Grace S. Beck Elementary School
Pressurization Test 5/18/2003

Introduction

On May 18th, 2003 WPB and Infiltec met Larry king and Joe Byrd of McClure Mechanical Services at Beck Elementary School in Sunbury, PA to determine the ratio between increasing outdoor air being forced into the school and the resulting inside to outside pressure increase. This test was performed using a special piece of equipment know as a blower door that has a calibrated orifice installed inside high velocity fans. The pressures derived from these orifices are used to determine the amount of air being moved through the fan. At the same time as the air flowing through the fan is being determined the pressure difference between inside the building and the outside is measured. These measurements can be used to determine how much inside pressure is obtained from varying amounts of outdoor air supply. This measurement can also determine approximately how much leakage area there is in the shell of the building. The blower door in this case needed to be much larger than typical residential units because of the size and construction of the school. A specially fabricated three stacked blower door fan was used that had a combined total velocity of 18,000 CFM.

Building Conditions

The Elementary School has two distinct building components. The first is a two story building that has a total volume of about 356000 cubic feet. This building has over 20 classrooms, a kitchen, a mechanical room, school offices and numerous bathrooms. A second building component is the Multi-Purpose room which has a total volume of about 148,000 cubic feet.

The building heating system has a mix of air handlers and individual classroom uni-vents. The HVAC systems are also capable of providing A/C. Pressurization of a building is obviously induced by supplying outdoor air to a building. This outdoor air needs to be in sufficient quantity to overcome numerous different loses of conditioned air that happen in every building. These loses include the natural escape of heater air out of the upper portion of the building induced by stack effect, the loss of building air due to wind effect, the loss of air from exhaust fans, the loss of air out of the building shell from intentioned and un-intentioned openings adjacent to pressurized portions of the building. These influences tend to cause significantly greater building condition air loses during heating periods, especially if there are sizeable openings in the upper shell of the building.

The Beck Elementary school was designed to obtain outdoor air by the uni-vent heaters around the perimeter of the building, and by the outdoor inlet of the multi-purpose room air handler and other Main Building air handlers. The classrooms have passive grills to the hallways. On the roof of both buildings are situated numerous passive relief hoods with internal dampers. The dampers that were visible appeared closed. There are also numerous exhaust fans throughout the building. The main kitchen has a typical huge range hood.

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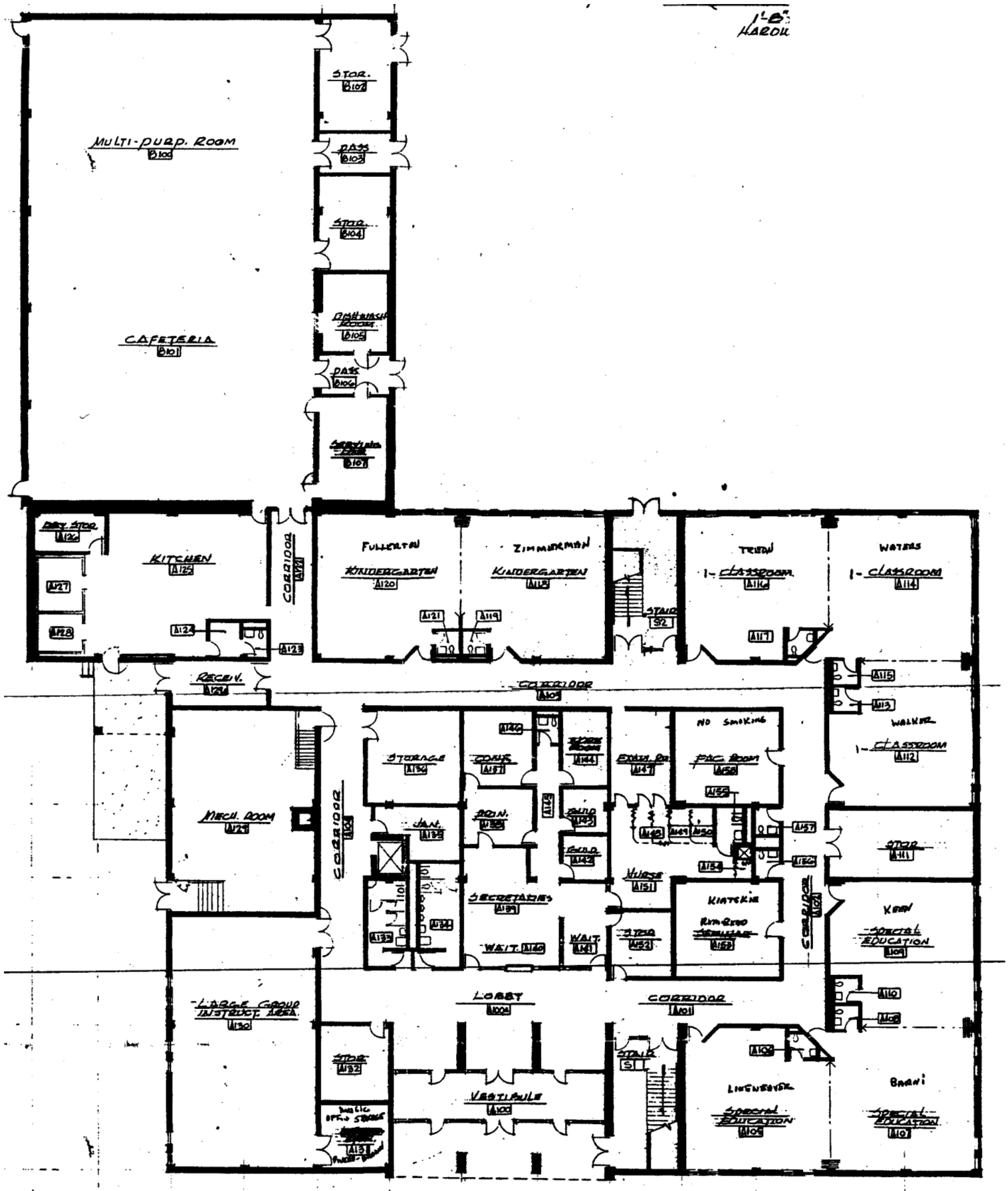


Grace S. Beck Elementary School
Pressurization Test 5/18/2003

Outdoor and Inside Conditions

The day of the test the outdoor conditions had a temperature range of 45 to 60 degrees. It was overcast in the morning with clearing in the afternoon. The wind was a moderate 0 to about 6 mph.

The school was not in operation or occupied the day of the test. The HVAC systems throughout the school were turned off. No exhaust fans were operating.

The inside to outside pressure was measured at the multi-purpose room exterior door and the main school front door. The inside of the building was negative about 0.009" of static water. This is a typical of a building of this height with openings in the upper portion of the shell. This stack effect pressure will increase as the outdoor pressure deceases. Included is the ASHRAE formulae for determining stack effect pressures with changing temperatures. Wind also can cause drastic pressure changes. It was not unusual for the shell pressure difference at the front door to increase to as much as –0.030" the day of the test.

The stack effect happens because a building acts like a chimney with heated air escaping at the top, and cold air being drawn in at the bottom.

The following formulae for stack effect is from: ASHRAE Fundamentals, 1993, section 23.4

P=C*D*G*(Hm-Hnpl)*(Ti-To)/To

Where:

P =	stack pressure	
C =	unit conversion factor	0.00598
D =	air density	0.075 lb/ft3
G =	gravitational constant	32.2
Hm =	measurement height	30 ft
Hnpl =	neutral pres level	15 ft
Ti =	inside temperature	528 R
To =	outside temperature	?

The following are typical stack effect pressures at Beck using ASHRAE formula

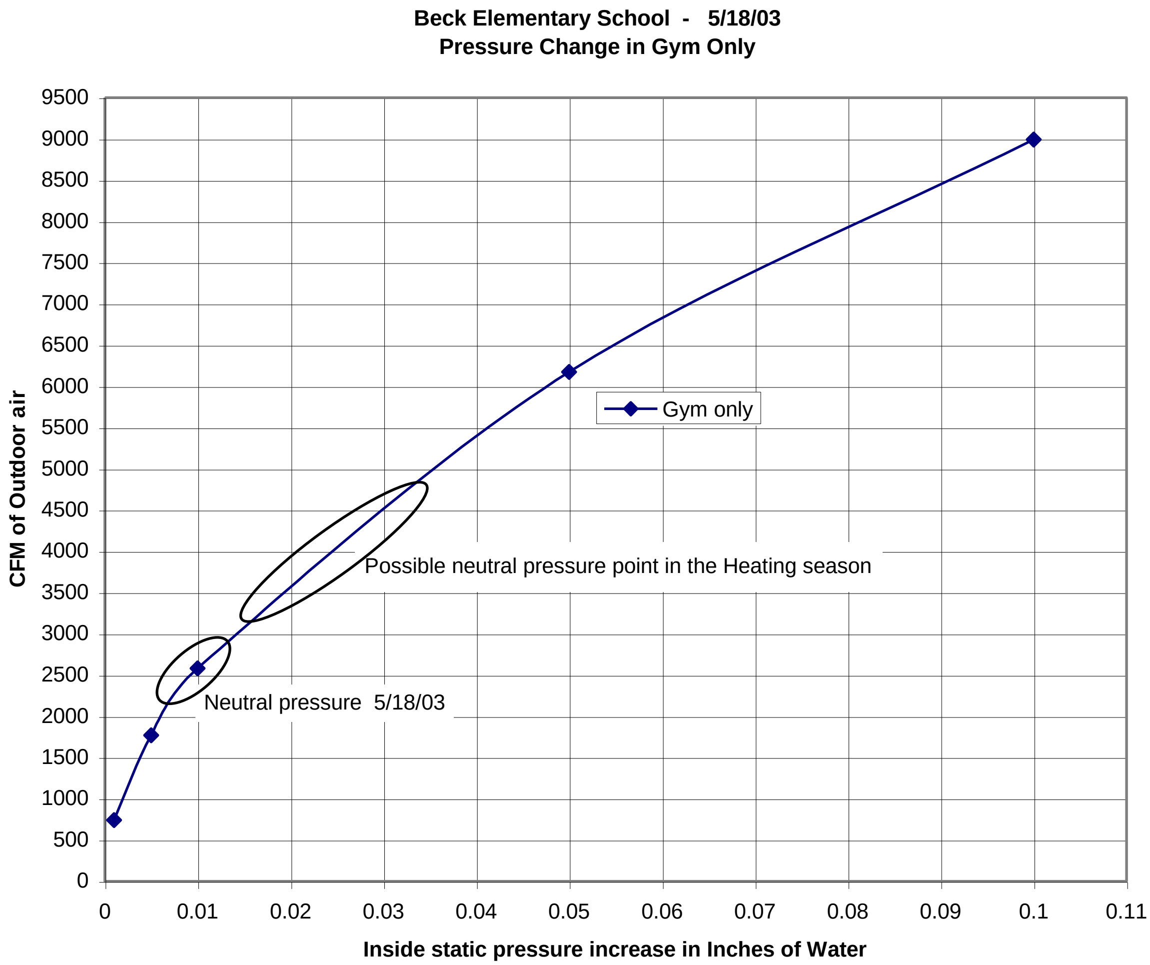
Outside Temp (F)	Stack Pres (in wc)
68	0.000
50	- 0.008
32	- 0.016
0	- 0.032
-10	- 0.038
-20	- 0.043
100	0.012

As can be shown in the far right chart above. At 50 degrees we would expect a 0.008" negative pressure at the bottom of the Beck Elementary School. Our field measurement of negative 0.009 was close to this. At an outside temperature of 32 degrees we would expect to see twice as much negative pressure. Keep in mind that the measured negative pressure that day was only that induced by stack effect and wind effect. During normal HVAC operation there can be significant influences from the outdoor air being induced into the building and operation of any exhaust fans. The HVAC can also induce pressure zones within the building that can significantly influence the leakage through the building shell.

Blower Door Results

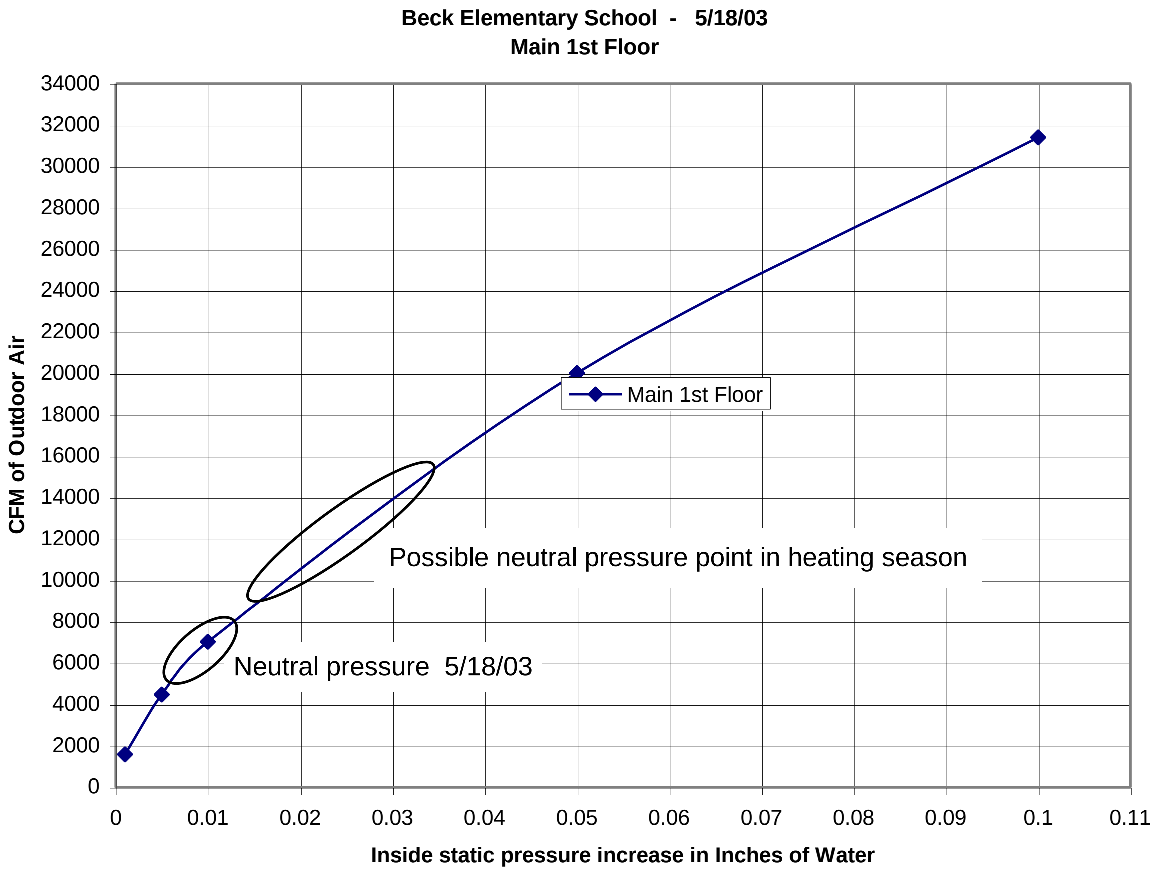
The following graphs were obtained by extrapolating from the measurements made with the stacked blower door.

The first graph is the amount air required to pressurize the Multi-Purpose Room with the doors to the side rooms closed and the doors to the main school building and kitchen also closed. Opening any of these doors can dramatically reduce the pressure in this room. There are about six pressure relief dampers on the roof for this section of the building. Sealing off half or more of these passive relief dampers would significantly reduce the amount of air necessary to pressurize this building. The blower door test indicated there was 11 square feet of opening in the multi-purpose room building shell. The equivalent of a hole three feet by almost four feet.



The graph above represents the correlation between increasing outdoor air and pressure in the multi-purpose room. The notation on the chart indicates a general indication of how much air will be needed in the heating season to neutralize stack effect. In previous work done on residential and commercial buildings in which pressurization was used it was generally found that the induced pressure needed to be 4 to 6 pascals greater than the neutral pressure condition. This is 0.016” to 0.024” of static water. This equals an additional 1200 to 2000 cfm beyond neutral pressure condition. Once again, the amount of air necessary to obtain the neutral pressure condition will be determined by all of the pressure influencing factors.

The next graph is the ratio of increasing outdoor air and pressure in the main school building. These results were obtained with the doors to all the classrooms closed as well as the door to the multi-purpose room and doors to the stairwells closed. The building shell leakage area determined by the blower door in this test was equal to 35.4 square feet. This is more than three times greater than the multi-purpose room. The equivalent of a hole four feet by nine feet in the building shell. There were numerous passive relief dampers on the main building roof.



In the main building the same issues of varying pressures due to HVAC operation, outside wind and temperature will change the neutral pressure point. Once again it is recommended that there be from 0.016” to 0.024” of positive pressure beyond the neutral pressure condition to ensure continuous positive pressure. This translates into about an additional 5000 to 8000 cfm above neutral pressure condition.

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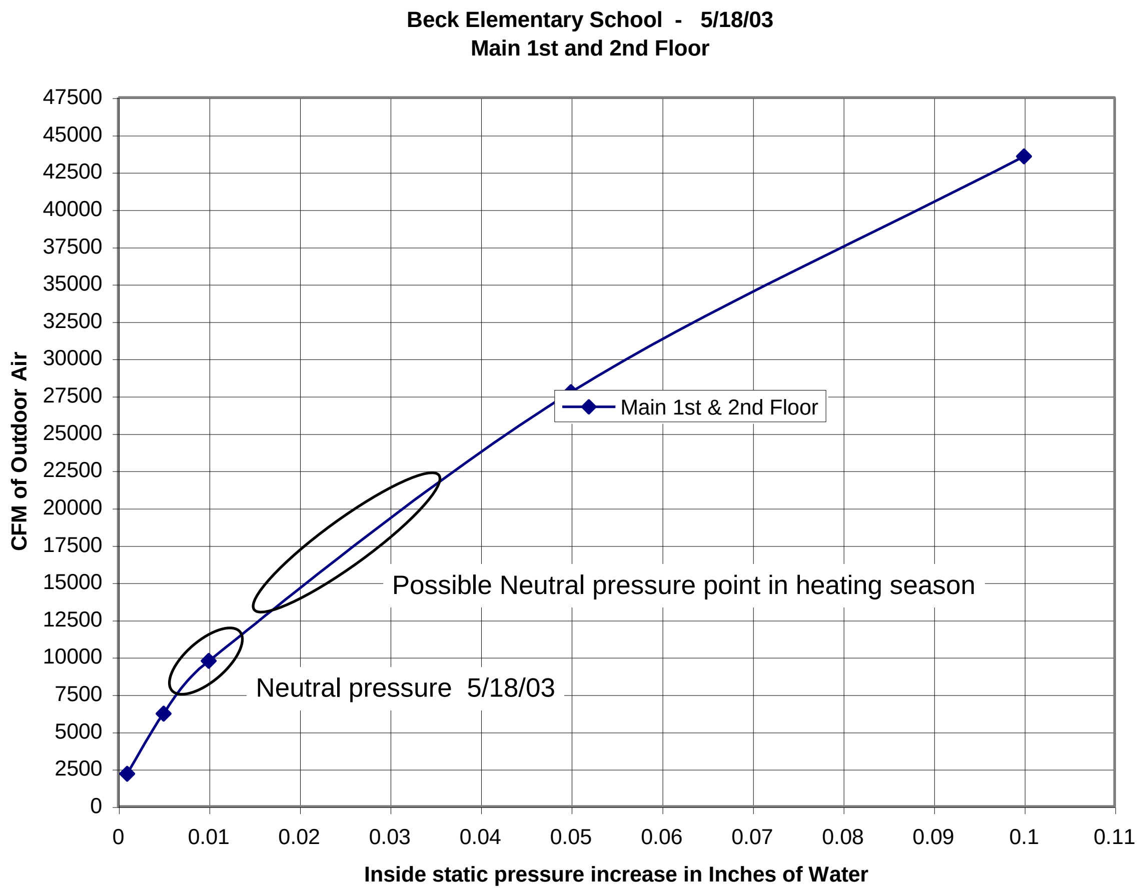
Pressurization Test 5/18/2003

If the stair well doors are kept open a significant increase in additional outdoor air is needed to induce building pressure. The following graph gives the ratio of outdoor air to increasing pressure in the whole main building. Note that the classroom doors were not open during this test, nor was the door to the multi-purpose room left open. Once again there was no HVAC fans operating in the building. The shell leakage determined by the blower door was 49.1 square feet.



The amount of additional outdoor air to have a 0.016” to 0.024” increase pressure would be about 7000 to 12000 cfm.

Active Soil Depressurization

The same affect, pressurizing the building, that is accomplished by increasing the amount of outdoor air being drawn into the building can be achieved by withdrawing air from under the building. This method is know as Active Soil Depressurization or ASD. ASD systems have been shown to be extremely effective at controlling soil gas entry into a building. WPB has been using this technique successfully for over 15 years. In the last few years we have also used ASD to effectively eliminate CO^2 and methane from entering different buildings. In general it is typically must less expensive to depressurize the soil beneath a building versus pressurizing the building. The energy and maintenance cost to depressurize the soil under a building is typically a fraction of the cost to pressurize the building. Last and most important, active soil depressurization systems are much less likely to be overcome by occupant behavior or weather conditions.

The Beck Elementary School had a partial ASD system installed during the schools construction. The installed system has an eight inch duct rising from approximately the center of the Main Building slab to the main building roof. A curb mounted fan is installed on the roof. This size duct is considered more than adequate to depressurize the sub-slab space if there is sufficient size aggregate under the slab, no significant barriers to pressure field extension and limited leakage through the slab and the surrounding soil. This system appears to have been constructed with inlet vents. ASD systems have reduced system performance when indoor or outdoor inlets are connected to the sub-slab space.

Recommendations

An HVAC system should be considered that addresses all the compounding issues of competing pressures and air flows as well as the operating costs and comfort levels of the occupants. An energy recovery ventilation system should also be considered since the operational cost of a 100% outdoor air system is very high. The long term payback could justify any additional cost for an ERV option. If the operational energy cost is not clearly understood, the pressurization system may be compromised in the future because of budget considerations.

An ASD system should be fully investigated because of its many positive benefits and because the system is already partially installed. The present ASD system components need to be evaluated. This is done by measuring the difference in pressure between the sub-slab and the room above the slab with a micro-monometer capable of reading down to 0.001”. These measurements need to be made in all the corners of the building with the ASD fan off and then on. An additional measurement needs to be made with the sub-slab inlet pipes closed. Additional test holes may also be needed. These test holes need only be 3/8” in diameter. The capacity of the present roof mounted ASD fan also needs to be measured.

If the present ASD system is not producing enough pressure difference across the slab it will be necessary to do communication testing of the sub-slab to determine how many additional suction points and or additional radon fans will need to be installed to obtain complete sub-slab depressurization. Modifications to the existing ASD system and/or installation of additional ASD systems could be installed and completed during the coming summer months.

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