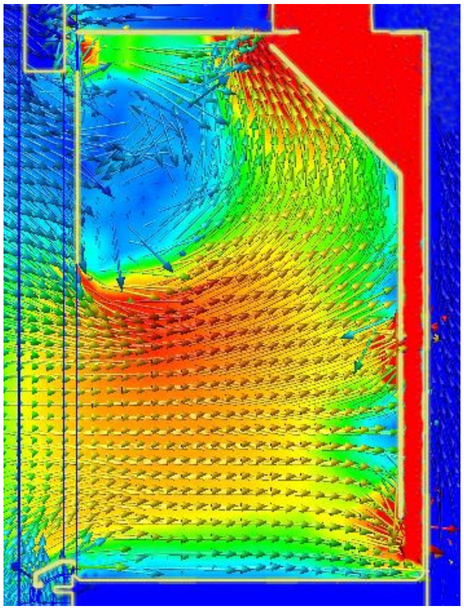
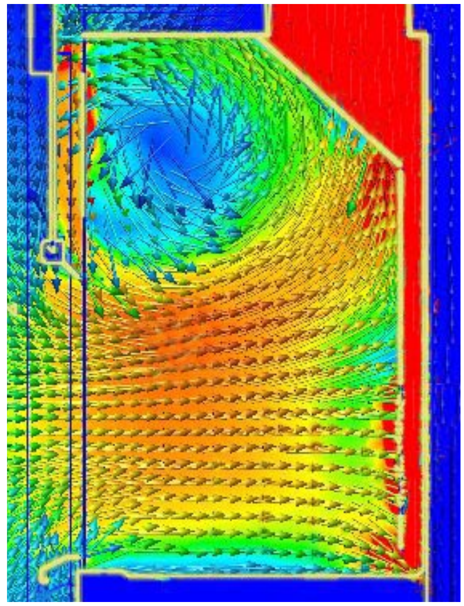
Bypass Fume Hoods Compared Using CFD

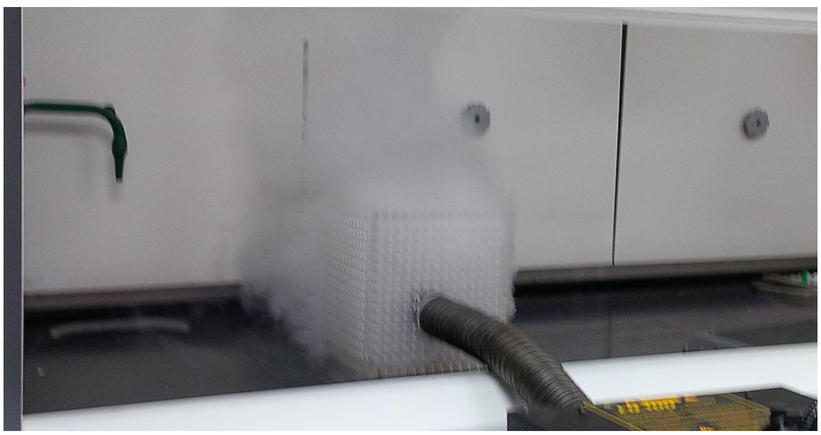


Legacy



Modified

Legacy Hood and Modified Hood at 80 FPM Face Velocity and 28" Sash Opening



Actual Test, Modified

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Background:
A Legacy (Standard) Flow Sciences fume hood was developed, modeled, and constructed using Auto Desk and CFD (Computational Fluid Dynamics) at our manufacturing facilities here at Flow Sciences. Containment analysis was done under:

1) “Standard conditions” (80 FPM face velocity and sash height of 28”)
2) “Low flow conditions” (60 FPM face velocity and 18” sash height)

In both *normal flow* and *low-flow* cases, air flow and potential containment issues were then identified and documented.

Next, the legacy hood baffle system, airfoil, and bypass were modified and new hood parts constructed reflecting design changes believed to help improve fume hood containment. The CFD analysis described above was then run again at the same face velocities with the modified hood.

The Modified Fume Hood performed significantly better than the Legacy model in the following areas:

1) Size and severity of upper front interior vortex area
2) Distribution of internal transport currents carrying fumes out of containment area.
3) Worktop airflow

These *theoretical* advantages predicted by CFD comparisons were then tested using ASHEA 110 and other aerodynamic tests on the physically altered legacy hood. This testing showed the predicted improved results actually occurred.

The advantages suggested above by modeling and demonstrated with physical testing also offer a potential opportunity to save significant amounts of energy and simplify operation with lower flow options. The current *Saf T Flow* fume hood Flow Sciences offers *is* the “Modified” fume hood from this study.

Perhaps an even more significant result from the above analysis is the demonstration that CFD can save time and money in our industry’s efforts to rapidly produce and improve fume containment designs without physically testing each design change separately.

Procedure:
In the past, whenever manufacturers attempted to "improve" a fume hood, they made design changes based upon customer grievances, job specification demands, or economic considerations. Recently, energy savings and highly demanding containment testing were also added to the mix.

With all these levels of often competing requirements, it became obvious that the old multi-step "tinkering" model of altering one fume hood component at a time and then testing containment and air flow changes before moving on to the next item was frustratingly slow.

Recently, Flow Sciences attempted to more efficiently improve fume hood performance. In this approach, a fume hood design is represented in Auto Desk *Inventor*, and then processed by Auto Desk *Simulation CFD.*

Various representations generated by these two linked programs can then be used to generate an actual forecast of flow performance for the fume hood represented. Changes *to the original model* can then be undertaken and CFD simulations run. If these changes, all run at once, produce better results, a prototype model for physical and mechanical testing can then be more quickly produced.

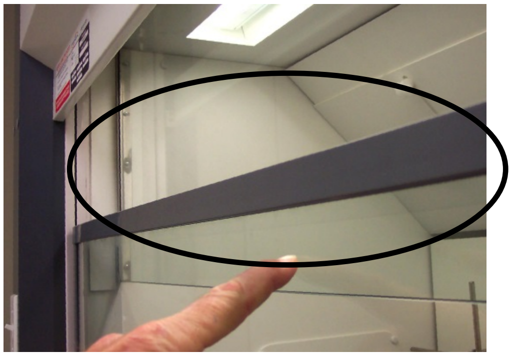
For those of you readers "familiar with the art", we are basically suggesting replacing iteration with cardboard and duct tape with an analysis of a simplified 3D model whose parameters can be more easily altered. After this phase, an "improved" CFD-verified design with simultaneous improvements will stand a higher likelihood of being successful when actually built and tested.

Here are photos of the two baffle designs (Legacy & Modified) modeled using CFD at Flow Sciences:

Legacy Standard Bypass and Baffle System

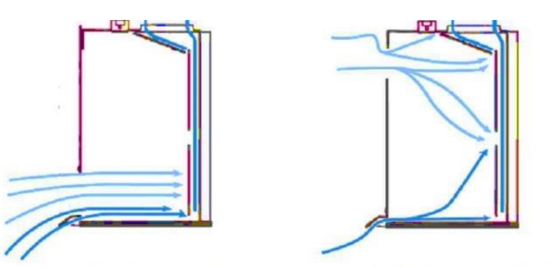
Single piece back baffle and modified slots + OSB Bypass

Additional unique improvements added to the Modified design are an overlapping sash bypass system and sash flange shown below:

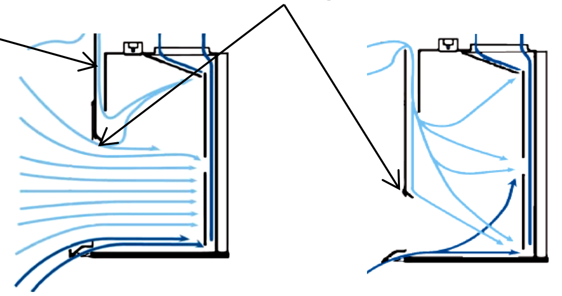


Front-to back overlapping slot bypass

Sash Flange



(Legacy Bypass Function)



Overlapping sash bypass function

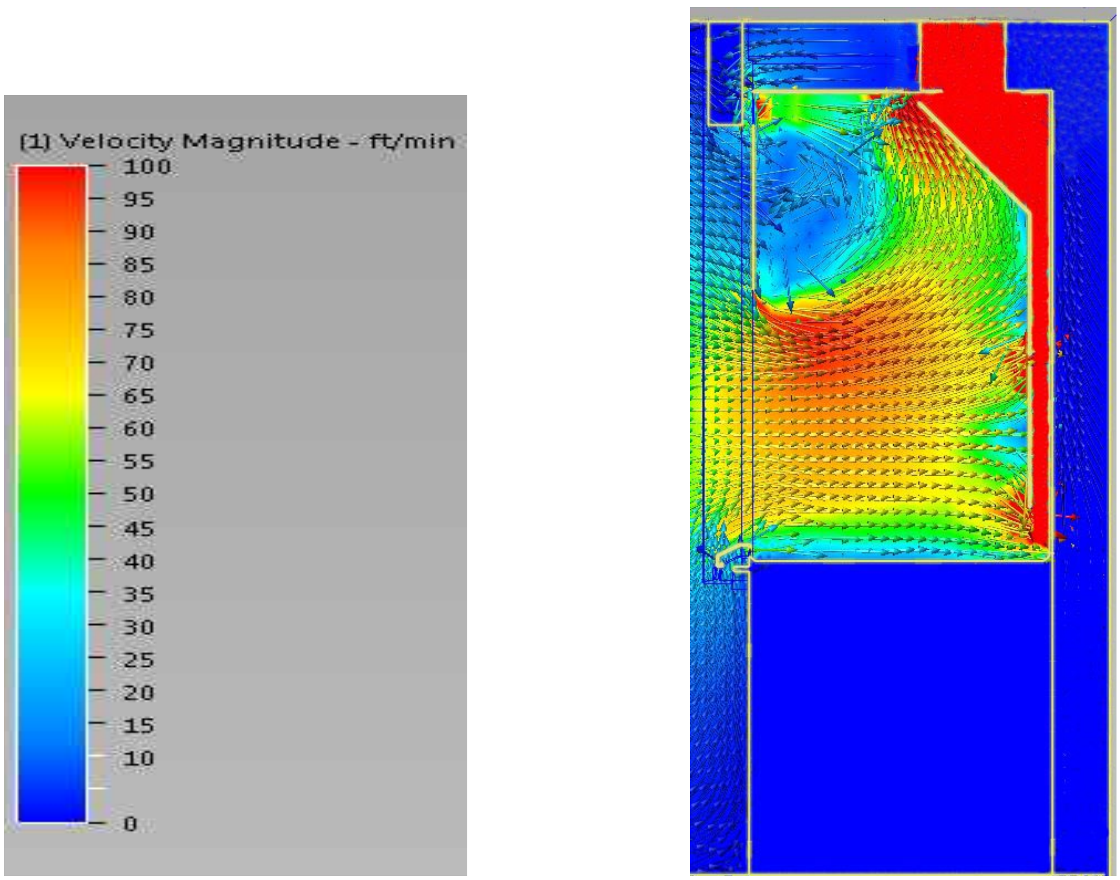
Observations:

A. Legacy and modified fume hood CFD representations were run to identify potential containment improvements. Because Auto Desk *Simulation* CFD is an iteration program, each representation took two hours to run:
   1) Standard Fume Hood with 28” opening and 80FPM Face velocity
   2) Standard Fume Hood with 18” opening and 60FPM Face velocity
   3) Modified Fume Hood with 28” opening and 80 FPM Face velocity
   4) Modified Fume Hood with 18” opening and 60 FPM Face velocity
   5) Each legacy case is shown below with additional performance parameters:

Legacy Hood at 80 FPM:

28" Opening, 80 FPM, 28" sash opening:

a) Small 3" top bypass slot
b) Topmost slot = 0.5"
c) Middle slot = 1.0"
d) Lower Slot = 3.0"
e) CFM (Specified) = 778 CFM
f) CFD velocity plot:



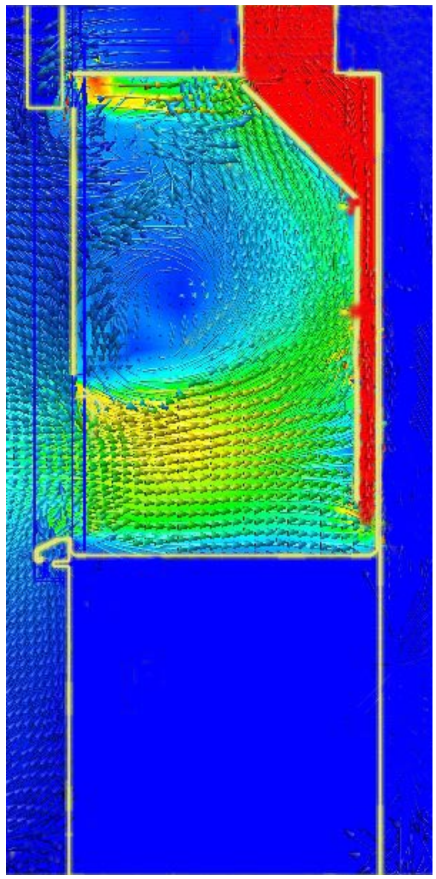
1) The air inflow is nearly laminar and increases as the sash plane is approached.
2) Inside the containment cavity, there is more rapid air flow near the center front of the hood and all along the rear baffle system, particularly where exhaust slots are located.
3) A small low Velocity spot with a slowly rotating vortex is located just above the mid, front high flow spot.
4) This slow vortex runs right up next to the sash interior.

These air flow characteristics were generally accepted without complaint in the era of legacy fume hoods (1970-1990). They generally achieve good containment at 100 FPM face velocity as evaluated by ASHRAE 110-1995.

Legacy Hood at 60 FPM:

18” Opening, 60 FPM:

a) Small 3” top bypass slot
b) Topmost slot = 0.5”
c) Middle slot = 1.0”
d) Lower Slot = 3.0”
e) CFM (Specified) = 375 CFM
f) CFD velocity plot:



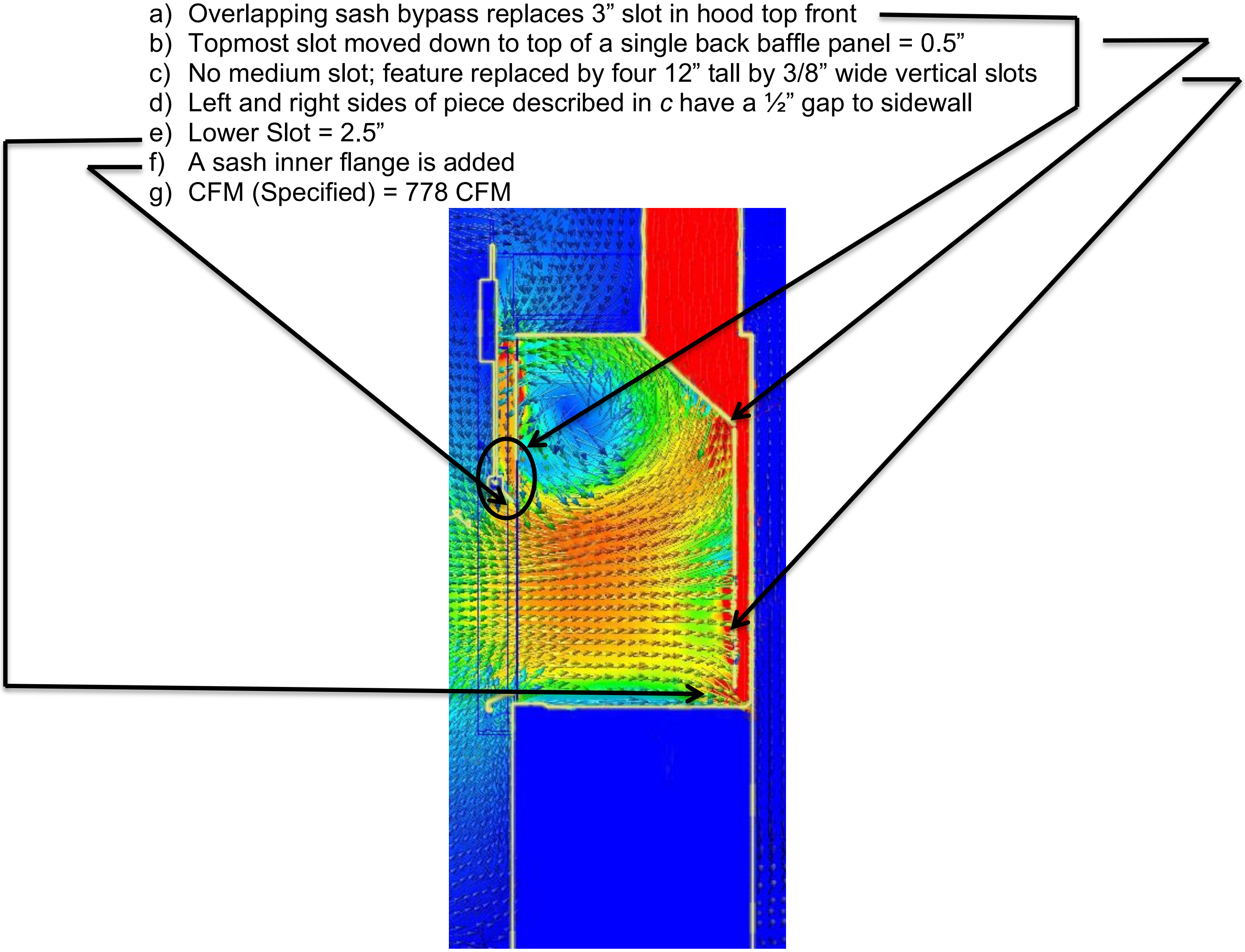
1) Outside the containment cavity, the air inflow is nearly laminar with some diminution of velocity around the opening perimeter and increases as the sash plane is approached.
2) The most rapid air flow is near the center front of the hood, with some flow reduction near the slotted rear baffle system, away from the actual slots.
3) An important containment issue has developed in this legacy hood: a *very large* slow-moving air spot is located just above the mid, front high flow spot and extends upward nearly to the hood roof. This huge area touches the sash rear and is approximately 40% of the hood interior and is surrounded by a slow-moving vortex.
4) If the sash is opened wider for any reason during a vapor-producing procedure, contaminants could easily escape from the hood.

Therefore, in these first two CFD legacy models, the high flow application is acceptable, while the low flow application appears dubious.

Modified Hood at 80 FPM:
The following "modifications to the legacy design were run through CFD analysis before being built:

80 FPM, 28" sash opening:

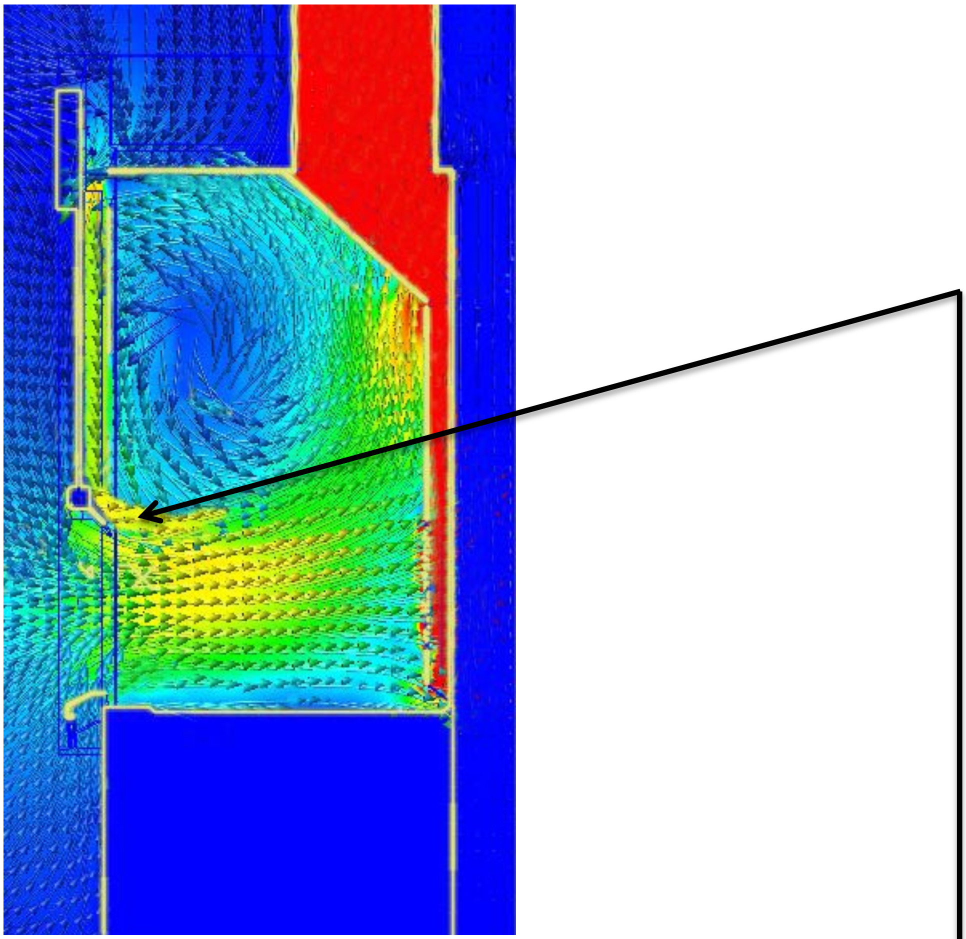
a) Overlapping sash bypass replaces 3" slot in hood top front
b) Topmost slot moved down to top of a single back baffle panel = 0.5"
c) No medium slot; feature replaced by four 12" tall by 3/8" wide vertical slots
d) Left and right sides of piece described in *c* have a ½" gap to sidewall
e) Lower Slot = 2.5"
f) A sash inner flange is added
g) CFM (Specified) = 778 CFM



1) Outside the containment cavity, the air inflow *is more laminar than Legacy*, particular near the work top.
2) Inside the cavity, there is a significantly smaller low velocity area near the top front of the sash opening. There is more rapid air flow near the center front of the hood and all along the modified rear exhaust slots. A much smaller low velocity area with radial arrows rather than cyclonic vectors is located just above the mid, front high flow spot.
3) Also noted is the separation of the remaining blue area from the back of the sash plane by downward outside air movement caused by the overlapping sash bypass.

Low Velocity Modified Hood:
60 FPM, 18” sash opening:

a) Overlapping sash bypass replaces 3” slot in hood top front
b) Topmost slot moved down to top of a single back panel = 0.5”
c) No medium slot; feature replaced by three 12” tall by 3/8” wide vertical slots
d) Left and right sides of piece described in *b* have a ½” gap between to sidewall
e) Lower Slot = 2.5”
f) CFM (Specified) = 375 CFM
g) CFD velocity plot:

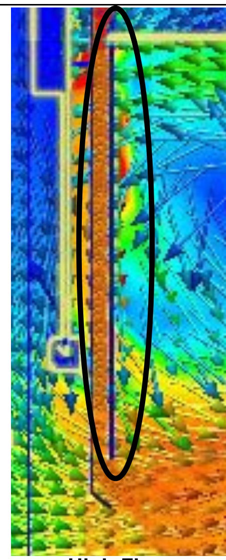
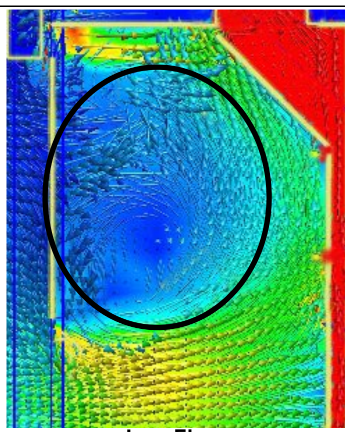
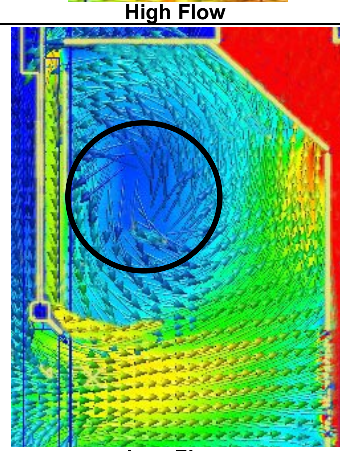


1) Inside the cavity the flow shows significantly reduced “low velocity” area near the top front of the sash opening.
2) Inside the containment cavity, there is more rapid air flow near the center front of the hood and all along the rear baffle system, particularly where exhaust slots are located.
3) There is a high, downward CLEAN air flow just behind the sash (yellow).

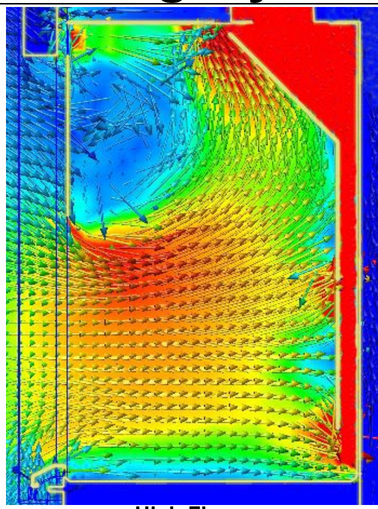
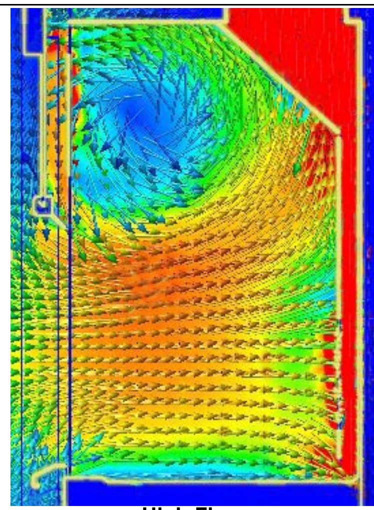
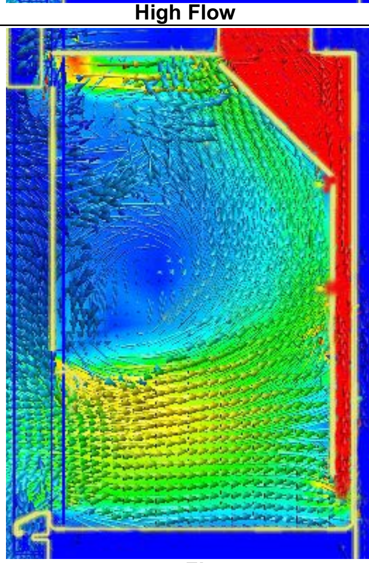
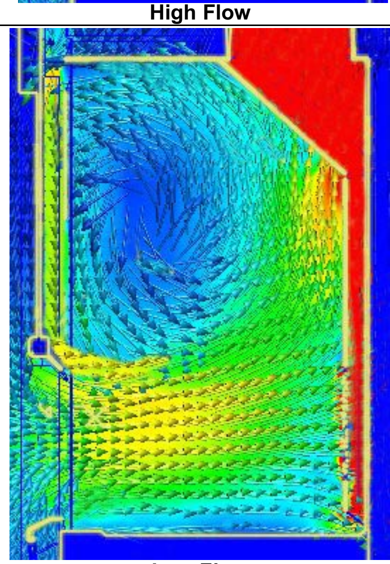
Because there is a lot going on in these CFD’s, the author directly compares key features in the *Legacy* and *Modified* designs below:

Comparisons at a Glance

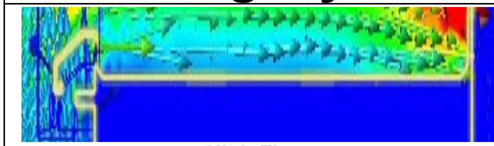
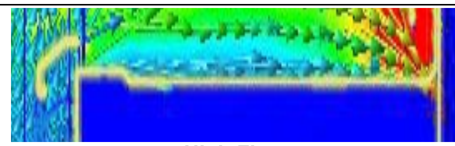
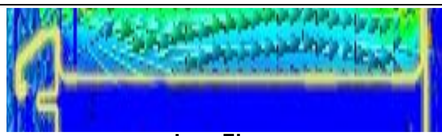
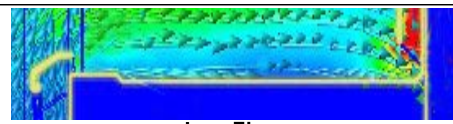
Comparison # 1: Area behind the sash

Legacy	Modified	Comparison
 High Flow	 High Flow	**AREA BEHIND SASH:** **Legacy:** ***Large and possibly contaminated vortex of slow-moving air (blue) kisses back of sash glass.*** **May leave hood during rapid sash movement.** **Modified: High velocity fresh air (orange-red) prevents contaminated vortex from kissing sash, preventing loss of containment. Sash flange diverts this downwash rearward, improving containment.**
 Low Flow	 Low Flow	**AREA BEHIND SASH:** **Lergacy: Huge area of velocities less than 15 FPM occupies almost 40% of the hood interior.** ***Lifting sash may case trapped material in this area to escape.*** **Modified: High velocity fresh air from small overlapping sash bypass restricts size of contaminated low velocity air from kissing sash, preventing loss of containment. Sash flange diverts this downwash rearward, improving containment.**

Comparison # 2: Internal Transport Currents

Legacy	Modified	Comparison
 High Flow	 High Flow	**Transport Currents:** **Legacy: Adequate air speed and direction overall at 80 FPM except at top front, work top, and directly against back baffle.** **Modified: Much greater coverage of high velocity vectors in working area (red). Reduced area of slow air against baffle. Slightly improved work top flow.**
 Low Flow	 Low Flow	**Transport Currents:** **Legacy: Very inadequate air speed and direction overall at 60 FPM. At least 40% of interior is at < 15 FPM!** **Modified: Much greater coverage of higher velocity vectors in working area. Deep blue areas (< 15 FPM) are isolated away from open sash. Only about 15% of hood interior velocities are now < 15 FPM.**

Comparison # 3: Work Top Airflow

Legacy	Modified	Comparison
 High Flow	 High Flow	**Work Top Airflow:** **Legacy: Lazy air flow under the 2” top height averages about 25 FPM near hood front.** **Modified: Better airflow averages more than 80 FPM in same sampeling plane. This is roughly equal to the hood face velocity.**
 Low Flow	 Low Flow	**Work Top Airflow:** **Legacy: Air flow under the 2” top height averages about 60 FPM, which is hood face velocity.** **Modified: Similar airflow averages more than 60 FPM in same sampeling plane, which is the hood face velocity.**

The *Modified Fume Hood Model* performed far better than the *Legacy Model* in the following areas:

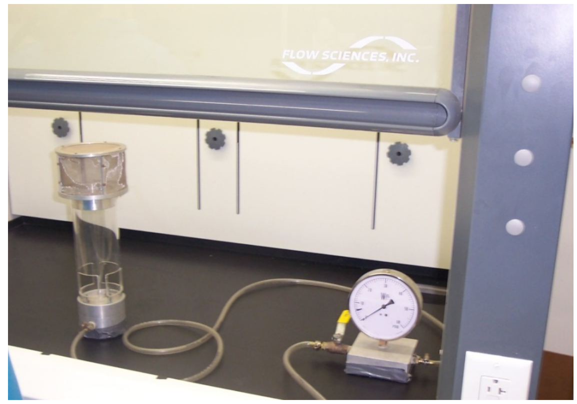
1) Size, location, and severity of upper front interior low velocity area
2) Distribution of internal transport currents carrying fumes out of containment area.

In the category of worktop airflow, both hoods were comparable at the low flow setting, while the *Modified Model* was better at the high air flow setting.

B. Comparisons of actual prototypes:

1. The Legacy and modified prototypes were tested in the Flow Sciences air flow test lab using ASHRAE 110.


Legacy Hood



Modified Prototype

2. The *Modified Prototype* (now our Saf T Flow standard fume hood) showed more stable face velocity grids and much better containment in the low velocity mode than the *Legacy Hood*.

Key ASHRAE 110 results are detailed here under actual test conditions!

	Legacy	Modified
1) Uniform face velocity @ 60 FPM	23% variation	15% Variation
2) Uniform face velocity @ 80 FPM	22% variation	12% Variation
3) SF_6, rapid sash movement @ 60 FPM	0.025 PPM	0.015 PPM
4) SF_6, rapid sash movement @ 80 FPM	0.016 PPM	0.007 PPM
5) HAM Average@ 60 FPM	0.025 PPM	0.015 PPM
6) HAM Average@ 80 FPM	0.025 PPM	0.007 PPM

Conclusions:

1) The modified hood prototype showed significant improvement over the legacy prototype in six measurable performance categories shown in the chart above. These changes were all made at once using CFD *before* either hood was built or tested.

2) Improved fume hood aerodynamics and containment performance offer an opportunity to save significant amounts of energy by reducing hood face velocity and corresponding recommended exhaust CFM

3) CFD modeling in this study allowed a considerable savings in time and expense by allowing multiple changes to be made in initial design, then *testing* forecast performance before building any prototypes.