Redesign

The current mechanical system employed in the Michael Baker Corporation Headquarters is an overhead VAV system supplied air from 6 air-handling units on the roof of the building (2 air-handling units per floor). These air-handling units are gas-fired. They currently supply air at 55 F. The building is designed for summer outdoor air conditions of 86°F DB/71°F WB and winter outdoor air conditions of 5°F.

Changes to the mechanical systems in the building will involve restructuring the building for an underfloor air distribution system. The building will consist of 35 zones per floor (19 interior and 16 perimeter) that will be distributed air from air-handling units on the roof through VAV boxes in the underfloor plenum. The focus will be on conserving the amount of air changes throughout the building which will in turn same money on energy usage.

For this building there are 2 types of zones: Interior and Perimeter Zones. Through calculations considering necessary air changes, cfm/person, and/or cfm/sf, it has been established that proper design requires 0.9 cfm/sf in interior zones and 1.2 cfm/sf to adequately control the necessary thermal load for thermal comfort of the occupants. The building's mechanical system was redesigned overall from an approximate 1.5 cfm/sf to 1.0 cfm/sf overall which is quite an improvement. The bulk of the air is supplied to interior zones which also make up the majority of the rentable space. The perimeter zones due to the thermal transfer experience more air changes to account for outside temperature.

On the western side of the building which is supplied by air-handling units 1, 2 and 3, have 8 interior zones which makes up around 10,000 sq. ft. and a little over 9,000 cfm per floor. There are 8 perimeter zones for air-handling units 1, 2 and 3 that make up just less than 5,000 sq. ft. and 6,000 cfm per floor. On the eastern side of the building which is supplied by air-handling units 1a, 2a and 3a, have 11 interior zones which makes up around 13,000 sq. ft. and about 12,000 cfm per floor. There are 8 perimeter zones for air-handling units 1a, 2a and 3a that make up around 5,000 sq. ft. and 6,000 cfm per floor. In all there are 105 zones supplying about 100,000 sq. ft. of rentable space with about 100,000 cfm throughout the building. More detail can be seen in the Appendix.

The current floor system used in the building is raised by 2 inches for telecommunication and electrical cables. It will be raised to 24 inches to allow for necessary ductwork to be put under the raised floor and to provide ample space for supply air to be supplied to the floor diffusers from terminal units connected to the ductwork. The plenum in the ceiling will in turn be reduced considerable due to the lack of lack of supply duct work in the plenum from the redesign.

New ductwork was designed at .1 in H_2O/100 ft at a maximum to reduce noise and pressure drop. Typically, the new ductwork was designed at .085 to .09 in H_2O/100 ft. There is significantly less ductwork than in an overhead system. Overall, there is significantly less in cost for ductwork.

The existing air-handling units are going to be used for the redesigned system. Along with the air-handling units, all shafts from connection to the units will be kept and added or subtracted from where needed. This makes the overall change from an overhead system to an underfloor system more practical in terms of redesign.

Underfloor Air Distribution Systems and Raised Floor Systems

Underfloor air distribution and access floor systems provide multiple advantages to many commercial building owners and the occupants who inhabit the buildings in comparison to the traditional overhead air distribution systems. This also includes plumbing, wiring, telecommunication and electrical distribution systems. Underfloor air distribution systems (UADS) can provide substantial energy savings while improving indoor air quality and comfort in many applications. Most commonly, any additional costs of the access floor systems are partially offset by savings in electrical and telecommunication wiring and HVAC installation costs. Also, in buildings where frequent remodeling or redistribution of personnel is required, savings in remodeling costs alone can easily pay for the system. As mentioned before, improvements in indoor air quality lead to improved occupant health and production can be seen from applying a UADS.

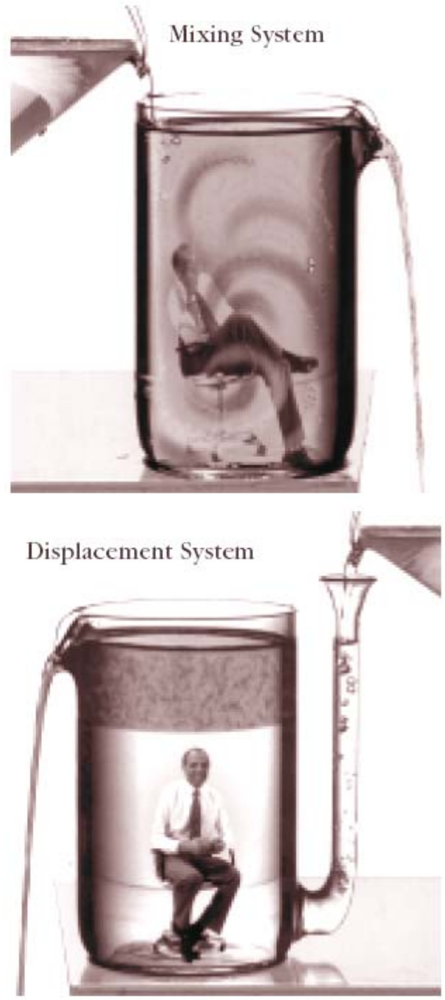
Access Floor Systems

An access floor system is a modular system of architectural floor panels installed on pedestals above the structural floor to create an easily accessible underfloor space. Typically, access floor systems have been widely used in clean rooms an in spaces with large amounts of electrical equipment. However, with the increasing demand of technologically laden office environments, there is a rise in demand for access floor systems. Building and corporation owners need their buildings to be “technology-ready,” with ample power, voice and data services that are easily accessible and reconfigurable.

Underfloor Air Distribution Systems

With the applications the Michael Baker Corporation had in mind, this provides an excellent solution to supplying air to their headquarters. UADS can provide better comfort, higher indoor air quality and lower energy costs. It does this while an access floor system provides flexibility in the open office space and still allows easy maintenance and remodeling of power, voice and data wiring. Integrating the UADS with the access floor creates the opportunity for better management of communication and data infrastructure with improved HVAC. This is typically a worthy investment an owner can rely upon to provide a substantial return.

Underfloor Air Distributions Systems introduce air to spaces at the floor level, with return grilles located in the ceiling. The spaces are divided into 2 zones: An occupied zone extending from the floor to the head level, and an unoccupied zone extending from the top of the occupied zone to the ceiling. The design of the system conditions the lower occupied zone only; temperature conditions in the upper zone are allowed to remain above normal comfort ranges. To avoid occupant discomfort, air is introduced into the space between 62 °F and 68 °F typically.



Source: Healthy Buildings International

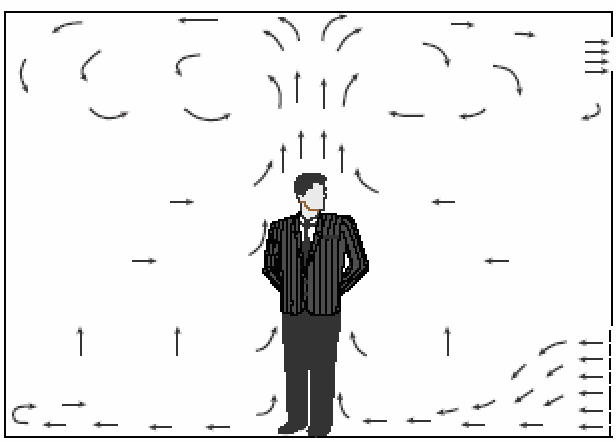
Why is an underfloor system an advantage over a typical overhead system?

Traditional overhead ventilation systems supply and return air at the ceiling. The system produces a large single zone of fully-mixed, room-temperature air. Using a simple analogy, as seen in the figure, it can be illustrated that the difference between mixing and displacing air can be quite important. In the underfloor system, cool liquid introduced from below floors pushes air through the occupied zone, picking up heat and contaminants and pushing them into the unoccupied zone above. However, as can be seen in the fully-mixed system, cooler liquid delivered from above mixes with all the liquid to maintain a constant temperature throughout the beaker. This dilutes contaminants but doesn't purge them from the space as effectively.

Types of Underfloor Air Distribution Systems

There are 2 types of UADS and they are distinguished from one another by the temperature and velocity profiles they create in the occupied space. The first type is a displacement ventilation system (DVS); the second is a hybrid ventilation system (HVS).

Displacement Ventilation

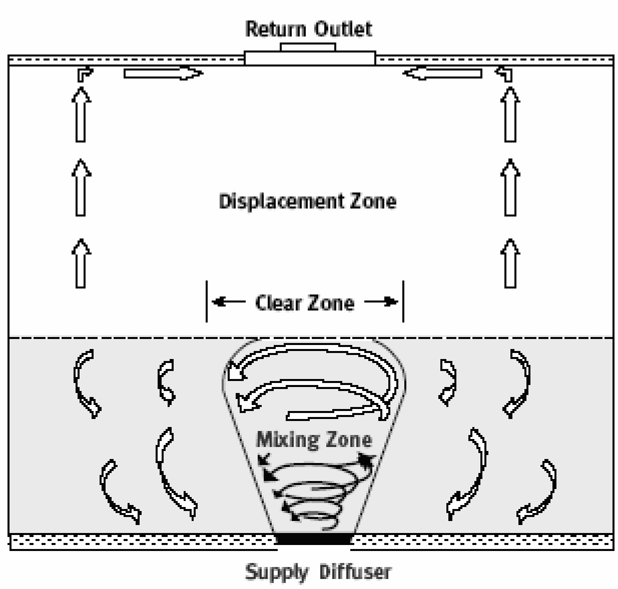


Source: Architectural Energy Corporation

DVS delivers supply air at floor level into the space at a very low velocity, which is typically less than 50 feet per minute (fpm). At this velocity, the air coming out of the diffuser can barely be felt. The system produces 2 distinct zones of air, one characterized by stratified layers of relatively cool and fresh air, while the other by fairly uniform hot and stale air. The vertical flow profile in the lower zone can be generally described as upward laminar flow. The effect of this flow is to displace the hot stale air into the area well above the breathing level of the occupants, giving occupants the benefit of breathing significantly higher-quality air. Draft isn't usually an issue in spaces served by displacement ventilation systems, but the temperature difference between the floor and head levels is an important design issue. Displacement ventilation systems can be applied to spaces with cooling loads up to 38 Btuh/sq.ft.

Hybrid Ventilation

HVS is a combination of displacement ventilation and conventional mixing systems. Like displacement ventilation, the hybrid underfloor system attempts to condition only the occupied lower portion of space, producing 2 distinct zones of air, one cool and relatively fresh, the other hot and stale. Unlike the DVS, however, the HVS aims to reduce the stratification in occupied lower portion by delivering air at higher velocity, usually somewhere between 200 and 400 fpm. This results in a mixed and turbulent, rather than laminar, vertical flow profile and a smaller temperature gradient (the temperature between the floor and head levels). While HVS may more or less reduce the comfort problems associated with an excessive temperature gradient, they usually create smaller zones within the zone of excessive draft called "clear zones" that occupants need to avoid. HVS may not provide as dramatic an improvement of air quality at the breathing level as DVS, but HVS can handle higher cooling loads than DVS. The cooling load capacity is limited only by the number of diffusers used and the number of clear areas created.



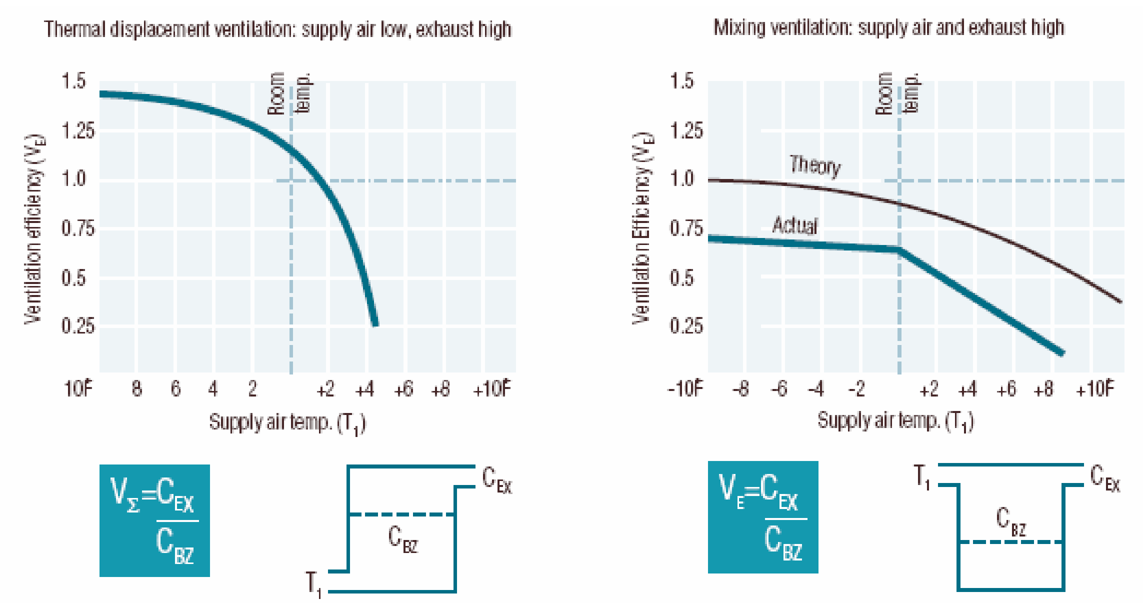
Source: Loudermilk, 1999

Indoor Air Quality

UADS, particularly DVS as mentioned before, provide a natural advantage over conventional overhead systems. This is due to their ability to effectively and efficiently move stale and contaminated air out of the occupied space. The pollution level of the air at breathing level is always lower in spaces served by DVS. This is known as the "ventilation effectiveness" of the system. In simpler terms, the ventilation effectiveness indicates the efficiency of the system and how it is able to contaminated air from the room to the return air duct. In engineering terms, ventilation or "air-change" effectiveness is defined as the ratio of contaminated concentration in the return air to the contaminated concentration in the breathing zone of the room.

Conventional overhead, fully-mixed systems are designed in hopes of providing exactly 100 percent ventilation effectiveness throughout the room. Since the air in the room is assumed to be perfectly mixed, the concentration of the return air should be the same as that of the room air; hence, the ratio of contaminants in the return air to contaminants in the room air is one. Because of this, spaces served by overhead systems are prone to common comfort-related problems such as "short-circuiting", "dumping" and "dead spots". Short-circuiting occurs when a portion of the air discharged from the overhead diffuser never reaches the occupied lower space, but instead flows directly into a return grille. This will happen if the supply air is warmer than the room temperature. Dumping occurs when the velocity of the supply air is too slow to induce mixing and the cold air simply falls or "dumps" to the floor. This can happen when the air velocity and/or supply air temperatures are lower than the diffuser can handle. Dead spots occur when the location of partitions and furniture relative to the diffuser location inhibit complete mixing in the space creating "dead spots" in the air.

In the occupied lower zone of a DVS, ventilation effectiveness around the knee level can be as high as 200 percent, while at the breathing level it can be as high as 120-150 percent. HVS, however, do not necessarily provide the dramatic increase in ventilation the DVS offer. They are still an important. The system will still mix the air to a degree while stratifying it and pushing contaminations up to the higher zone. Also, while doing this, it will promote recirculation of room air. HVS generally provide about 100 percent ventilation effectiveness in the cooling mode, the same as a well-designed overhead system. However, the fact that the occupants can control the airflow rate to their space improves the perceived quality of air. So, the overall acceptance of the system is greater than overhead systems.



Source: Healthy Buildings International

Comfort Control and Productivity

Improved comfort can be achieved when the occupants themselves take advantage of the local control features available with an underfloor system. Uncomfortable draft and temperature inconsistencies are two of the most common sources of occupant complaints. With the diffusers in the floor, the occupants can easily redirect or modulate the airflow into their own space to their own liking, a benefit that is inconceivable with the conventional overhead system. Since the diffusers are housed in modular access floor, it is easier to reposition the diffusers to another location. Comfort is also improved by the reduction in inherent noise levels for pressurized floor systems. They usually operate at lower pressures and velocities; UADS generally produce less noise than traditional overhead systems. However, fan-powered terminals used in non-pressurized system may cause a small increase in noise levels.

Comfortable employees are productive employees. Space comfort and air quality are the top occupant complaints fielded by building owners and operators. According to the Building Owners and Managers Association (BOMA), studies by BOMA point to a potential increases in worker productivity of 20 percent by improving indoor air quality.

Design Considerations

In order to maintain occupant comfort, UADS must limit the temperature gradient in the occupied space. Therefore, the supply air temperature should be 62 °F with recommended minimum ceiling heights of 8 feet. The supply air must be introduced to the lower space at a high enough flow rate to prevent an uncomfortable temperature gradient between head and foot, but still at a low enough velocity to prevent the sensation of draft and preventing the mixing in the upper stratified zone. For instance, a temperature gradient higher than 5 °F is considered excessive. About 3.5 °F is considered a good design for the temperature gradient.

Airflow Rate

The airflow rate must be balanced against temperature gradient considerations. Lower temperature gradients imply higher flow rates and excessive fan energy. If the air volume is too high, occupants are more likely to be exposed to drafty conditions that resulted from high-velocity currents discharging into the occupied lower portion of space. However, if the air volume is too low, the occupants are more likely to be exposed to uncomfortable temperature gradients between their ankles and head. The high load problem may be mitigated in applications where sufficient floor area is available to supply high volume through more or larger diffusers, effectively reducing the localized air velocities while maintaining a high limit on temperature gradient. Installing diffusers that give the occupant the benefit of local control may also mitigate the high load problem, as they allow immediate adjustment of both velocity and direction of flow.

Plenum Conditions and Indoor Air Quality

UADS are typically thought of as a more occupant friendly environment in terms of indoor air quality. However, consideration must be given to the possible effects of condensation buildup in the plenum. Condensation must be a concern in UADS if the cool plenum is suddenly exposed to warm, moist air. The dewpoint temperature in the air entering the plenum must always be greater than the lowest temperature of any exposed surface within the plenum, otherwise condensation will occur. This phenomenon can be avoided if the plenum is well sealed against outside air infiltration, and if sudden step-changes in supply air conditions are avoided.

An example of this would be when the fan shuts down at the end of the day, warm and moist air should be blocked from rushing into the cool plenum. Also, during the building's occupied hours, if the mechanical cooling abruptly shuts down and the dewpoint temperature of the supply air suddenly rises, the fan may need to be shut off, or the dampers adjusted.

There are also some minor problems that can arise affecting the inherent quality of the air. Off-gassing from cabling, cement dust shed from the slab, debris and spills sifted down through the floor, and biological growth due to moisture are all possible sources of pollution that could degrade the quality of the ventilation air before it enters the space. Construction can alleviate these problems using proper design techniques. Floor panels can be manufactured and installed properly to close tolerances, floor diffusers can have traps to capture spills and debris that can be easily cleaned, and slabs can be sealed to reduce dust and inhibit bacterial growth.

Pluses and Minuses for the Michael Baker Corporation Headquarters

UFAD is a very good application for an open plan office building. It helps with the reduction of cost involved in moving offices. Since this building has a relatively low perimeter to interior ratio the amount of highly variable loads is smaller and that also makes a UFAD system practical. The AHU's will deliver air to the space at 62 F at a ratio of about 0.98 cfm/sf. This temperature and delivery ratio should maintain the space so it is achieves excellent thermal comfort and with the proper use of air distribution diffusers good head to toe temperature variations without disrupting the benefits of a stratification zone. The ventilation effectiveness is also increase due to natural buoyancy. As the air mixes and rises due to warmth, pollutants are carried toward the ceiling. Also, the supply air doesn't have to travel through polluted air from the ceiling as it would in a typical overhead system. Rather, the fresh air is provided to the breathing zone. The perceived indoor air quality is better and may potentially be used to reduce total ventilation airflow, but this isn't recommended. The energy usage of a UFAD is less due to the lower fan static requirements. Also, the reduced life cycle costs that are associated with an open plan office building like the Baker building can't be ignored. This is due to the expectation of office churning from the staff of the building. Typically, the floor-to-floor height is also reduced. This is the same with the Baker building, since the building already incorporates a raised floor system for telecommunication and electrical wiring the potential for reduced shell construction cost is notable. This will come from the reduction of ceiling plenums which will now only be responsible for returning air back to the AHU's, sprinkler systems, and any lights that are recessed.

Issues to look for include: cold floors, condensation and humidity control. Since the ankle is one of the most sensitive points of thermal comfort on the body, the potential for a cold floor makes floor temperature a possible critical issue. Because of this floor diffuser placement is an issue that should be address. Fortunately, UAFS diffusers should be easy to move to improve the thermal comfort of any affected tenants. Condensation is an issue that involves keeping the air dew point temperature above the dew point temperature of the slab. The humidity control of the building is also an important issue. The acceptable amount of humidity that should be allowed in a building should be kept below 60%. This is very important to maintain thermal comfort and indoor air quality due to the potential for molds.

Comparisons and Savings

Current Design Annual Costs

Table 1. Annual Costs

Component	Michael Baker Headquarters ($)
Air System Fans	92,797
Cooling	1,783
Heating	388,619
Pumps	0
Cooling Tower Fans	0
HVAC Sub-Total	**483,199**
Lights	101,832
Electric Equipment	344,962
Misc. Electric	0
Misc. Fuel Use	0
Non-HVAC Sub-Total	**446,794**
Grand Total	**929,993**

Table 2. Annual Cost per Unit Floor Area

Component	Michael Baker Headquarters ($/ft²)
Air System Fans	0.937
Cooling	0.018
Heating	3.925
Pumps	0.000
Cooling Tower Fans	0.000
HVAC Sub-Total	**4.880**
Lights	1.029
Electric Equipment	3.484
Misc. Electric	0.000
Misc. Fuel Use	0.000
Non-HVAC Sub-Total	**4.513**
Grand Total	**9.393**
Gross Floor Area (ft²)	99009.0
Conditioned Floor Area (ft²)	99009.0

Note: Values in this table are calculated using the Gross Floor Area.

Table 3. Component Cost as a Percentage of Total Cost

Component	Michael Baker Headquarters (%)
Air System Fans	10.0
Cooling	0.2
Heating	41.8
Pumps	0.0
Cooling Tower Fans	0.0
HVAC Sub-Total	**52.0**
Lights	10.9
Electric Equipment	37.1
Misc. Electric	0.0
Misc. Fuel Use	0.0
Non-HVAC Sub-Total	**48.0**
Grand Total	**100.0**

Redesigned Annual Costs

Table 1. Annual Costs

Component	Michael Baker Headquarters ($)
Air System Fans	106,295
Cooling	1,872
Heating	245,289
Pumps	0
Cooling Tower Fans	0
HVAC Sub-Total	**353,455**
Lights	101,832
Electric Equipment	344,962
Misc. Electric	0
Misc. Fuel Use	0
Non-HVAC Sub-Total	**446,794**
Grand Total	**800,249**

Table 2. Annual Cost per Unit Floor Area

Component	Michael Baker Headquarters ($/ft²)
Air System Fans	1.074
Cooling	0.019
Heating	2.477
Pumps	0.000
Cooling Tower Fans	0.000
HVAC Sub-Total	**3.570**
Lights	1.029
Electric Equipment	3.484
Misc. Electric	0.000
Misc. Fuel Use	0.000
Non-HVAC Sub-Total	**4.513**
Grand Total	**8.083**
Gross Floor Area (ft²)	99009.0
Conditioned Floor Area (ft²)	99009.0

Note: Values in this table are calculated using the Gross Floor Area.

Table 3. Component Cost as a Percentage of Total Cost

Component	Michael Baker Headquarters (%)
Air System Fans	13.3
Cooling	0.2
Heating	30.7
Pumps	0.0
Cooling Tower Fans	0.0
HVAC Sub-Total	**44.2**
Lights	12.7
Electric Equipment	43.1
Misc. Electric	0.0
Misc. Fuel Use	0.0
Non-HVAC Sub-Total	**55.8**
Grand Total	**100.0**

Annual Saving with redesign is \$929,993 - \$800, 249 = \$129, 744 ~ \$130,000 annually. Which equals about 1.3 \$/square foot.

New design values from redesign

AHU-1

Zone	Area	cfm/sf	cfm	duct	vav	diffusers	type	return	type(Titus)
1P	725	1.2	870	12X12	KUFM-4	9	FPD-R	2	PAR
2P	725	1.2	870	22X12	KUFM-4	9	FPD-R	2	PAR
3P	500	1.2	600	22X14	KUFS-3	6	FPD-R	2	PAR
4P	680	1.2	816	12X12	KUFM-4	9	FPD-R	2	PAR
5P	725	1.2	870	22X12	KUFM-4	9	FPD-R	2	PAR
6P	725	1.2	870	22X14	KUFM-4	9	FPD-R	2	PAR
1	1350	0.9	1215	14X14	KUFM-7	12	FPD-R	1	50F
2	1440	0.9	1296	22X14	KUFM-7	13	FPD-R	1	50F
3	1440	0.9	1296	22X20	KUFM-7	13	FPD-R	1	50F
4	980	0.9	882	22X10	KUFM-4	9	FPD-R	1	50F
5	1350	0.9	1215	14X14	KUFM-7	12	FPD-R	1	50F
6	1440	0.9	1296	22X14	KUFM-7	13	FPD-R	1	50F
7	1440	0.9	1296	22X20	KUFM-7	13	FPD-R	1	50F
8	980	0.9	882	22X10	KUFM-4	9	FPD-R	1	50F
Total	14500	0.984414	14274			145		14&8	

AHU-2,3

Zone	Area	cfm/sf	Cfm	duct	vav	diffusers	type	return	type(Titus)
1P	725	1.2	870	12X12	KUFM-4	9	FPD-R	2	PAR
2P	725	1.2	870	22X12	KUFM-4	9	FPD-R	2	PAR
3P	500	1.2	600	22X14	KUFS-3	6	FPD-R	2	PAR
4P	680	1.2	816	12X12	KUFM-4	9	FPD-R	2	PAR
5P	725	1.2	870	22X12	KUFM-4	9	FPD-R	2	PAR
6P	725	1.2	870	22X14	KUFM-4	9	FPD-R	2	PAR
7P	336	1.2	403.2	10X8	KUFS-3	4	FPD-R	1	PAR
8P	336	1.2	403.2	10X8	KUFS-3	4	FPD-R	1	PAR
1	1350	0.9	1215	14X14	KUFM-7	12	FPD-R	1	50F
2	1440	0.9	1296	22X14	KUFM-7	13	FPD-R	1	50F
3	1440	0.9	1296	22X20	KUFM-7	13	FPD-R	1	50F
4	980	0.9	882	22X10	KUFM-4	9	FPD-R	1	50F
5	1350	0.9	1215	14X14	KUFM-7	12	FPD-R	1	50F
6	1440	0.9	1296	22X14	KUFM-7	13	FPD-R	1	50F
7	1440	0.9	1296	22X20	KUFM-7	13	FPD-R	1	50F
8	980	0.9	882	22X10	KUFM-4	9	FPD-R	1	50F
Total	15172	0.993963	15080.4			153		14&8	

AHU-1a,2a,3a									
Zone	Area	cfm/sf	cfm	duct	vav	diffusers	type	return	type
1P	610	1.2	732	22X16	KUFM-4	8	FPD-R	2	PAR
2P	610	1.2	732	22X14	KUFM-4	8	FPD-R	2	PAR
3P	610	1.2	732	14X14	KUFM-4	8	FPD-R	2	PAR
4P	500	1.2	600	14X8	KUFS-3	6	FPD-R	2	PAR
5P	700	1.2	840	22X16	KUFM-4	9	FPD-R	2	PAR
6P	610	1.2	732	22X14	KUFM-4	8	FPD-R	2	PAR
7P	610	1.2	732	14X14	KUFM-4	8	FPD-R	2	PAR
8P	610	1.2	732	14X8	KUFM-4	8	FPD-R	2	PAR
1	980	0.9	882	22X20	KUFM-4	9	FPD-R	1	50F
2	1100	0.9	990	22X16	KUFM-4	10	FPD-R	1	50F
3	1100	0.9	990	22X14	KUFM-4	10	FPD-R	1	50F
4	1125	0.9	1012.5	14X12	KUFM-4	10	FPD-R	1	50F
5	1540	0.9	1386	22X22	KUFM-7	14	FPD-R	1	50F
6	1540	0.9	1386	22X16	KUFM-7	14	FPD-R	1	50F
7	1505	0.9	1354.5	16X12	KUFM-7	14	FPD-R	1	50F
8	980	0.9	882	22X20	KUFM-4	9	FPD-R	1	50F
9	1100	0.9	990	22X16	KUFM-4	10	FPD-R	1	50F
10	1100	0.9	990	22X14	KUFM-4	10	FPD-R	1	50F
11	1125	0.9	1012.5	14X12	KUFM-4	10	FPD-R	1	50F
Total	18055	0.980753	17707.5			183		16&11	

Current Design Values

Zone	Diffusers	cfm	type	area	windows	z. type
VAV-1-1	4	1360	Open	522	3	perimeter
VAV-1-2	4	1340	Open	457	3	perimeter
VAV-1-3	7	1335	Office	535	3	perimeter
VAV-1-4	12	1380	Office	1152		interior
VAV-1-5	3	345	Conf	487		interior
VAV-1-6	2	250	Conf	222		interior
VAV-1-7	19	1990	Open	1627		interior
VAV-1-8	7	1785	Office	683	4	perimeter
VAV-1-9	3	1335	Conf	424	3	perimeter
VAV-1-10	3	1305	Conf	424		interior
VAV-1-11	14	1820	Open	1950		interior
VAV-1-12	4	1250	Office	502	3	perimeter
VAV-1-13	2	330	Conf	302		interior
VAV-1-14	11	1320	Open	1195		interior
VAV-1-15	5	1350	Office	452	3	perimeter
VAV-1-16	2	740	Office	245	1	perimeter
VAV-1-17	4	840	Office	240	2	perimeter
VAV-1-18	6	1260	Office	231	1	perimeter

Zone	Diffusers	cfm	type	area	windows	z. type
VAV-1a-1	6	1200	Office	372	3	perimeter
VAV-1a-2	16	1920	Open	2705		interior
VAV-1a-3	10	1770	Office	1681		interior
VAV-1a-4	2	330	Conf	302		interior
VAV-1a-5	15	2100	Open	1670		interior
VAV-1a-6	10	1780	Open	1120	9	perimeter
VAV-1a-7	5	1255	Open	755	5	perimeter
VAV-1a-8	12	1500	Open	2666		interior
VAV-1a-9	7	2005	Open	711		interior
VAV-1a-10	16	1730	Open	1804		interior
VAV-1a-11	12	1500	Office	1086		interior
VAV-1a-12	9	1465	Office	700	2	perimeter
VAV-1a-13	14	2030	Open	1873		interior

Zone	Diffusers	cfm	type	area	windows	z. type
VAV-2-1	5	1200	Office	372	3	perimeter
VAV-2-2	6	1080	Office	312	1	perimeter
VAV-2-3	15	2100	Office	1673		interior
VAV-2-4	10	1750	Open	1413	10	perimeter
VAV-2-5	12	1260	Open	1514		interior
VAV-2-6	8	1120	Open	1025		interior
VAV-2-7	1	210	Open	173		interior
VAV-2-8	16	2000	Conf	1306		interior
VAV-2-9	4	520	Open	330	2	perimeter
VAV-2-10	16	2080	Conf	1300		interior
VAV-2-11	7	1275	Open	982	6	perimeter
VAV-2-12	1	205	Open	180		interior
VAV-2-13	2	330	Conf	371		interior
VAV-2-14	12	1380	Open	1356		interior
VAV-2-15	7	1330	Open	934	6	perimeter
VAV-2-16	16	1920	Open	1780		interior
VAV-2-17	9	1550	Office	545		interior

Zone	Diffusers	cfm	type	area	windows	z. type
VAV-2a-1	6	1200	Open	346	3	perimeter
VAV-2a-2	1	315	Open	144	1	perimeter
VAV-2a-3	3	1065	Open	430	3	perimeter
VAV-2a-4	15	1950	Open	1762		interior
VAV-2a-5	3	1065	Office	440	3	perimeter
VAV-2a-6	6	1180	Conf	566	4	perimeter
VAV-2a-7	1	210	Open	174		interior
VAV-2a-8	14	1960	Conf	181		interior
VAV-2a-9	4	1120	Open	331	1	perimeter
VAV-2a-10	17	1635	Office	1935		interior
VAV-2a-11	7	1995	Open	642	5	perimeter
VAV-2a-12	5	2000	Open	756	5	perimeter

VAV-2a-13	12	1980	Open	1900		interior
VAV-2a-14	12	1440	Open	1416		interior
VAV-2a-15	3	1350	Open	375	3	perimeter
VAV-2a-16	17	2040	Open	2071		interior
VAV-2a-17	2	485	Open	256	2	perimeter
VAV-2a-18	4	660	Office	235	2	perimeter

Zone	Diffusers	cfm	type	area	windows	z. type
VAV-3-1	4	520	Conf	330	2	perimeter
VAV-3-2	10	1705	Open	1412	12	perimeter
VAV-3-3	15	2025	Open	1460		interior
VAV-3-4	1	205	Conf	173		interior
VAV-3-5	5	1205	Office	372	3	perimeter
VAV-3-6	19	2090	Open	1854		interior
VAV-3-7	5	1085	Office	314	1	perimeter
VAV-3-8	5	1245	Office	357	3	perimeter
VAV-3-9	1	315	Open	132	2	perimeter
VAV-3-10	5	1975	Open	720	6	perimeter
VAV-3-11	17	2040	Open	2310		interior
VAV-3-12	12	1860	Open	1508		interior
VAV-3-13	15	2025	Open	1579		interior
VAV-3-14	1	205	Conf	174		interior
VAV-3-15	6	1930	Open	712	5	perimeter
VAV-3-16	4	1120	Conf	330	2	perimeter

Zone	Diffusers	cfm	type	area	windows	z. type
VAV-3a-1	6	1640	Office	539	4	perimeter
VAV-3a-2	1	225	Conf	180		interior
VAV-3a-3	17	1635	Open	1850		interior
VAV-3a-4	12	1990	Open	1536		interior
VAV-3a-5	4	1780	Open	550	4	perimeter
VAV-3a-6	14	1820	Open	1630		interior
VAV-3a-7	5	1900	Open	640	5	perimeter
VAV-3a-8	1	210	Conf	134	2	perimeter
VAV-3a-9	6	990	Office	352	3	perimeter
VAV-3a-10	12	1560	Open	1416		interior
VAV-3a-11	9	1510	Office	550	3	perimeter
VAV-3a-12	15	1575	Open	1886		interior
VAV-3a-13	19	1995	Open	2124		interior
VAV-3a-14	8	1330	Open	1078	8	perimeter
VAV-3a-15	1	225	Conf	180		interior
VAV-3a-16	15	1950	Open	1723		interior

Comparison between Old and New Designs

AHU	Zones	cfm	area	old cfm/sf	new zone	new cfm/sf	new area	new cfm
AHU-1	18	21335	11650	1.83	14	0.99	15200	15080.4
AHU-1a	13	20585	17445	1.18	19	0.97	18165	17707.5
AHU-2	17	21310	15566	1.37	16	0.99	15225	15080.4
AHU-2a	18	23650	13960	1.69	19	0.98	18065	17707.5
AHU-3	16	21550	13737	1.57	16	0.99	15225	15080.4
AHU-3a	16	22335	16368	1.36	19	0.98	18065	17707.5
		130765	88726	1.47		0.98	99945	98363.7

The average reduction in ventilation air required for the redesigned UADS system is about 0.49 cfm/sf less than the current design.

Height Reduction

The following table shows the change in height that occurs in each floor due to the reduction of the ceiling plenum and the raised floor system.

Original floor-to-floor height	17 feet
Slab thickness	4 inches
Floor plenum height	18 inches
Floor thickness	2 inches
Floor to Ceiling height	12 feet
Ceiling plenum height	16 inches
Total	15' 4"
Total Reduction per floor	1' 8"
Total Reduction	5 feet
Cost Savings per foot	10645.05
Estimated Cost Reduction per floor	17741.75
Total Cost Reduction	53225.25

Cost estimates where found in the Means catalog.

Equipment Costs

Redesign of the overhead systems into an underfloor air distribution system will required new terminal units, diffusers, return grilles, raised floors and ductwork. In the following tables, there are the estimated current costs of the building and the redesigned costs.

Item		Cost	Old Diffusers		Total	Price	Total Cost
Old Raised Floor		1300000	Titus TDC		879	21.07	18520.53
Old Ductwork		750000	Titus 355RL		12	9	108
New Raised Floor		1400000	Titus PAR		240	40	9600
New Ductwork		300000	Total				28228.53
Diffusers		Total	Price	Total Cost			
New Supply		1000	12	12000			
New Return		80&57	15&30	2910			
Old Supply		891	NA	18628			
Old Return		240	NA	9600			
Terminals	Amount	Ave. Cost	Total Cost				
Old	98	1162	113876				
New	103	1067	109901				

Overall Mechanical-related Savings

Items			Costs
New Ductwork and Raised Floor			1700000
Old Ductwork and Raised Floor			-2150000
New Diffusers and Grilles			14910
Old Diffusers and Grilles			-28228
New Terminal Units			109901
Old Terminal Units			-113876
Reduction of Building Height			-53225
Initial Savings			**520518**
HVAC Operation			
Current Overhead System			930000
New Underfloor System			-800000
Annual Savings			**130000**

Conclusion

The Michael Baker Corporation Headquarters was designed to be a multi-functional, flexible, technologically-advanced faculty. Within the building, there is a raised floor system used to house the majority of electrical and telecommunication wiring systems. The building has easily maneuverable wall partitions that can be used to create cubicles for the over 500 occupants of the facility. The building also is extremely well lit for occupant use incorporating indirect lighting and natural daylighting. The current mechanical system supplies plenty of air to the spaces to achieve quite acceptable indoor air quality using a traditional overhead VAV system.

An underfloor air distribution system is the focus of redesign of this building. The goal of the design is to be able to maintain the flexibility of the current system while not seriously disturbing the other systems in the building and reducing the overall construction costs and the annual energy costs necessary to run the facility.

The underfloor air distribution system did all of this. In addition, it achieves a more occupant friendly environment. The UADS will be incorporated using a non-pressurized plenum with displacement ventilation. This system should improve the indoor air quality of the building dramatically while reducing the amount of supply air necessary to do so. As long as the building is constructed and maintained properly, the indoor air quality should remain higher than any traditional overhead system can promise. With these conditions in place, the occupants at the Michael Baker Corporation Headquarters should be able to maintain and surpass their current production levels.