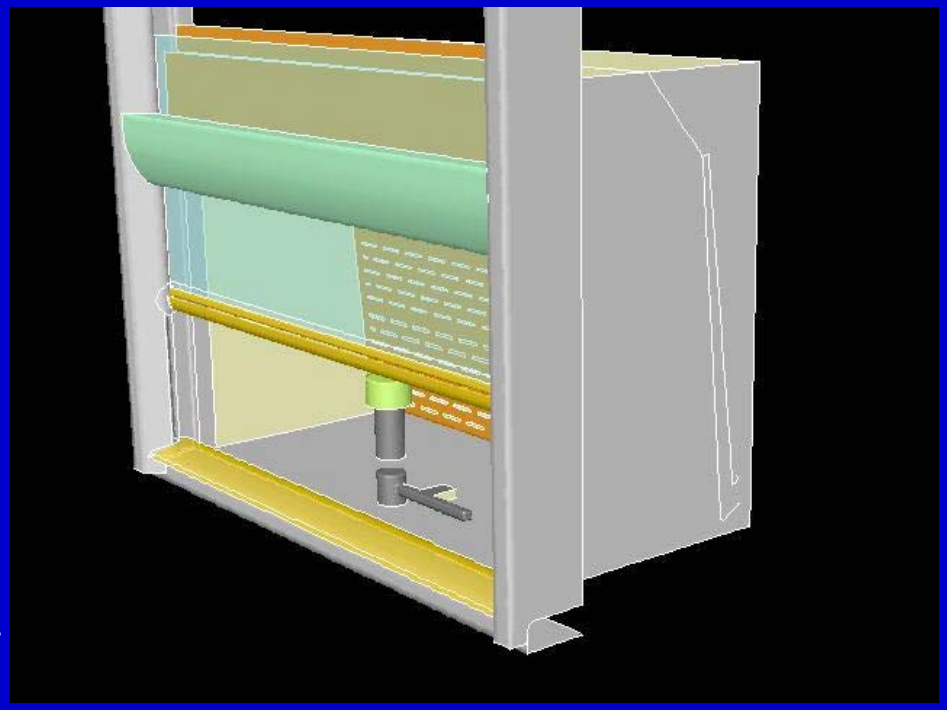
- CFD is a computer technique that dices a domain (hood) into many thousands or millions of imaginary cells.
- Each cell is described by a set of complex partial differential equations relating flow momentum to turbulence, energy, species and influence on surrounding cells.
- The combined behavior of all cells provides an accurate approximation of the behavior of a contiguous domain.

CFD Output Types

- Velocity vectors ?arrows in space that demonstrate both air velocity and direction.
- Contours ?lines or fills on a section through the domain that gauge temperature, pressure, concentration, speed, etc.
- Iso-surfaces ?3-D contour surface representing a specific level (eg - 3 ppm SF_6).
- Particle tracks ?3-D trails left behind by imaginary particles in a domain.

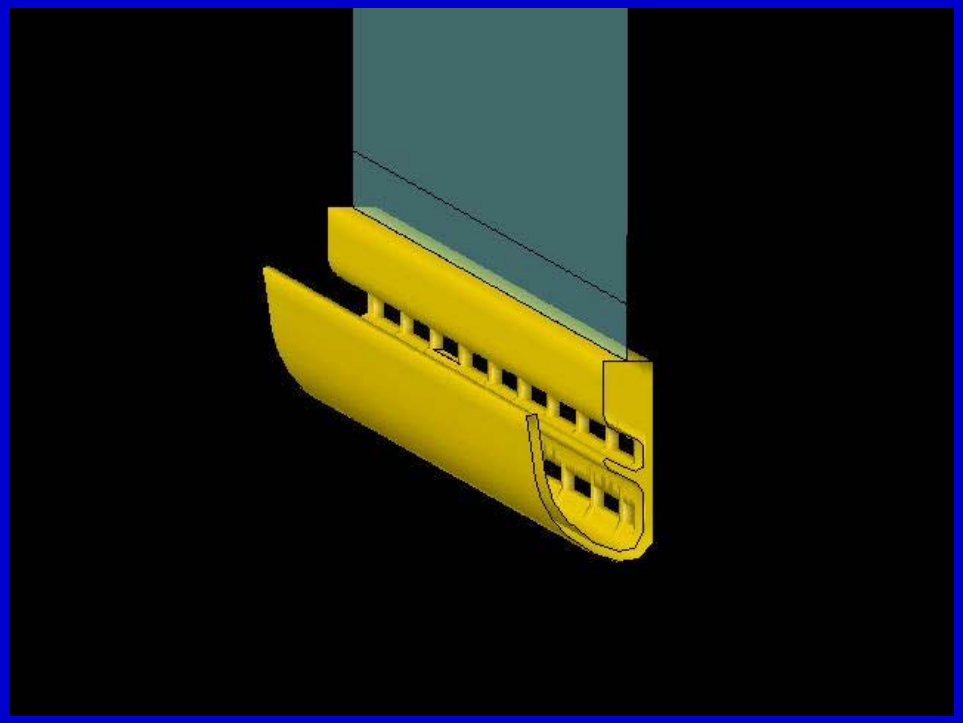
CFD Example

- Fumehood domain
  - hemispherical approach.
  - Accurate representation of sash handle, foil, ejector, perforations.
  - 2.7 million cells

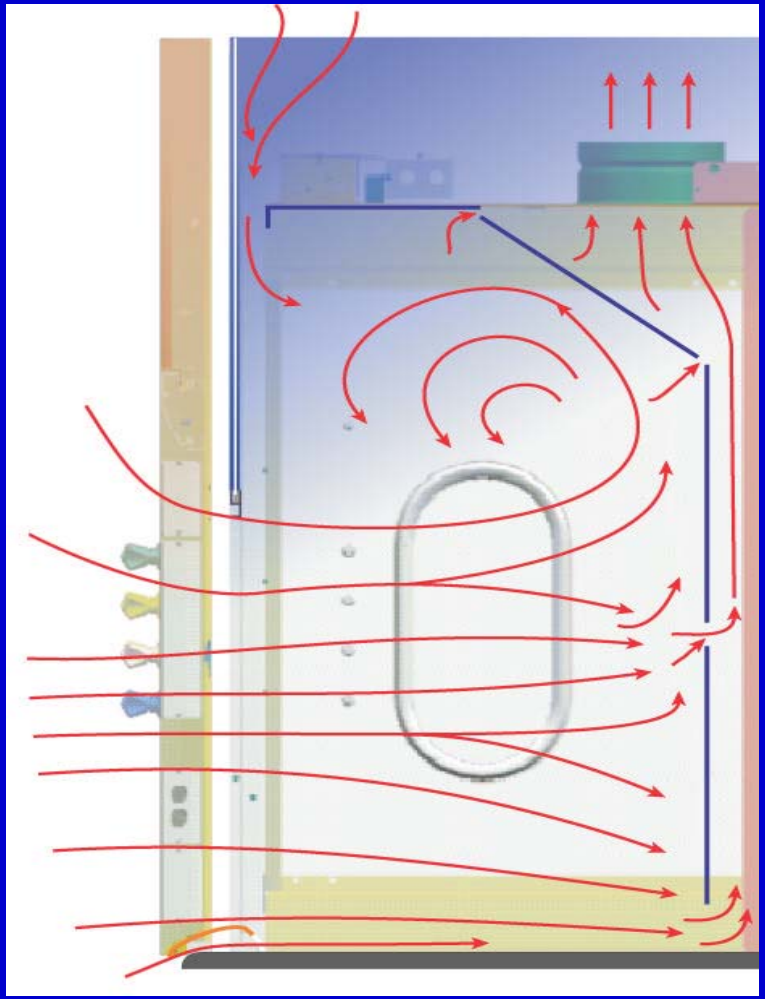


CFD Example (continued)

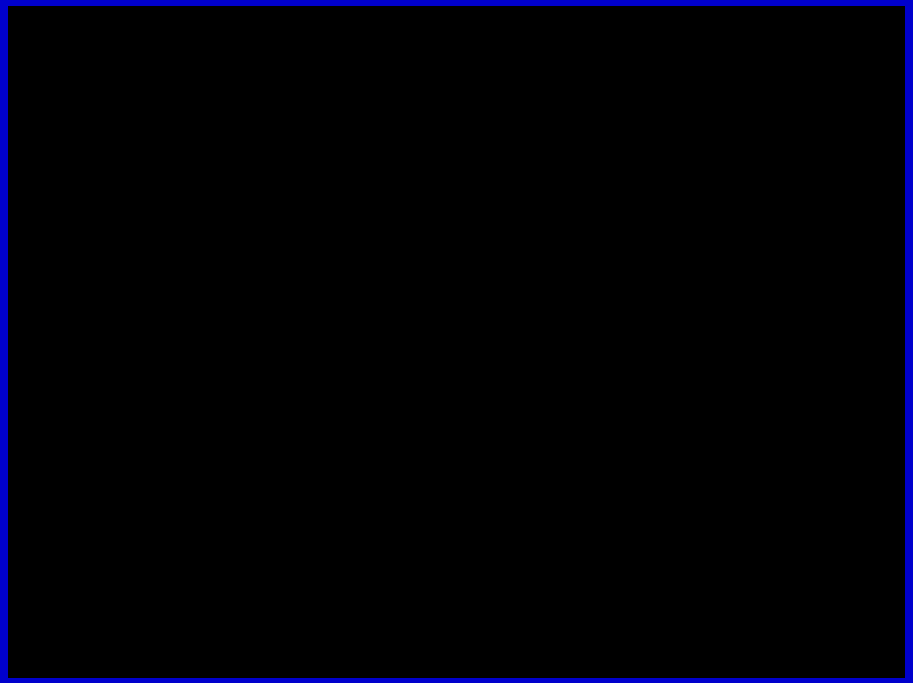
- Sash handle details
  - complex shape
  - slots and holes
  - adaptively meshed



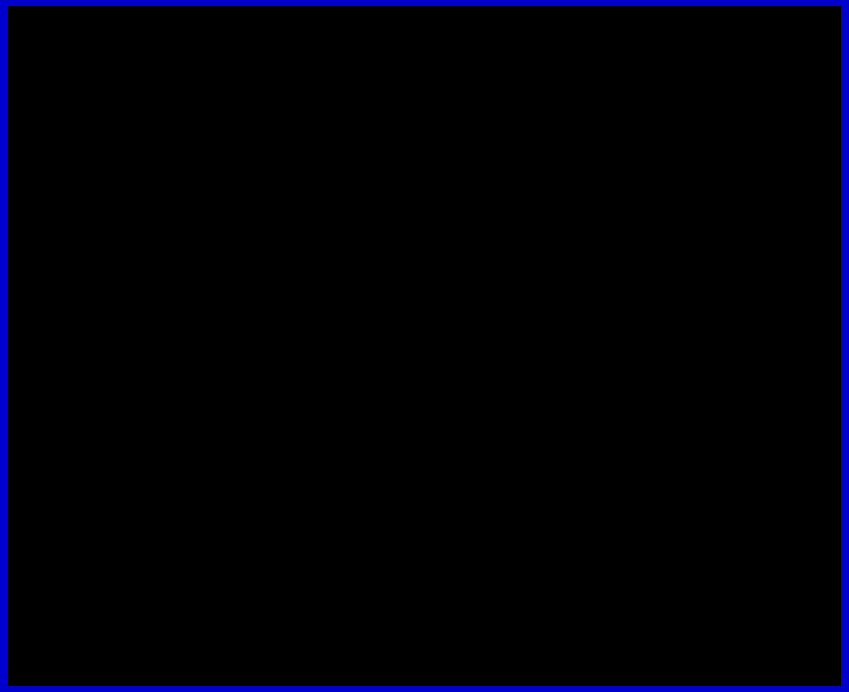
Traditional Bypass Design



Traditional Bypass Design



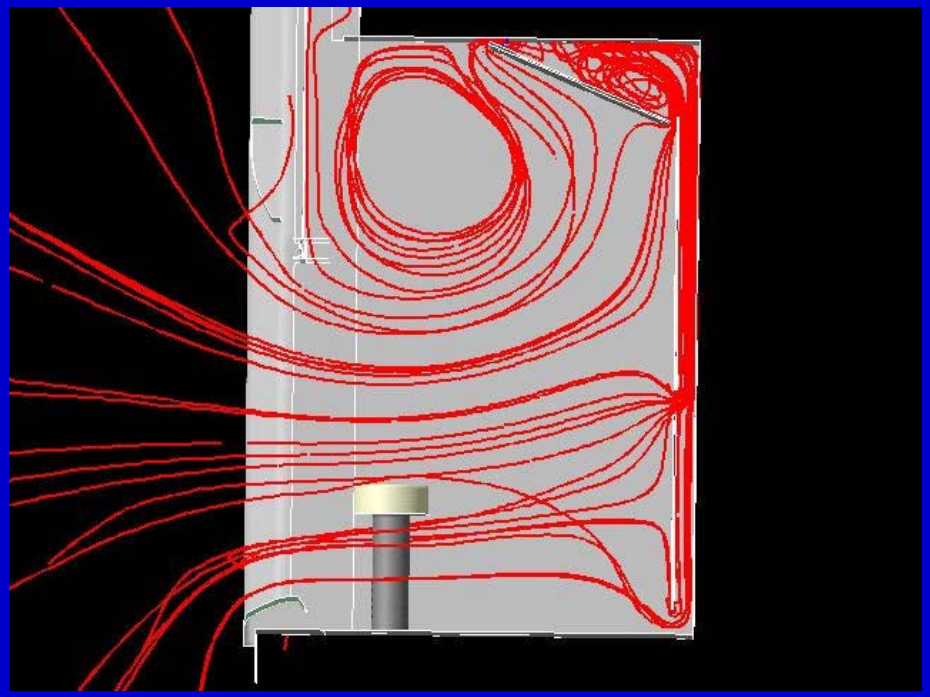
Front View



Side View

CFD of Traditional Hood

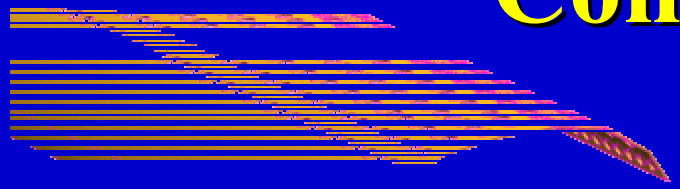
- Traditional Design
  - Vortex close to sash
  - Exhaust through four slots
  - High flowrate



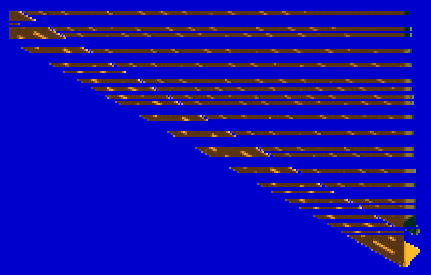
High Performance / Low Flow Fumehood Design Goals

- Reduce contaminate time within the hood
- Enhance the hood face for "robust" containment
- Sash operable at all positions
- No internal moving parts
- Containment equal or better at 60 fpm compared to conventional hood @ 100 fpm

Four Unique Performance Components

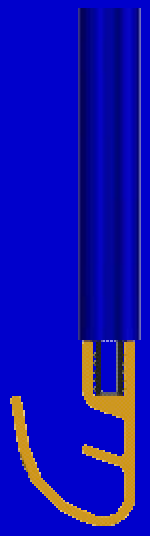


Perforated Sash Foil



Rear Downflow Dual Baffle

Upper Dilution Air Supply

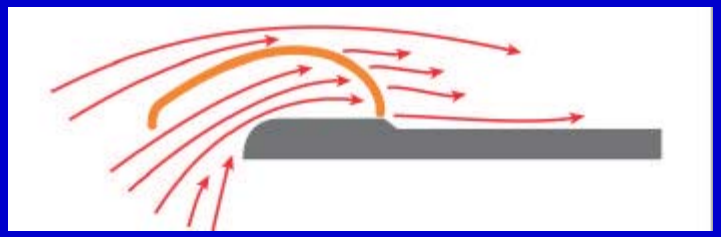


Unique Sash Handle

Unique Air Foil

with Clean-Sweep ™

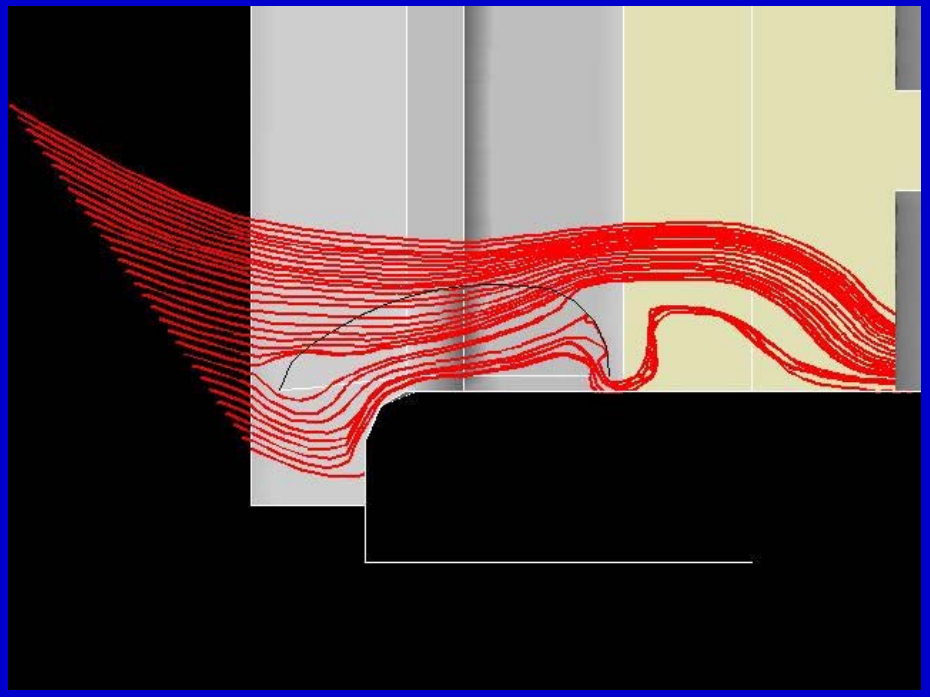
- Perforated Sash Foil with 10 Rows of High Velocity Holes
- Sweeps Lower Portion of the Hood
- Provides Lower Barrier
- Ergonomic Design



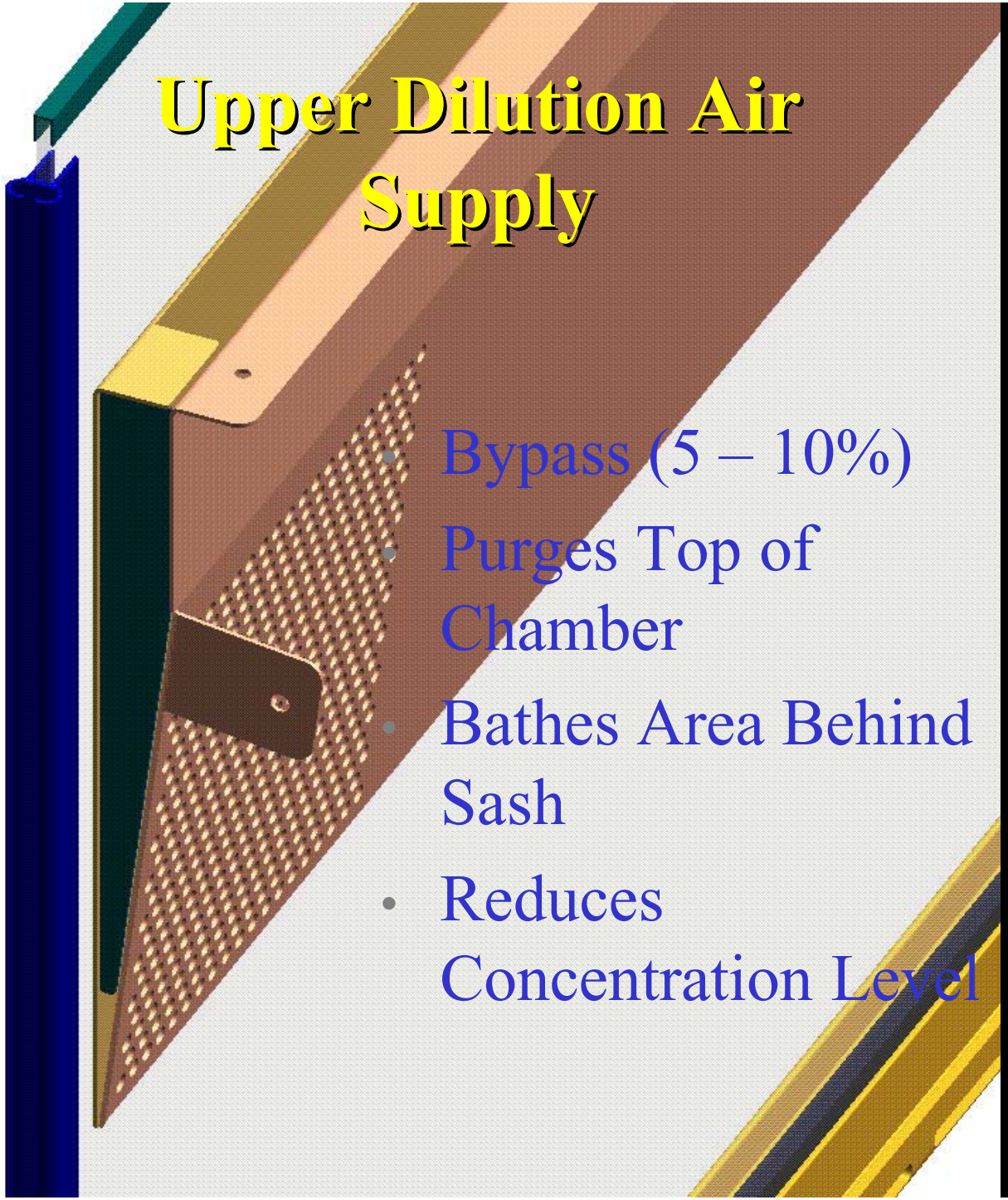
Clean-Sweep ™ Air Foil

CFD of Airfoil Area

- Airfoil area
  - Airfoil geometry imported from solid model
  - Adaptively meshed
  - contains zones of perf and solid sheet



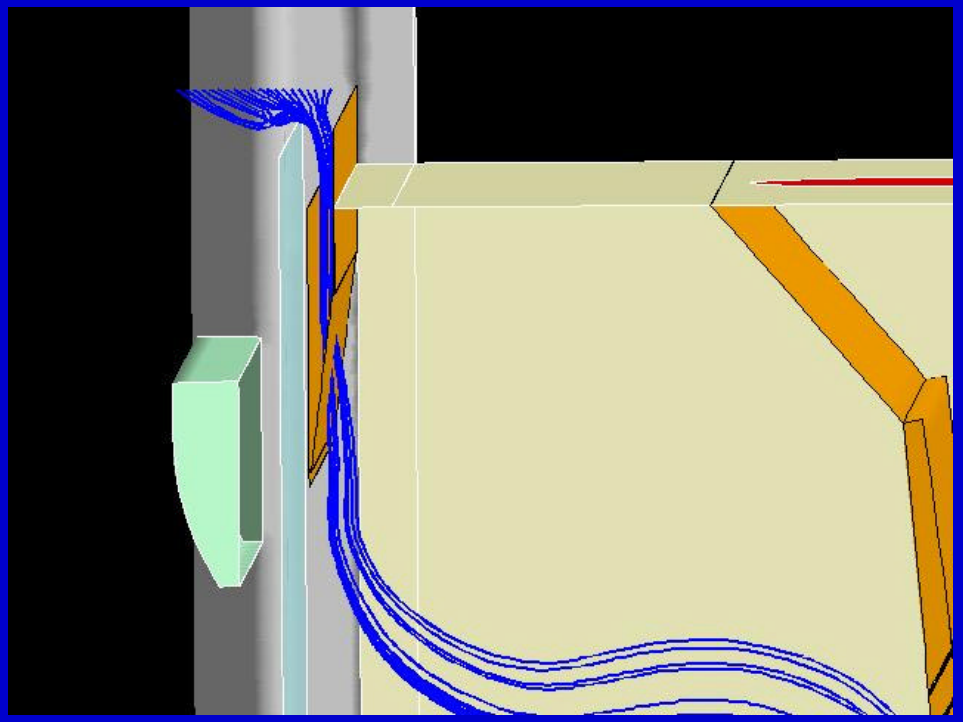
Upper Dilution Air Supply



- Bypass (5 – 10%)
- Purges Top of Chamber
- Bathes Area Behind Sash
- Reduces Concentration Level

CFD of Bypass Area

- Bypass area
  - Geometry imported from solid model
  - contains both perf and solid sheet
  - shows sweeping action of fresh air



Containment-Enhancing Sash Handle

- Aerodynamic Shape
- Horizontal Slots
- Reduces Contaminants Behind Sash
- Provides Upper Barrier

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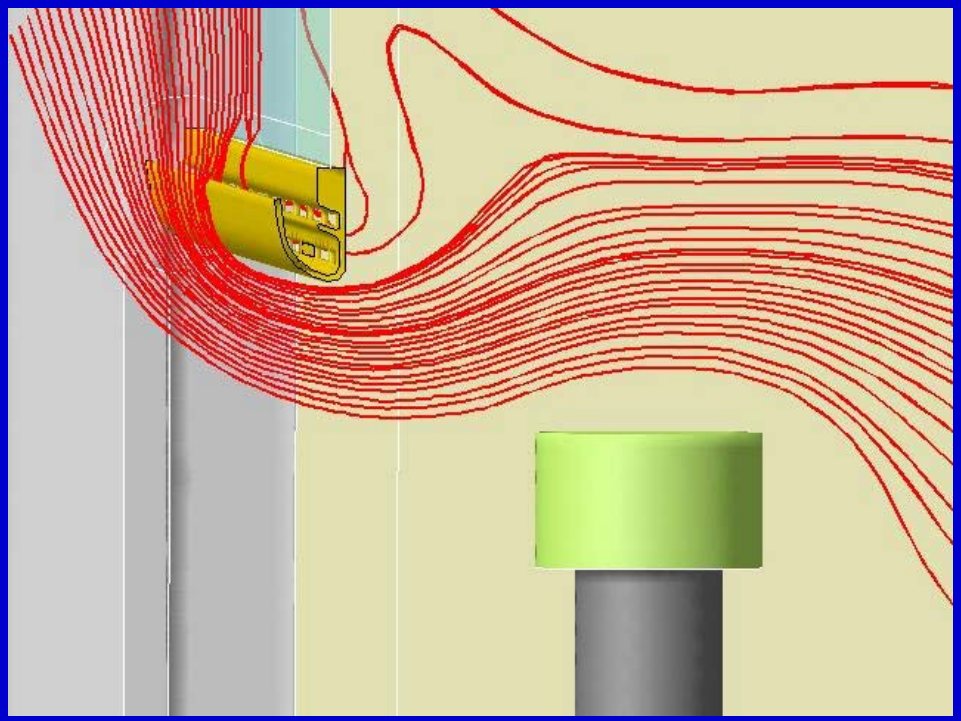
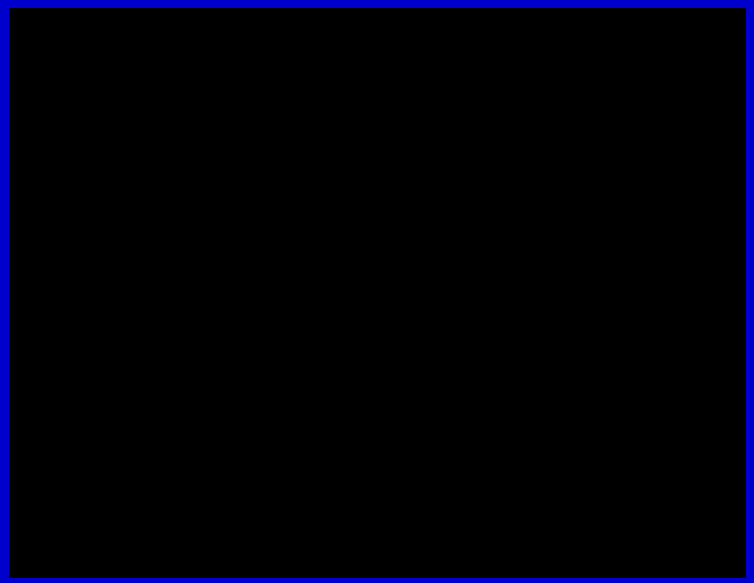
CFD of Sash Handle Area

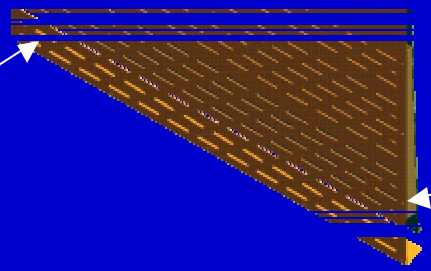
- Handle Area
  - Imported from a solid model
  - contains slots and holes exactly as designed.
  - Shows the effect of aerodynamic shape.



Rear Downflow Dual Baffle

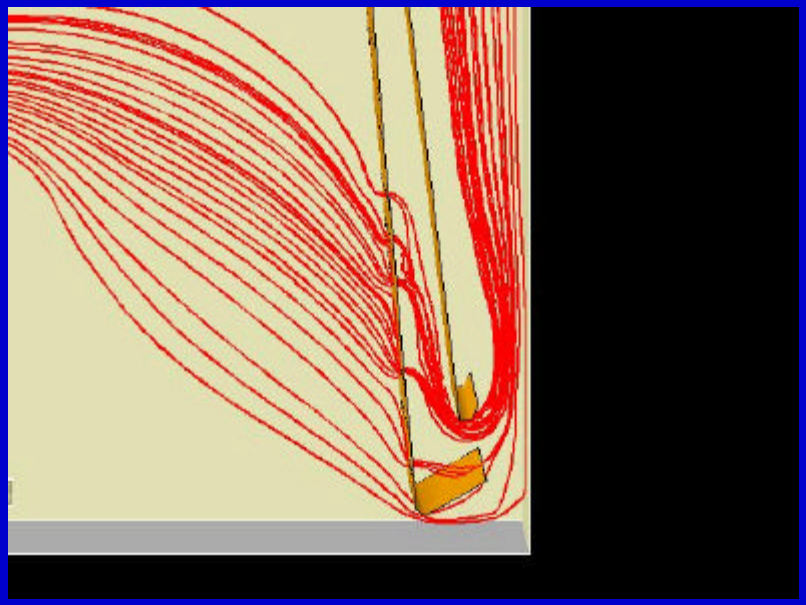
- Greatly Reduces Vortex (Roll)
- Horizontal Slots
- Draws Air Down, and Up
- Provides Horizontal Flow

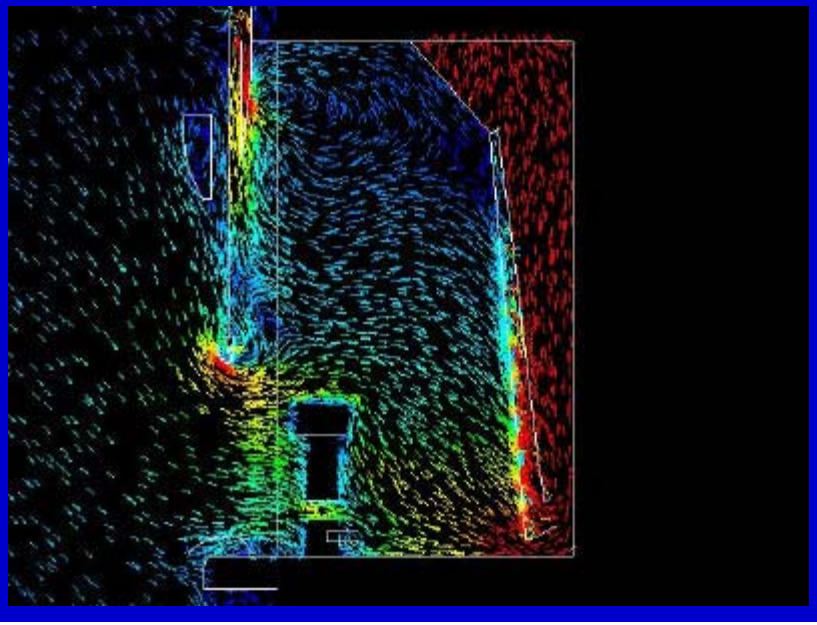




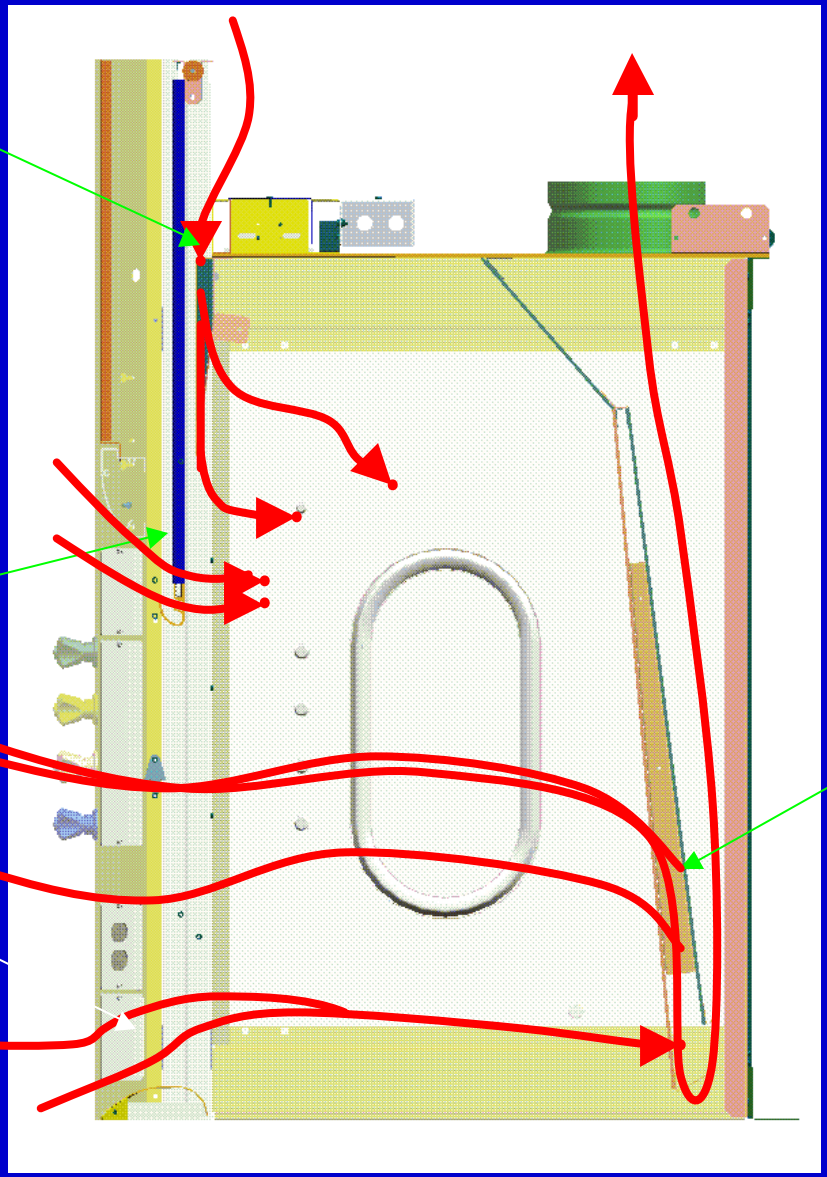
CFD of Rear Downflow Dual Baffle

- Baffle Area
  - Imported from solid model
  - shows all slots and holes
  - shows airflow inside baffle and through critical areas



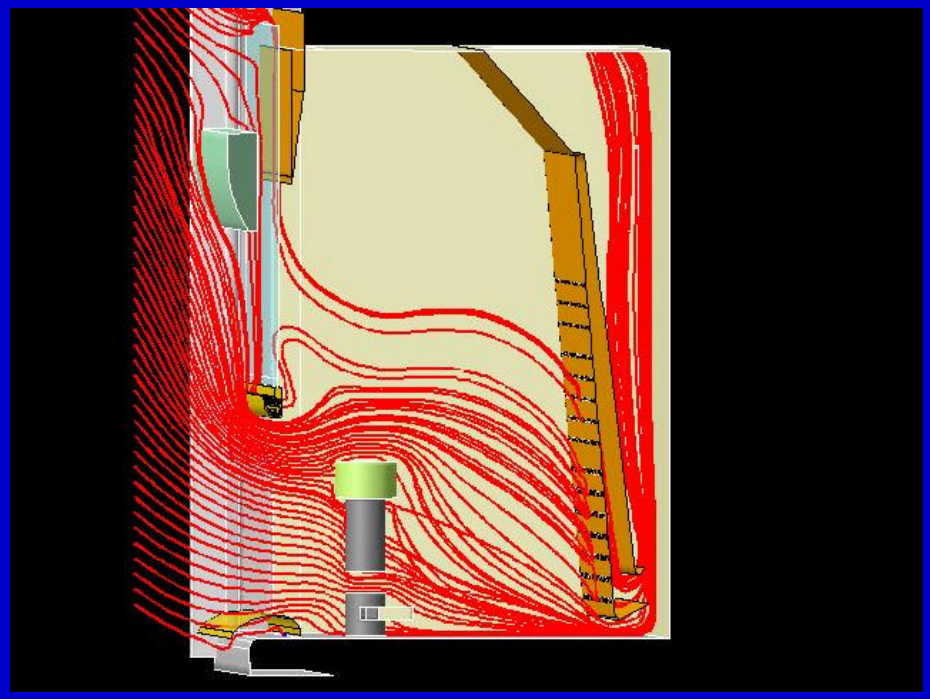


Protector XStream Airflow Dynamics

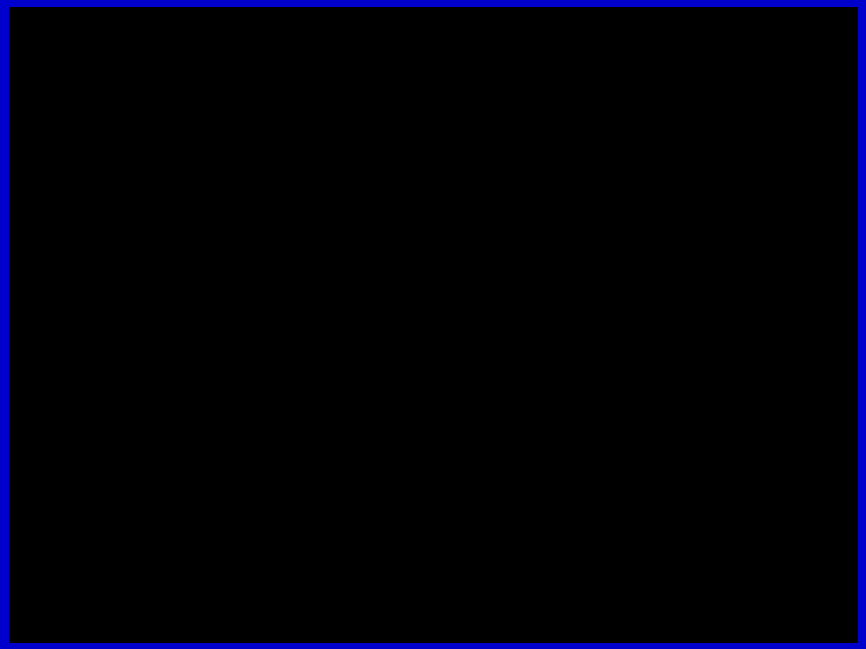


CFD of Protector XStream Airflow

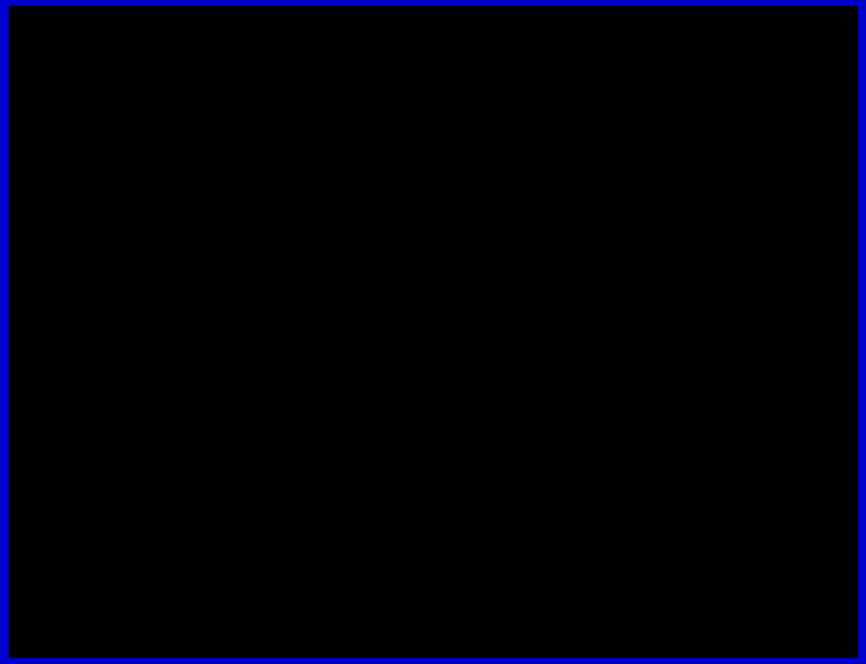
- Handle Area
  - Imported from a solid model
  - contains slots and holes exactly as designed.
  - Shows the effect of aerodynamic shape.



Protector XStream Design



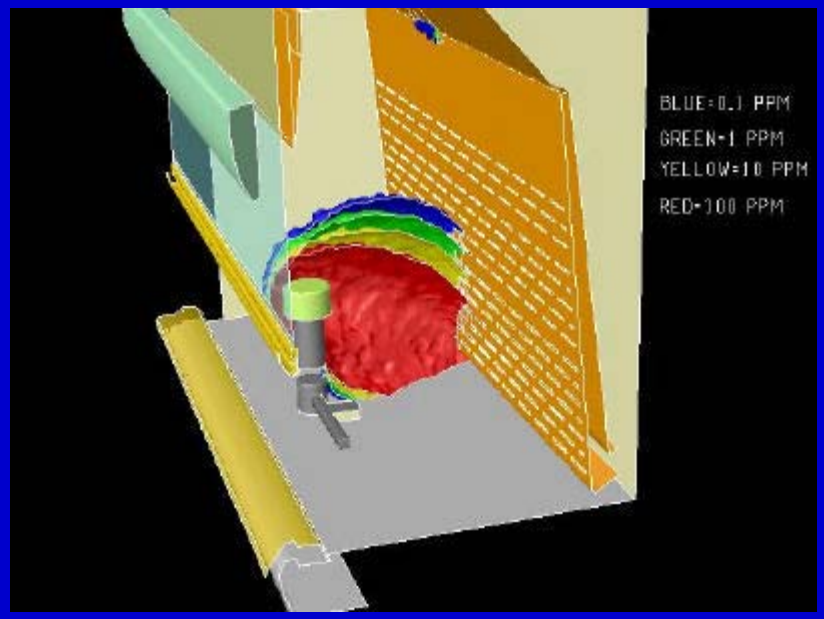
Front View

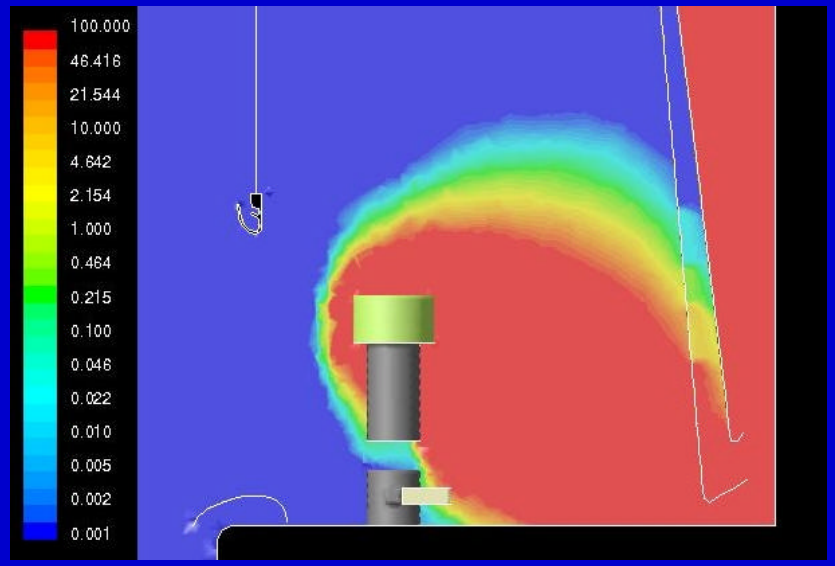


Side View

CFD of Protector XStream SF_6

- ASHRAE standard
  - Ejector blows from sides and top
  - SF_6 highly contained.
  - Works well for all sash heights.





ASHRAE TESTING - 6' XSTREAM VS 6' CONVENTIONAL HOOD

Models: 6' Low Flow XStream Hood
6' Conventional Hood

Conditions: ASHRAE Test 110-1995 Modified as noted

28" Sash Test Position						
15" Ejector Ht. BZ 3" from Sash	**100 fpm**		**60 fpm**		**40 fpm**	
	XStream (ppm)	Conv. (ppm)	XStream (ppm)	Conv. (ppm)	XStream (ppm)	Conv. (ppm)
	0	0	0	0.02	0	0.13
	18" Sash Test Position					
	0	0	0	0	0	0.05

Notes: 1. All measurements taken in the center of the hood only.
2. Standard ASHRAE test.
3. Labconco does not recommend a face velocity of 40 fpm.

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ASHRAE TESTING – 6' XSTREAM VS 6' CONVENTIONAL HOOD

Models: 6' Low Flow XStream Hood
6' Conventional Hood

Conditions: ASHRAE Test 110-1995 Modified as noted.

15" Ejector Ht.		28" Sash Position				18" Sash Position			
		100 fpm		60 fpm		100 fpm		60 fpm	
		XStream (ppm)	Conv. (ppm)	XStream (ppm)	Conv. (ppm)	XStream (ppm)	Conv. (ppm)	XStream (ppm)	Conv. (ppm)
3"	BZ	0	0	0	0.02	0	0	0	0
3"	Chest	0	.01	0	0.05	0	0	0.01	0
3"	BB	0	1.75	0	1.44	0	0	0.01	0.03
2"	BZ	0	0	0	0.01	0	0	0	0
2"	Chest	0	0.02	0.03	0.12	0	0	0	0
2"	BB	0.02	1.88	0.09	1.94	0	0.01	0.01	0.02
1"	BZ	0	0.01	0	0.03	0	0	0	0
1"	Chest	0.04	0.28	0.12	1.07	0	0.01	0	0
1"	BB	0.16	1.98	.78	1.97	0.02	0.03	0.11	0.08

Notes:
1. Sampling probe distance from the sash given by 3", 2", and 1".
2. BZ, Chest, and BB represent manikin's breathing zone, chest and belly button sampling areas.
3. All measurements taken in the center of the hood only.

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	28” Sash Height 100 fpm 30 fpm Cross Draft					
	Left		Center		Right	
	XStream (ppm)	Conv. (ppm)	XStream (ppm)	Conv. (ppm)	XStream (ppm)	Conv. (ppm)
BZ	0	0	0	0	0	0
CH	0	0.01	0	0.12	0	0
BB	0	0.18	0	1.20	0	0.01

	28” Sash Height 60 fpm 30 fpm Cross Draft					
	Left		Center		Right	
	XStream (ppm)	Conv. (ppm)	XStream (ppm)	Conv. (ppm)	XStream (ppm)	Conv. (ppm)
BZ	0	0.01	0	0.01	0	0.04
CH	0	0.20	0	0.23	0	0.10
BB	0	0.53	0	1.25	0	1.98

	28” Sash Height 40 fpm 30 fpm Cross Draft					
	Left		Center		Right	
	XStream (ppm)	Conv. (ppm)	XStream (ppm)	Conv. (ppm)	XStream (ppm)	Conv. (ppm)
BZ	0	(-)	0	(-)	0.08	(-)
CH	0.01	(-)	0.02	(-)	0.09	(-)
BB	0.03	(-)	0.31	(-)	0.89	(-)

ASHRAE TESTING – 6’ XSTREAM VS CONVENTIONAL HOOD

Models: 6’ Low Flow XStream Hood
6’ Conventional Hood

Conditions: ASHRAE test 110-1995 Modified as noted – Gas SF_6

Notes: 1. Sampling probe placed 3” from sash.
2. BZ, CH, and BB represents manikin’s breathing zone, chest, and belly button sampling areas.
3. (-) not tested due to expected high results.
4. Labconco does not recommend a face velocity of 40 fpm

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Conclusion

- Design a high performance, low-flow fumehood with excellent containment. ?
- Address the shortfalls of conventional hoods and apply the changes to the low-flow hood design. ?
- Use the latest state-of-the art computational and experimental tools to assess performance. ?
- Combine both computational and experimental techniques to optimize the hood design. ?