**Response to Comments by John Hamilton (TABB) on "2008 California Building Energy Efficiency Standards" Measure Information Template – Underfloor Air Distribution**



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## Introduction

After reading the public comments submitted by John Hamilton on February 15, 2006, we feel compelled to respond with our own public comments. To provide some context, we offer this introductory discussion. After reading what Mr. Hamilton writes, one is struck by the highly negative and combative nature of his input directed against UFAD systems. A common theme throughout his discussion is "where is the data?" or more simply, "this is not true." While on the one hand attacking UFAD systems as not having demonstrated many of the claimed benefits (e.g., energy, IAQ, costs) because of lack or real world data, he uses exactly the same approach himself by making wild claims and statements with not a single reference or piece of data to back-up his points. We have been researching UFAD systems for well over a decade and base our responses below on unbiased research findings and interpretations of field experience. It is important to understand that as University researchers we are not promoting UFAD systems as the best solution for all applications, but rather as a technology that has the "potential" to offer improvements over conventional overhead air distribution systems, when used in the right application, and designed, installed, and operated in an effective manner. In order to help make this happen, our goal is to develop and distribute information about this technology that is truthful, scientifically sound, and useful to practicing professionals in the building industry. We feel that many of Mr. Hamilton's comments are misleading, inaccurate, and biased. We will explain below.

As a historical perspective, it should be noted that this is not the first time that members of the Testing Adjusting and Balancing Bureau (TABB) have written articles with similar unsubstantiated claims against UFAD systems, typically as part of the advertising insert entitled TABB TALK, periodically appearing in ASHRAE Journal and other common HVAC trade magazines. Examples of TABB TALK issues on UFAD are as follows: (*ASHRAE Journal*, Feb. 2004; and *Engineered Systems*, October 2004). None of these articles have ever passed a peer-review process. Many of the misleading points repeated by Mr. Hamilton below were first introduced in these earlier TABB TALK issues. These points have been reviewed and discussed at length on several occasions, in many cases refuted, and at a minimum, they have had qualifying statements added to capture the true meaning of the claims. CBE has been involved in some of these exchanges. Examples include the following:

- Bauman, F. 2005. "The real facts on UFAD." Letter to editor, *Consulting Specifying Engineer*, Vol. 37, No. 1, January.
- Review of U.S. General Services Administration (GSA) PBS Guideline for Raised Floor systems With and Without Underfloor Air Distribution. CBE was invited to review several drafts of this document, which is still undergoing internal review within GSA; a final version had not yet been released as of January 2006. The original draft of the GSA UFAD Guideline was widely criticized as lacking objectivity, clearly being biased against UFAD

systems, and favoring conventional air distribution (CAD) systems. It has been revised substantially, although not enough in our opinion, since the first draft. Of note is the fact that the primary author of the GSA Guideline receives a significant amount of funding from TABB, and not surprisingly, many of these same biased points against UFAD found there way into the draft document and remain in the current version. In addition, GSA hosted a full-day Roundtable Discussion of UFAD Systems on May 5, 2005, in which approximately 50 experts, practitioners, and other experienced users of UFAD technology were invited to discuss the draft GSA UFAD Guideline in particular and UFAD technology in general.

We find it very troubling that after all this back and forth with much time and energy expended explaining and clarifying what is really known about UFAD, we are faced with another rehash of many of these same biased points, as if nothing has been learned during the past couple years.

As we see it, the comments submitted by Mr. Hamilton can be divided into two primary groups: (1) those that contain, or are based on, inaccurate information, data, and assumptions, and (2) those that have some truth to them, but their implications in terms of UFAD systems are blown out of proportion. In this second category, the topic of finding reliable performance data from UFAD installations is a key one. In the U.S. building industry, obtaining energy use, IAQ, or cost data from any project (CAD, UFAD, or other) is a challenge and requires time, effort, and money. Given that UFAD technology is still relatively new, it is not surprising that there is a limited amount of data available. While we agree with Mr. Hamilton that data are limited, we heartily disagree with the way that conclusions are drawn from reported poorly performing UFAD buildings. If a building is not performing well, some valuable lessons can often be learned if the reasons behind the poor performance are investigated. A good example of this for UFAD installations has been excessive air leakage from the underfloor air supply plenum, leading to higher energy use and overcooled spaces. The primary causes of these problems have been unfamiliarity on the part of the contractor who built the plenum and the building operators. So a logical conclusion would be that improved training of construction and facility management personnel is needed, not that all UFAD buildings use more energy. The same can easily be said about CAD buildings. There are numerous examples of poorly performing CAD installations. That does not lead us to conclude that it is impossible to build and operate an efficient CAD building, but rather to find out the reason behind (lessons learned) the poor performance. As someone involved with building commissioning, I'm sure Mr. Hamilton can appreciate the critical impact that proper control and operation have on a building's performance, regardless of how well it was designed. Three recent articles listed below, all written by design engineers with UFAD experience, discuss lessons learned, pros and cons of UFAD systems, and report on successful and well-performing projects.

- Daly, A. 2002. "Underfloor Air Distribution: Lessons Learned." *ASHRAE Journal*, Vol. 44, No. 5, May, pp. 21-24.
- Stein, J., and S. Taylor. 2005. "It's in the Details: Engineering for Low Cost and High Efficiency." *ASHRAE Journal*, Vol. 47, No. 10, October, pp. 50-53.
- Spinazzola, S. 2005. "Air Distribution Turned Upside Down." *Building Operating Management*, November.

The point of this lengthy introduction is to make a plea to both sides of the UFAD fence, those that support it and those that oppose it, to be truthful in their statements and claims. We are all well served by the sharing of accurate and well-justified expert knowledge in the hopes of improving the way that building systems, including UFAD, are designed, installed, and operated.

In the following document, we first list Mr. Hamilton's comment, followed by the CBE response.

***Hamilton Comment 1, Page 1:***
*These are comments from John Hamilton*
*COO Testing Adjusting and Balancing Bureau*
*"2008 Building Energy Efficiency Standards [suggestions] or [comments]"*
*For UFAD Under Floor Air Distribution Systems*
**CBE Response:**
These responses to the comments from John Hamilton of TABB are submitted for the public record by Fred Bauman and Tom Webster, Research Specialists with the Center for the Built Environment (CBE), University of California, Berkeley.

***Hamilton Comment 1, Page 2:***
*"is basically a low energy cooling system"*
*This is not a true statement. Where is the data to back up this claim? UFAD systems usually cost more to operate, and many other higher associated cost. Much higher associated cost will be described in detail in the appropriate sections of this document. Many items in this document have been refuted from the original claimants of this information.*
**CBE Response:**
The correct answer about energy performance of UFAD systems is that it depends on the details. One can find examples of UFAD projects that use more or less energy than a comparable CAD system. If Mr. Hamilton has some actual data from a high energy consuming UFAD project, it would be great if he would share it, so we could learn what the causes are of this higher energy use. Stein and Taylor (2005), listed above, describe a San Francisco Bay Area UFAD office project. Compared to an adjacent CAD office building of similar size and same occupancy, electricity and gas consumption per square foot (based on utility bills) were roughly one-half and one-third of those for the CAD building, respectively. In a second ongoing field study by CBE of a California State office building in Sacramento with a UFAD system, utility data has shown that annual electricity use for this building (per square foot) is lower than almost all other comparable office or commercial buildings for which data could be obtained in the Sacramento or Central Valley areas [Shirai and Bauman 2004].

- Shirai, R., and F. Bauman. 2004. "Second Post-Occupancy Evaluation (POE) of Block 225: Capitol Area East End Complex." Interim Report to California State Department of General Services and California Energy Commission, August.

Clearly more details are needed to fully understand the differences in energy use between these buildings, but these two examples certainly provide evidence that UFAD systems can successfully provide low-energy cooling in a California climate.

***Hamilton Comment 2, Page 2:***
*This section wants to rely more on modeling then real world testing and documentation.*
**CBE Response:**
Again, the underlying assumption here appears to be that in Mr. Hamilton's opinion, there is no real world data that demonstrates that UFAD systems can save energy. See above.

***Hamilton Comment 3, Page 2:***
*What does significantly warmer mean? They do not mention the additional need for bypass air used to keep the discharge temperate higher then the temp it leaves the coil at and de-humidification still need to take place at lower coil discharge temps. The designer could add a de-humidification unit to the building at an increase expenses to climate this problem.*

**CBE Response:**
Depending on heat loads and cooling airflow quantity, the supply air temperature leaving the air handler will typically be in the range of 60-65°F. One gets the impression from reading Mr. Hamilton's response that he is only accustomed to thinking about systems that are operating in climates where humidity control of the outside air is always required. He is certainly correct that in humid climates, conventional cooling coil discharge air temperatures (close to 55°F) will be required to dehumidify the incoming outside air, and most commonly, a face and bypass coil arrangement will allow the proper amount of warmer return air to bypass the cooling coil and blend with the coil discharge air to produce the required warmer supply air temperature for UFAD systems. Nobody is contemplating adding a separate dehumidification unit. The key point to consider for most California climates is that dehumidification is rarely needed. In fact, it is needed so infrequently that most designers leave it out of their designs for many commercial/office buildings. In California climates, therefore, the use of 100% outside air economizing, which takes full advantage of warmer supply air temperatures leaving the AHU, is one of the reasons why UFAD systems are particularly well-suited for application.

***Hamilton Comment 4, Page 2:***
*Where is the data on this claim? Where is the data on this claim? They are trying to use the calculation change from the latent capacity which is change at higher conditioning temps. With that higher temp change you also need to change the air flow rate and that calculation would double the air flow. Now with the air flow doubled the coil configuration also needs to change. It is changed from a 4-5 row deep coil to a thinner 2-3 row coil, and larger surface area which means needing to increase the physical size coil and making the air handle much bigger. The formula used is as follows (Q= M x Sp x deltaT). The definatins for the formula is as follows Q = heat M = quantity, of air Sp = specific heat, and deltaT the difference between 2 temps. If the delta T is cut in half the M or quantity of must be double to extract the same amount of heat.*
**CBE Response:**
This comment demonstrates a lack of understanding of how UFAD systems work. The assumption of a well-mixed space (as in the above equation) is no longer valid in a stratified UFAD system. Higher supply air temperatures do not translate into higher airflow quantities, and in fact, if designed and operated properly, UFAD systems have been shown to use about the same amount of cooling airflow as a comparable CAD system. The above claims that a larger and different air handler configuration will always be required are incorrect. See references below:

- Bauman, F. 2003. *Underfloor Air Distribution (UFAD) Design Guide.* Atlanta: ASHRAE, American Society of Heating, Refrigerating, and Air-Conditioning Engineers.
- Webster, T., F. Bauman, and J. Reese. 2002. "Thermal Stratification in Underfloor Air Distribution." *ASHRAE Journal*, Vol. 44, No. 5, May.
- Stein, J., and S. Taylor. 2005. "It's in the Details: Engineering for Low Cost and High Efficiency." *ASHRAE Journal*, Vol. 47, No. 10, October, pp. 50-53.
- Also addressed by the ASHRAE Professional Development Seminar on "Designing UFAD Systems," offered most recently at the ASHRAE Winter Meeting, Chicago, IL, Jan. 21, 2006.

It is certainly possible to operate a UFAD system using a higher airflow quantity than is necessary. Under these circumstances, room air stratification and the return air temperature will be correspondingly reduced, a topic discussed by Daly (2002). Currently, no validated cooling airflow design tool exists for UFAD systems, creating a situation where many designers will take the conservative approach in their airflow design calculations and supply more air than is needed. CBE is currently under contract with CEC PIER to develop such a cooling airflow design tool for UFAD systems. The project is due to be completed at the end of 2006.

***Hamilton Comment 5, Page 2:***
*The CBE (Center for Built Environments) modeled this but has since found the stratification is not happening and has presented this new finding (ASHRAE Chicago 2006 Dave Arnold CBE) CBE (Center for Built Environments) own data shows this stratification is not happening. The new CBE data show that the ceiling temps are identical to a conventional over head duct system.*
**CBE Response:**
In the first place, Dave Arnold is not in any way associated with CBE and was never authorized to make incorrect statements in our name. Presumably he was referencing some comments we had made and either reported them incorrectly, or Mr. Hamilton drew his own incorrect conclusions. Looking at the general content of the remark that Dave Arnold is said to have made at the ASHRAE meeting, he was clearly referring to the observation we have made (discussed in our previous response above) that many UFAD systems do not show as high of room air stratification as anticipated. Again, the correct interpretation is that these particular UFAD buildings are using too much airflow – it means that they are being operating incorrectly. It does not mean that UFAD systems can't produce higher temperatures at the ceiling.

***Hamilton Comment 6, Page2:***
*At design load the coil will see the identical building load in either system, the UFAD coil will see the same*
**CBE Response:**
This is basically a true statement if there is no economizing taking place in the system. However, in most California climates, there is a significant opportunity for energy savings through the use of the outside air economizer.

It should also be pointed out that the Measure Information Template on UFAD was not prepared by CBE and we would recommend some changes to fix incorrect statements, improve clarity, and avoid confusion, especially in this section on Energy Benefits.

***Hamilton Comment 7, Page 2:***
*This is only true when much lower then normal humidity conditions exist. Building location and orientation must be used on every single case to valid this as a potential savings. Economizers are either on or off for both UFAD systems and CAD systems.*
**CBE Response:**
While it is true that economizer benefits are climate dependent and must be carefully considered based on any humidity control requirements, the fact of the matter is that in most California climates, humidity control of outside air is not needed and therefore use of an outside air economizer is very appropriate and should be taken advantage of.

***Hamilton Comment 8, Page 2:***
*The GSA guide for UFAD systems helps insure that careful design is used.*
**CBE Response:**
The final GSA UFAD Guideline has not yet been released. While the most recent version does contain useful information, it also contains information and guidance that has never passed a peer review. It is difficult for the reader to distinguish between guidance that is accurate and well justified and guidance that is not. We have first-hand knowledge of this because we served as reviewers of the earlier drafts and most of our review comments submitted to GSA have been ignored in the latest version of the UFAD Guideline. See additional discussion of GSA UFAD Guideline in the Introduction.

***Hamilton Comment 9, Page 2:***
*3 points on this statement:*
*1st the chiller size will not change. The coil load for a building is the coil load period. Look at a simple house will the cooling or heating load change by changing how the heat is delivered of removed? No.*
*2nd point. The external static pressure may or may not change it depends on the location which varies by design. A big open plenum may pick up some pressure drop. Consider the entire distribution ducting is pressurized and the entire floor is pressurized.*
*3rd point of consideration. A CAD system has less peripheral components. The UFAD system needs to pressurize the exterior zone with auxiliary fans and VAV boxes. These additional fans and components must be considered to make the claim of less external pressure for the fan.*
**CBE Response:**
1st point – We agree that the coil load is roughly the same for a CAD and UFAD system when no economizing is taking place. However, as we have stated above, California climates are well-suited for economizer use.
2nd point – The primary fan static pressure will definitely reduce by about 25% (0.5-1.0 in. $H_2O$) for a UFAD system compared to a CAD system due to the replacement of branch ductwork with an open underfloor air supply plenum. CBE has conducted a full-scale experimental study demonstrating that underfloor plenum pressures are very uniform within the same plenum zone. There is no pressure drop. See Bauman et al. (1999)

- Bauman, F., P. Pecora, and T. Webster. 1999. "How Low Can You Go? Air Flow Performance of Low-Height Underfloor Plenums." Final Summary Report, Center for the Built Environment, University of California, Berkeley, October. Available in pdf format at: http://www.cbe.berkeley.edu/underfloorair/publications.htm.

3rd point – This point is conjecture and is completely dependent on the details of each design. It is true that many UFAD systems include fan-coil units in the perimeter zones, whose additional energy use will need to be considered in the overall energy assessment of the building. However, there are other commonly used approaches to UFAD perimeter zones that use fan-coil units only for heating – no perimeter fans are used for cooling. Title-24 requires that heating airflows cannot exceed 30% of cooling airflow quantities, meaning that these units are much smaller and are used much less frequently in most mild California climates. It should also be stated that there are many examples of CAD system designs that use fan-powered solutions in perimeter zones. Again, the devil is in the details!

***Hamilton Comment 1, Page 3:***
*More time and man-hours are required for moving things with UFAD consider moving all furniture fixtures in a 16 square foot area, removing carpeting, removing floor tiles this is all to just access the area beneath the floor. Compared to using a ladder and removing ceiling tiles as in a CAD systems. Also consider how long it would take to look at a VAV box in the floor or in the ceiling.*
**CBE Response:**
This comment demonstrates a selective and misleading use of information about flexibility in UFAD systems. The benefits of flexibility in the use of a raised access floor as part of a UFAD system apply to all building services that can be provided through the underfloor plenum, which include not only the HVAC, but also at a minimum, all power, voice, and data cabling. In fact, the use of raised floor systems is often justified on the cost savings of cable management alone, in particular in buildings with high churn rates. These life-cycle cost savings are well recognized by the building industry and are the reason why the use of raised flooring, with or without UFAD has increased significantly during the past 5-10 years.

***Hamilton Comment 2, Page 3:***
*This stratification does not happen so this claim is invalid. Particulate size and weight affect their flow in the air. vapors rise by natural convection in any system. Demonstrated modeling show that this does not happen as the modeling predicted it would.*
**CBE Response:**
Part of the problem here is that the author of the Template has stated that stratification and incomplete mixing (which do happen) will result in "significant improvement in indoor air quality." Because UFAD systems do not completely mix the air in the room, we know that ventilation effectiveness, Ez, will be no worse than that for any CAD system, which can never do better than Ez = 1.0 for perfect mixing. The ventilation performance of a UFAD system will be dependent on the amount of mixing that the floor diffusers provide. To first order, if larger amounts of air are supplied, thereby increasing mixing and reducing stratification, the ventilation effectiveness will approach the well-mixed conditions of a CAD system. On the other hand, when airflow quantities are reduced, or other means are used to reduce mixing (such as using lower throw diffusers), stratification will increase and the ventilation effectiveness will approach that of a true displacement ventilation (DV) system (ASHRAE Standard 62-2004 allows a value of Ez = 1.2 for DV systems). Recall that DV systems introduce air at floor level with minimal mixing. So the real answer here is that ventilation performance will depend on the manner in which the UFAD system is operated. It is not guaranteed that ventilation performance for a UFAD system will be significantly better than that of a CAD system on a strictly measurement basis. Research is needed to conduct a well-controlled study investigating ventilation performance for UFAD systems that would produce quantitative results.

We do, however, have evidence that the indoor air quality as perceived by occupants of UFAD buildings is noticeably better than that for CAD buildings. Since 2002, CBE has conducted occupant surveys in 8 UFAD buildings using a web-based survey instrument [Zagreus et al. 2004]. When asked how satisfied they were with the air quality in their workspace, the average building-wide occupant response (1,861 responses) for all 8 buildings was +0.83 on a 7-point satisfaction scale (where -3 = very dissatisfied, 0 = neutral, and +3 = very satisfied). In contrast, the average response to this same question from CBE's larger survey database of 152 CAD buildings (25,749 responses) was only +0.19 [for survey results, contact CBE at www.cbesurvey.org]. Occupant comments indicate that people perceive that the nearby floor diffusers provide increased air motion and improved indoor air quality compared to a room with overhead diffusers.

- Zagreus, L., C. Huizenga, E. Arens and D. Lehrer. 2004. "Listening to the Occupants: A Web-based Indoor Environmental Quality Survey." *Indoor Air*, Vol. 14, Supplement 8.

The comment by Mr. Hamilton that stratification does not happen and therefore none of this is valid is just another attempt to jump to conclusions without bothering to fully understand what is really happening. His last statement doesn't make any sense. There is no demonstrated modeling that shows that stratification does not occur as (some other?) modeling predicted it would. If he knows of such modeling, please provide the reference!

***Hamilton Comment 3, Page 3:***
*not true the coil size will increase due to the new airflow required, the coil load will not change from one system to the next. The air handler will be bigger and require more filtration.*
**CBE Response:**
Mr. Hamilton is half right and half wrong. Under peak cooling load conditions, when the economizer will presumably not be operating due to warm outside air temperatures, the coil

loads between CAD and UFAD systems should be very similar in magnitude. However, the assumption that UFAD systems require more airflow is simply incorrect. This has been verified in completed installations and laboratory testing. See response above to Comment 4, Page 2.

***Hamilton Comment 4, Page 3:***
*Not true there are many negative environmental impacts. Added draft complaints under light loads/ economizer cycle. VAV systems are needed to control temps under light load conditions. Another increase cost is seismic restraint and vibration systems that need to be added in UFAD systems. Catastrophic floor failure is much higher then a CAD system. If the UFAD system buckle or fails computers crashing to the floor etc. A UFAD system in CA will need additional seismic restraints and possibly lateral reinforcements. The air in UFAD has shown it is actually mixing not stratifying so the IAQ claim is erroneous. The list of failures and additional security risks from biological and chemical agents also needs to be reviewed. A UFAD system is a way to distribute these toxins as first air and the ease of administration of these must be considered?*
**CBE Response:**
This is another example of Mr. Hamilton reporting only the part of the answer the serves his purposes. Sure, you can find examples of UFAD buildings where there are draft complaints. You can also easily find examples of CAD buildings where there are draft complaints. In most cases, the correct interpretation of draft complaint problems in both UFAD and CAD buildings is not that there is something inherently wrong with these systems, but rather that they are being controlled and operated improperly. The truth is that it is possible to design and operate a CAD or a UFAD system without imposing draft discomfort on the occupants. In addition, we know from CBE survey results of UFAD buildings, that occupants prefer the option of having personal control of their local airflow and environment by adjusting their nearby floor diffuser, when compared to a CAD building [for survey results, contact CBE at www.cbesurvey.org]. The use of VAV control in UFAD systems is the preferred approach of experienced designers, just as it is for CAD systems as well. His comment on seismic restraint is another example of making claims without knowing the facts. In California, building codes require additional seismic restraint (e.g., diagonal bracing), as well as underfloor sprinkler systems, only when underfloor plenum heights exceed 18 inches in height. It is for this very reason that developers want to avoid added costs and complexity in their underfloor plenum design, and as a result, virtually no UFAD systems are being installed with plenum heights above 18 inches. I know of no catastrophic failure of an installed raised floor system. If Mr. Hamilton knows of such, please provide the data. See earlier response to Comment 2, Page 3 on IAQ and ventilation performance. The final statements about failures and security risks associated with the distribution of toxins and chemical agents are conjecture. There is no data that demonstrates that these risks are any higher in a UFAD building compared to a CAD building.

***Hamilton Comment 5, Page 3:***
*UFAD is not general construction and you must select on manufacture for the flooring system and then you are locked into that system as the current available systems are not integrated together or made to be integrated together. Fan powered boxes and other peripherals must fit under the floor and in between the pedestals so these are not off the shelve typical pieces of equipment.*
**CBE Response:**
All of the information contained in this comment is inaccurate and misleading. Commercially available raised floor systems are completely compatible with any combination of floor diffusers, underfloor fan terminals that fit under different height raised floors, modular wiring, and other UFAD system components. As the UFAD market has grown during the past 10 years, more and more products made by more and more manufacturers have been developed, so that a designer can easily choose from a variety of manufacturers and system design approaches. If

Mr. Hamilton is not familiar with the choices that are currently on the market, we will be glad to provide such information.

***Hamilton Comment 6, Page 3:***
*Not true the air handler will run at varying loads in either a UFAD system or a CAD VAV system. The UFAD system does not change the HVAC system life expectancy at all.*
**CBE Response:**
The primary air handler for a UFAD system will supply about the same amount of air as a CAD system AHU, although at a reduced static pressure. Chiller life expectancy should increase for UFAD designs that utilize economizer operation, because of the increased number of hours when the chiller can be turned off and the system can run on 100% free cooling.

***Hamilton Comment 7, Page 3:***
*This test does not measure duct or plenum leakage Category 1 or Category 2. Additional training to construction personnel is needed so they understand the problems of plenum leakage from general construction. It needs to be noted may change economizer settings. This will depend on each building case by case with location and building orientation considered. Filtration has not been noted in this paper so I will comment on it. These systems have more air flow then a CAD system that means larger filter banks will need to be constructed in the HVAC systems. Possibly more Outside air bringing in more contaminates for more filter loading.*

**CBE Response:**
We agree that plenum air leakage is important with proper training of contractors, careful attention to plenum sealing details, and rigorous and repeated inspections during construction a must. Mr. Hamilton's comments about the need for larger filter banks are again based on his incorrect assumption that UFAD systems require more airflow than CAD systems. See previous response to Comment 4, Page 2. Mr. Hamilton is correct that if underfloor fan terminals contain filters, they will require access for maintenance. Furniture layout on the floor above these underfloor units will be important to allow proper access. It should be mentioned that only underfloor fan terminals that use unfiltered return air directly from the room require a filter. In configurations where the fan or VAV box uses 100% plenum air, filters are not required since all air entering the underfloor supply plenum will be filtered.

***Hamilton Comment 8, Page 3:***
*Conjecture! Many GSA building have shown to cost up 300% more for energy usage "energy hog". Many addition construction expenses are needed from glazing to needing drains in the floor so the floor will not fill up with water when fire sprinklers discharge their water. This could result in the building pancaking down from this additional water weight not accounted for in the structural design. The need for fire detectors in the UFAD system needs to be looked at. Cable trays and the inside of conduits need to be sealed to prevent leakage. Fire wall pressure zones for containment and special fire smoke dampers to control a fire need to be evaluated.*

**CBE Response:**
Mr. Hamilton again produces a long laundry list of problems from selected UFAD projects (without providing any data to back it up) and then attempts to jump to the conclusion that this somehow proves that UFAD systems can't be cost effective or energy efficient! Most of these

points are among the same biased and misleading issues that have been discussed at length during the review of the GSA UFAD Guideline document (see Introduction). It is simply irresponsible to cite a building using 300% more energy (energy hog) as evidence that UFAD doesn't work without providing any more details. Was any attempt made to find out why the building was using so much energy? What was the basis for comparison? Again, as a commissioning agent, Mr. Hamilton should be well aware that the devil is in the details.

There has never been one recorded instance of a UFAD building somehow having its plenums fill up undetected with water and suffering a catastrophic structural collapse. During the GSA UFAD Roundtable in May 2005, several reasonable, affordable, and relatively straight-forward design solutions for detecting and controlling water leakage in underfloor plenums were presented in response to this highly conjectural statement. This issue is not a show-stopper!

Mr. Hamilton's final point about the load of the plenum representing an extra load not included in a CAD system demonstrates his complete lack of understanding of how the energy performance of a UFAD system works. CBE has been investigating this UFAD energy performance in collaboration with researchers at UC San Diego and Lawrence Berkeley National Laboratory for the past 3 ½ years using a combination of fundamental laboratory testing, numerical and analytical modeling, and field experimentation (see http://www.energy.ca.gov/pier/buildings/projects/500-01-035-1.html). As part of this work, we have recently completed and submitted for publication to ASHRAE a technical paper describing how heat is removed from a room with UFAD under stratified conditions [Bauman et al. In press]. It is shown that the warmer temperatures near the ceiling in a multi-story building result in a portion (30-40%) of the total room cooling load being transferred into the underfloor plenum. The remaining portion of the load remains in the room. There is no additional cooling load that needs to be removed. It is simply split between the underfloor plenum and the room. Total system load will remain the same. Mr. Hamilton's comments and claims are wrong.


- Bauman, F., H. Jin, and T. Webster. In press. "Heat Transfer Pathways in Underfloor Air Distribution (UFAD) Systems." Submitted to *ASHRAE Transactions.*


***Hamilton Comment 1, Page 4:***

**CBE Response:**
See all of our comments above.