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The Myth of Face Velocities in Fume Hoods

The Significance of Laboratory Fume Hood Face Velocities

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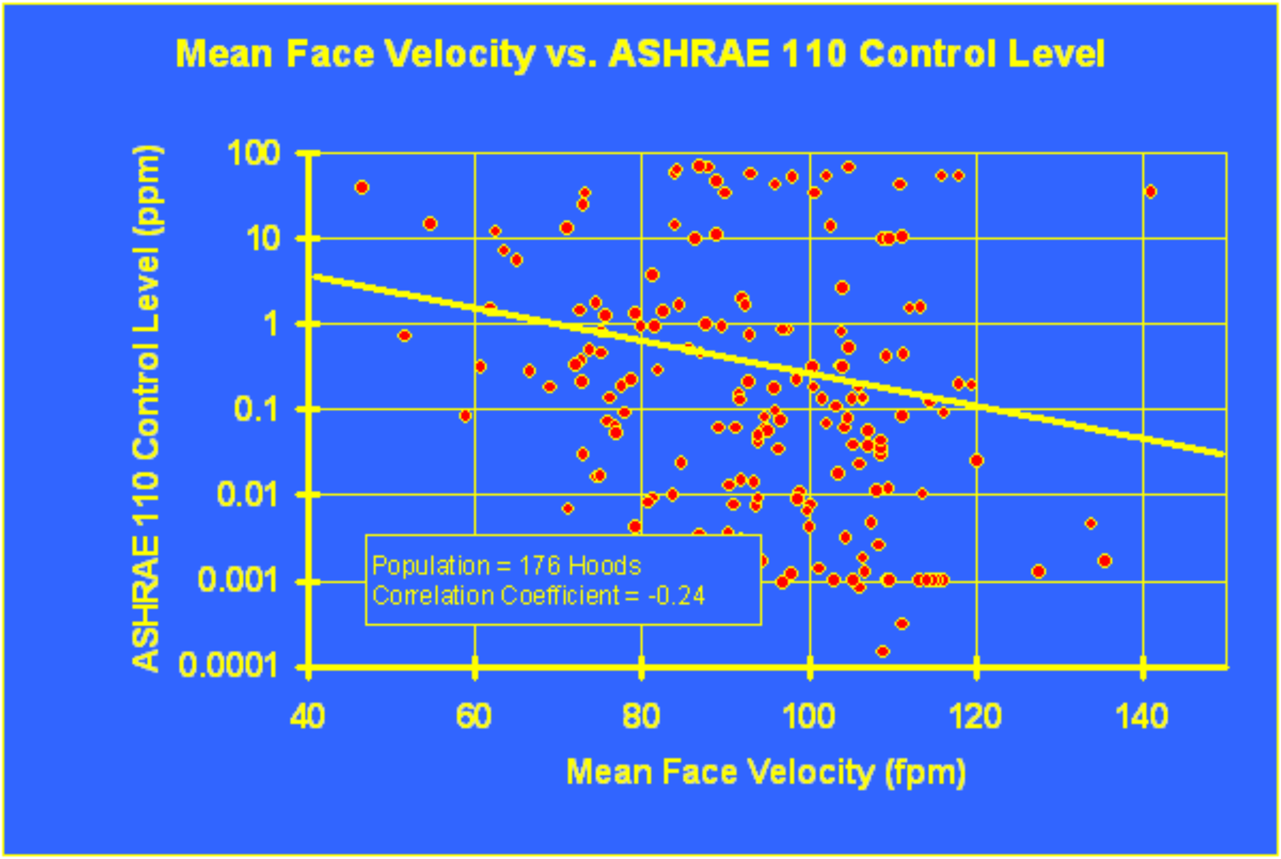
FACTs provides lab fume hood assessments and evaluations in a variety of laboratories and industrial facilities. Most lab managers are aware of the provisions in OSHA codified in 29 CFR §1910.1450 *Occupational exposure to hazardous chemicals in laboratories*. This standard places several regulatory burdens on industrial laboratories including the requirement to establish a Chemical Hygiene Plan and a requirement to take specific measures to ensure that laboratory fume hoods are functioning properly (§1910.1450(e)(3)(iii)).

But the significance of fume hood face velocity is largely misunderstood by many lab personnel who erroneously believe that face velocities are an indication of how well a hood works. Although face velocities have traditionally been the focal point of a fume hood evaluation, research accumulated over the last 35 years indicates that although face velocity is a factor in hood performance, it has a low intrinsic value when determining the efficacy of a fume hood. Face velocities are useful as diagnostic indicators in the event that the hood does not perform well, but should not be used as the method for determining the how well a hood is performing.

Graphics reference

Excellent work performed by Dale Hitchings [1] demonstrated the insignificance of face velocity as the exclusive factor or even the primary factor in predicting fume hood efficacy. In the graphic below, Hitching's work plots hood capture against face velocity. The graphic shows that not only is there no correlation between face velocity and capture efficiency, there is actually a *trend* (statistically insignificant) which shows a negative correlation.



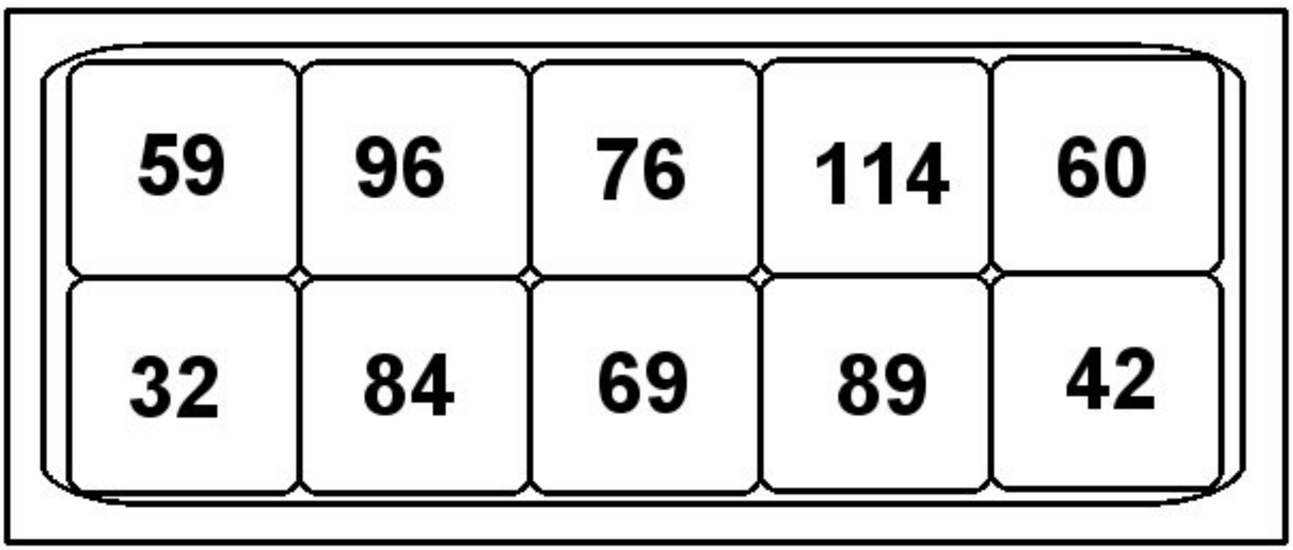
Graphics reference

Additionally, all too often we see fume hoods being “tested” in a manner that is incapable of actually achieving the stated goal of measuring the face velocity. Frequently, we find hoods being “tested” by an individual who is instructed to stand to the side of a hood (to avoid disrupting the air flow), and place an anemometer in the center of the face of the hood, and read the instrument.

This technique can no more determine an hood’s face velocity than can a single photograph determine the mean traffic flow on a major highway. The velocity profile of the hood face is extremely dynamic; large changes in velocity occur over the face of the hood and with time, and with actual use. For a standard 10 square foot hood, a minimum of 25 readings should be taken at equidistant points.

By stepping off to the side of the hood, one artificially creates a situation that never occurs with an hood – that is, an employee will never use the hood while standing off to the side, so why would one evaluate a hood in such a manner? Face velocity readings should be taken while one is occupying the hood in a normal working condition (usually standing in center of the hood).

At FACTs, we occupy the center of the hood, and with a fixed array, we measure the velocity at 16 points for EVERY square foot of face area. In this way, for a standard 10 square foot lab fume hood, we collect 160 velocity points; each 16 point reading is integrated into a single reading for that square foot of face. A typical face profile will appear like this:



Typical standard deviations for ten readings may be as high as 40 linear feet per minute.

Many hoods fashionably have “face velocity” alarms affixed to the front of the hood. In our experience, the alarms never actually indicate the mean flow, and NEVER indicate if an hood is operating properly. Such alarms are essentially a sales gimmick that robs the lab from precious financial resources and offers no benefit in return.

In an ordinary fume hood, for a given hood static pressure, face velocities are inversely proportional to the cross sectional area of the open face according to the following relationship V=Q/A.

Where V is the face velocity, Q is the volume of air evacuated from the hood per unit time and A is the cross sectional area of the hood. The face velocity can be increased by merely lowering the sash; this would allow an investigator to artificially demonstrate that the hood has met some arbitrary minimum face velocity, such as 100 feet per minute, but it will not alter, much less improve, the performance of the hood.

For example, in a hood which has an inadequate evacuatory volume and consequently a face velocity of, say, 25 feet per minute (fpm), one could increase the face velocity to 100 fpm by lowering the sash three quarters of the way (thus reducing the face area). However, in so doing, one would overlook the fact that only the face velocity has increased; the actual evacuatory volume would remain inadequate.

The issue becomes more complex if the hood in question is a by-pass hood (used in most facilities). By-pass hoods have a variable inlet baffle which permits more air to enter the hood via a special inlet as the sash is lowered. The effect is to maintain a non-linear increase of face velocity as the sash is lowered, thus avoiding excessive face velocities when the sash is only opened by a few inches; again, the velocities change but the evacuatory volume remains essentially constant.

Other factors appear to be far more important than the face velocity. Many investigators have reported on the importance of controlling room air. One investigator [2] found that in a properly designed laboratory, fume hoods with face velocities as low as 50 fpm provided protection factors 2,200 times greater than hoods with face velocities of 150 fpm. Another study [3] indicated that with the exception of one particular type of hood operation, there was no difference in hood containment with face velocities between 59 and 138 fpm. In another study, [4] the authors concluded that "The terminal throw velocity through the grilles had a greater effect on the spillage rate (from the hood) than the face velocity of the hood."

Following an exhaustive study conducted for the U.S. EPA, [5] the authors concluded that "[fume hood face] Velocities of 50 feet per minute (FPM) would usually suffice if the particle kinetics for aerosols or the molecular diffusion of gases and vapors were the only forces to overcome." These same authors conclude that:

"...face velocities of 80 to 100 FPM are adequate if the overall installation can be rated as good to excellent. The increased turbulence within the hood and around the operator when higher velocities (150 FPM) were used, compounded the bad performance of installations rated poor."

Additionally, the authors of the above mentioned report observed that if the room air was poor, the operation of fume hoods could not be made acceptable regardless of the control face velocity used. This is a vital conclusion if one is to dispel the notion that all you need to do to correct a poorly operating hood is install ever bigger fans.

The following short video is an example of reverse vector flow in an hood that otherwise meet the manufacturer's specifications:

Safari Power Sav
Click to Start Fla

:

Video of Reverse Vector Flow

This video and other field videos taken by FACTs are available here.

Not all the available literature supports the views expressed thus far. For example, one study conducted by the Oak Ridge National Laboratory in 1978 [6] concluded that hoods used for highly toxic materials should have a minimum face velocity of 125 fpm. This study however was not based on a real laboratory setting, and the criteria for an "acceptable" face velocity was arbitrary. Clearly, such an approach is no longer considered to be the highest standard of care by the industrial hygiene community.

Although OSHA does specify minimum face velocities for laboratory fume hoods in several compound specific standards (29 CFR §§1910.1003, .1004, .1007 *et al*), these standards are not applicable to laboratories by virtue of the decision by the United States Court of Appeals for the Third Circuit in Synthetic Organic Chemical Manufacturer's Association v. Brennan, 506 F. 2nd 385 (3d Cir. 1974), certiorari denied 423 U.S. 830. [7]

The U.S. is not alone in this regard. Some time ago, this author (Connell) spoke with Mr. Bernard Fletcher with the British Health and Safety Executive (HSE) who informed us the British Government is also moving away from establishing a minimum face velocity for fume hoods. Although Mr. Fletcher thought that there may be a couple of specified velocities for specific compounds, the HSE is moving toward "containment based" criteria. Nevertheless, the British Government holds the position that face velocities less than 0.3 meters per second (59 fpm) are "unlikely" to result in good containment.

Similarly, the German hood standard from Deutsches Institut für Normung (DIN 12 924 "Laboreinrichtungen Anforderungen an Abzüge, Abzüge für allgemeinen Gebrauch") does not specify a minimum face velocity for a fume hood. Instead, DIN 12 924 states:

Der vorliegende Norm-Entwerf weicht insofern grundlegend von der seitherigen sicherheitsphilosophie ab, als nicht mehr die pro Zeiteinheit durch den Abzug strömende Luftmenge als Kriterium für die sichere Funktion angesehen wird.

Roughly translated:

This present standard is fundamentally different from historical philosophies in that the quantity of air (flow) passing through the hood per unit time is no longer considered to be the only criteria necessary to determine how well the hood will function.

For these reasons, we believe that identifying a face velocity for a hood on an evaluation label is meaningless unless the sash position and proportionality coefficient of the by-pass baffle while in that sash position (when present) are also specified. Further, it is my opinion that due to the general myth that face velocities somehow equate to hood performance, by specifying a minimum face velocity, a hood user could be lulled into believing that the hood is adequate just because an arbitrary face velocity has been achieved.

All too often we still see lab personnel measuring face velocities under the erroneous assumption that the information will somehow equate to how well the hood is working.

During an evaluation at one facility, (unpublished data) we evaluated approximately 150 hoods, the majority of which were bench-top Hamilton hoods. Fully 25% of those hoods which exhibited good control (Category 1) [8] were below the corporate minimum face velocity of 80 fpm; 55% of those hoods that exhibited good control had face velocities below the manufacturer's design criteria of a 100 fpm equivalent. Face velocities should be used as a diagnostic tool once a hood has been evaluated and has been determined to be operating in a substandard manner. The face velocities can help determine if the most basic problems exist - (Is the fan running? Is the fan meeting its design evacuatory volume? etc.) However, the face velocities will tell an evaluator nothing about how well the hood is working or whether the hood is affording any protection to the user.

Additionally, face velocities are traditionally measured using thermal wire anemometry. This method has many inherent problems. For example, most hand held hot-wire anemometers are very similar in design. For some instruments, slight changes in the orientation of the sampling wand can result in significant errors in the readings; for others, the errors are insignificant.

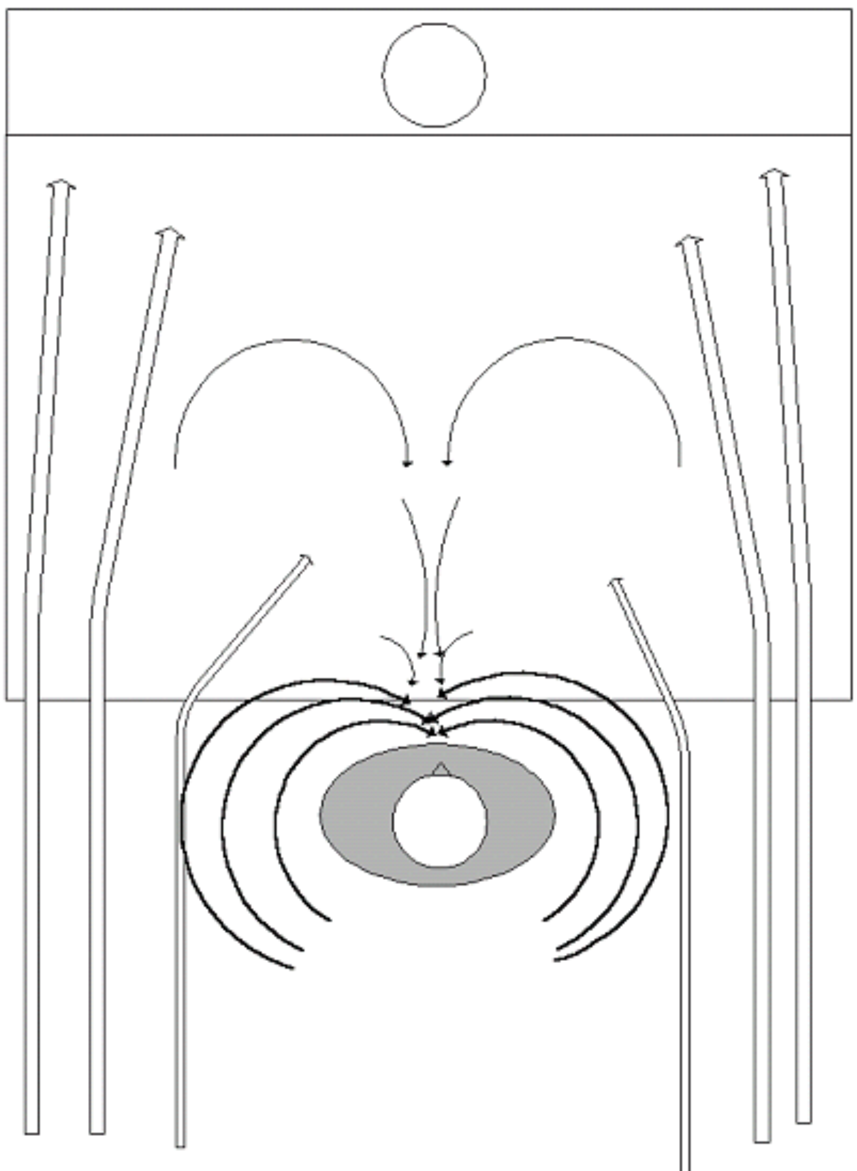
Degree of error as a function of yaw

Degree of Yaw	**-30°**	**-20°**	**-10°**	**0°**	**10°**	**20°**	**30°**

Instrument A (% accurate)	-78	-88	-96	0	98	-98	-86
Instrument B (% accurate)	-96	-97	-99	0	97	97	-99

Source: Air Flow Ltd. UK

When an individual steps into the face of a hood, they create a cone-shaped negative pressure zone in front of them that extends deep into the hood.



Negative Pressure Zone in a Standard Fume Cupboard

As a result, the face velocity readings vary immensely as one moves laterally across the hood. Yet, are these not valid face velocities? Of course they are, because these are the face velocities present when an employee uses the hood.

Nevertheless, many people are still blindly measuring face velocities based on tradition rather than the highest standard of care, and we think that a more rational approach should be forwarded by IHs. A proper evaluation of a laboratory fume hood can be effected without ever measuring a single face velocity. Similarly, measuring face velocities provides absolutely no *prima facia* information on the efficacy of the hood.

Based on years of experience standing in front of fume hoods as a chemist, and even more years of hood evaluations as an industrial hygienist, we have developed a simple and repeatable fume hood evaluation protocol that does not incorporate face velocities for the purposes of evaluating hood efficacy. Portions of the ASHRAE 110 were based on considerations of my protocol which we have successfully used in the evaluation of hundreds of fume hoods.

REFERENCES

1 Hitchings Associates, PC, 5320 W. 79th St., Indianapolis, Indiana. Copyright graphics were used with kind permission.

2ASHRAE Report Number 2438 RP 70, K.J. Caplan and G.W. Knutson, 1978

3A New Method for Quantitative, In-Use Testing of Laboratory Fume Hoods, R.E. Ivany, First, M.W., Diberardinis, Am. Ind. Hyg. Assoc. J. (50)5:275-280 (1989)

4 Laboratory Fume Hoods: Influence of Room Air Supply K.J. Caplan and G.W. Knutson, ASHRAE Transactions, Vol. 84, No 2, 1978.

5 Laboratory Fume Hood Standards Recommendations for the USEPA, R.I. Chamberlin and J.E. Leahy, 1/15/78. Contract No. 68-01-4661

6 Minimum Acceptable Face Velocities of Laboratory Fume Hoods and Guidelines for Their Classification, N.E. Bolton, et al, Oak Ridge National Laboratory, June, 1978, ORNL/TM-6400

7 OSHA Letter of Interpretation to the Honorable Steve Symms, United States Senate, from OSHA Assistant Secretary Thorne G. Auchter, dated October 23, 1983.

8 To visit my discussion concerning hood protocols and classifications, click here..

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