PRESSURE BALANCING A HOUSE & "MAD-AIR"

John Tooley

PRESSURE DIFFERENTIAL (PD)

There are three possible pressure modes that can be found either within a house, across or within its interior partitions or from indoors to outdoors.

POSITIVE PRESSURE Positive pressure is also known as "high pressure". Positive pressure means air pressure that is higher on one side of a barrier (ie., interior partitions, exterior walls, ceilings, floors and slabs) than it is on the other side.

NEGATIVE PRESSURE Negative is also known as "low pressure". Negative pressure means air pressure that is lower on one side of a barrier than it is on the other.

NEUTRAL PRESSURE Neutral pressure means that the air pressure is the same on both sides of a barrier.

PD measurements are nothing more than the measurement of the pressure **difference** across a barrier. A higher pressure on one side of the barrier will result in air flow from the high pressure side to the side having a lower pressure if there is a hole in the barrier. It takes three ingredients to have air flow across a barrier. First there must be air, no problem there. Second there must be a hole and third there must be a pressure difference across the barrier. If any one of the three are not present or are reduced, air flow will be eliminated or reduced. Air flow is defined in this paper as infiltration or ventilation. Infiltration is uncontrolled building air leakage and ventilation is controlled. Eliminating or reducing the holes in a building can result in the elimination or reduction of both infiltration and ventilation.

Air is like crooked men, crooked rivers, teenagers and cheap labor, it always seeks the least line of resistance. Air flow, moisture vapor flow, soil gas flow and combustion gas flow all inter or exit a building the same way, through a hole, driven by one of the below listed forces or a combination of them.

DRIVING FORCES THAT CAUSE PRESSURE DIFFERENCE

Driving forces are grouped in three areas, ***wind, heat and fans.*** Within these groups there are six driving forces that may cause pressure difference in or across the exterior of the house or building.

WIND: A simple example... wind striking one side of a house will cause positive pressure on the outside of a wall on the windward side and negative pressure on outside of the leeward side.

STACK: Stack pressure is little more than the buoyancy of hot air rising due to the temperature difference between the inside and outside of the house and the height of the building. Generally stack pressure causes a positive pressure at the upper regions of the house and negative pressure at the lower regions.

COMBUSTION: Combustion is somewhat like stack. The exhausting of hot combustion by-products up a vent or chimney that is drawing its make-up air from within the conditioned space can cause negative pressure within the house or the area it is located. The pressures generated by vented appliances are generally quite low but

should be considered all the same. Large boilers and fireplaces that draw their combustion and dilution air from within the building can cause large pressure differences and should be considered at all times. ***They often compete for the same air as weaker combustion appliances, while exhaust fans are seeking the same air.***

EXHAUST FANS: Exhaust fans that draw their make-up air from within the house may cause negative pressures within the house.
These negative pressures can easily cause combustion appliances, fireplaces, wood stoves to spill or backdraft.

DUCT LEAKAGE: ***SUPPLY DUCT LEAKS:*** Supply duct leaks to the outside of the house can cause negative pressures within the house. The reason for this is, every cubic foot of air (CFM) that is lost to the outdoors through these leaks must be replaced. Supply air lost to the outdoors causes the return to starve for the air lost and then depressurizes the house to obtain the make up air. ***Remember air always seeks the least line of resistance. It will come in the first largest available hole first, and then every other hole in the building.***

Air supplied to remote areas outside the air barrier (ie., work shops, garages, etc.) having no returns act just like supply leaks to the outdoors and can cause negative pressures within the house.

Supply leaks within the air barrier and in enclosed areas (basements, laundry rooms, closets, rooms, floors, walls and dropped ceilings, etc.) can cause positive pressure in the enclosed area. This can drive air out of building leak sites and if the flow is large enough it can cause negative pressure within the main body of the house.

Supply leaks to the exterior of the building can caused combustion appliance, fireplace and wood stove problems. Moisture problems in warm moist climates and dry houses in cold climates.

RETURN DUCT LEAKS: Return leaks that draw air from the outdoors can cause positive pressures within the house. For every CFM that is drawn in by the return leaks a CFM must also be forced out through the cracks and holes of the house shell.

Return leaks within the air barrier and in enclosed areas (basements, laundry rooms, closets, rooms, floors, walls and dropped ceilings, etc.) can cause negative pressure in the enclosed area. The house leak sites then leak and if the flow is large enough it can cause positive pressure within the main body of the house.

If there are combustion appliances, a fireplace or wood stove in the same area that return leaks are depressurizing, all pressure related combustion problems are possible. If the house is pressurized by the return leak drawing in outside air, moisture related problems may be present in heating climates.

INTERIOR DOOR CLOSING: Interior door closing in a house that has a forced air distribution system can cause both positive and negative pressures within the house. Closing an interior door in a single return air inlet house can cause a positive pressure in the room behind the closed door and a negative pressure in the rest of the house.

The reason for this is; there is not a free return air path for all the air supplied to the closed room to get back to the return air inlet. The return then starves for the lost air and can cause a negative pressure in the remainder of the house.

Positive pressure can result in the closed room since the air being delivered to the room can't readily get back to the return air inlet. The same thing can happen in a multi-return house. If the supply or return in the closed room is larger than the other, then the larger of the two will either cause positive pressure (larger supply) or negative pressure (larger return).

Closed interior doors become a problem when closed for long periods of time. All problems related to pressure driven air flow, moisture vapor flow, soil gas flow and

combustion gas flow can be present. Return air paths and interior door closure should always be a part of Mechanical Air Distribution And Interacting Relationship, ("MAD-AIR"), investigations.

While discussing "MAD-AIR", PD and balancing a house we will limit ourselves somewhat to exhaust fans, duct leakage and interior door closure.

When dealing with "MAD-AIR" it is important to remember that pressure is dependent upon the tightness of the building and the amount of air flow delivered to or drawn from the area being tested. For example a room might have a low pressure differential across the exterior wall, say 2 pascals (pa.). This does not mean the low pressure is not a problem. It might be a very leaky room with reference to (WRT) the attic and outdoors and has a large amount of supply air delivered, therefore only able to maintain a 2.0 pa. pressure difference because a large amount of air is leaking out of the room. The flip of this would be if this room was 14.0 pa WRT outdoors because it was very tight. This room could have very low air flow delivered to it and have high pressure differentials with reference to the outdoors. Knowing how tight an area, zone or room is will help define how bad any given pressure might be WRT outdoors.

Another important consideration is always know and record where the reference point is during the measurements plus what was operating (fans, combustion appliances and fireplaces, etc.).

MANOMETER USE

In order to use a magnahelic gauge to measure both negative and positive pressure difference you will need to "zero" it on 15 or 20 pascals so the needle can move up when there is a positive pressure and down when there is a negative pressure. Digital gauges will read both negative and positive pressures. Placing the low pressure tap in the point of reference will help to make all measurements uniform and will insure a correct pressure sign. An example of this would be when measuring the pressure in a closed room, (bed, bath utility, etc.), during the operation of the furnace or air conditioner fan with the door to the room closed. If you want to know the room with reference to (WRT) the mainbody of the house and you are standing in the mainbody of the house you would place the tubing on the high pressure tap of the manometer and slide it under the closed door. The low pressure tap is with you in the reference point (the mainbody). If you wanted to know what the closed room was WRT outdoors a tube would be placed on the high pressure tap and slid under the closed door and another tube would be attached to the low pressure tap and placed outdoors in your reference point.

If the room is at a higher pressure than outdoors it might be due to the home having only one return inlet and the air delivered to the closed room can not readily return to the return air inlet, thus the room pressurizes. Another cause might be that the room has both supply and return and the supply air flow to the room is greater than the return air flow from the room. It is very important when measuring and recording PD that the procedure is uniform. The tube can be connected to either the positive or negative side of the manometer, what is most important is all measurements are done the same.

THE MANOMETER LAW IS, ALWAYS PLACE THE LOW PRESSURE TAP IN THE REFERENCE PLACE. Remember, this can be done by placing a tube on either tap when needed.

The pressure across the exterior wall, ceiling, floor or enclosed area being measured is also very important. This is because air flow from room to room normally is not a problem. However, air flow to and from outside the conditioned space can lead to problems, such as higher utility use, discomfort, moisture, mildew and indoor air quality. The main difficulty with taking pressure differential measurements to the outdoors is two fold...wind and stack pressures. Wind pressures are constantly changing and can be negative or positive depending upon where the measurement is

made and the direction of the wind. Stack pressures can be different depending upon the height of the building and the hole distribution throughout and where the measurement is taken. A good understanding of wind and stack pressures and their effects on building pressures is most important before "MAD-AIR" pressure differential measurements are done. ***"Mad-Air" is the measurement of the effect on a building or portion of the building due to exhaust fans, duct leakage, interior door closure or combination excluding wind and stack pressure.***

CONTROLLING MAD-AIR AND PD

There are four reasons for controlling "MAD-AIR".

1. Health and safety
2. Durability of the building
3. Comfort
4. Affordability to operate

Any one of the four or a combination will require "MAD-AIR" remedies. Increased infiltration caused by pressures produced by mechanical systems improperly designed, installed or just the interactions with the occupants must be dealt with when cost effective or when they are causing a health and safety problem. When the same pressures cause poor indoor air quality, such as, spillage and backdrafting of combustion appliances, fireplaces and wood stoves, pressure induced flame roll-out from the access doors of gas fired water heaters, or increased entry of soil gases into the living space "MAD-AIR" becomes most important and must be dealt with. The same pressures can cause increased amounts of air transported moisture, possibly resulting in poor health to the occupants and building decay and damage. Any one of these problems would require a solution to the pressures related to "MAD-AIR".

PRACTICAL FIELD MEASUREMENT:

When pressure balancing a house to reduce the effects of "MAD-AIR", there are several considerations that should be part of any practical field measurement protocol. The following are just a few that should be of help when diagnosing pressure induced building failure. The following protocol is progressive, it is designed to reduce the amount of work done, and repeated steps. An example of what is meant by progressive is; once the interior doors are closed in one step they should remain closed until instructed to open them. The same is true for the air handler and exhaust fans.

1. Close all windows, exterior doors and garage doors.

2. Open all interior bedroom, utility, laundry, basement and bath doors.

3. Close fireplace/wood stove flues.

4. Turn off or place on pilot all combustion equipment.

5. Turn off all exhaust fans, attic fans, crawlspace vent fans, dryers, radon, air conditioner and furnace fans. Remove the filter.

6. Measure the pressure difference house WRT outdoors.

This will be a measurement of wind pressures on the side of the house that the measurement is made or stack pressure, which ever is greater and their effect on the house. This pressure measurement may be different depending upon the side of the house that the measurement is made or the distance up or down the exterior wall that the measurement is made.

7. DOMINANT DUCT LEAK EFFECT: Turn on the air handler (AC, furnace) fan. If there is a basement, close the basement to house door. Measure the pressure difference between the inside and outside with the reference point being the outdoors. (House WRT outdoors) This

measurement is the effect the dominant duct leak has on the whole house.

NOTE OF CAUTION: Those houses having both air conditioning and gas heating might have different fan speeds for each. All testing should be done with the higher fan speed when possible.

If there is **no pressure** difference between the indoors and outside this might be an indication of one of the following;

- That the house is too leaky to pressurize or depressurize by duct leakage to the outdoors.

- That the supply ducts are leaking the same amount of air to the outside of the building as the return ducts are drawing from the outdoors.

- That there are equal supply and return leaks in the basement.

- That there is no duct leakage to outdoors.

If there is a **positive pressure** difference across the exterior wall of the building, with the reference point being the outdoors, (house WRT outdoors) this might mean one of the following:

- That there are return leaks drawing air from the outside. This can happen in basement houses as well as houses that have the ducts outside.

- There might also be supply leaks but the return duct leak will be drawing more air from outside than the supply leaks are leaking to the outdoors. The return leakage is the dominant duct leakage.

If there is a **negative pressure** difference across the exterior wall with the reference point being the outdoors, then this might mean one of the following;

- There may be supply duct leaks to the outdoors. This can happen in basement houses as well as houses that have ducts outside.

- There may be remote supplies to a portion of the building outside the conditioned portion of the building, having no return air path for the air delivered to that portion of the building, (ie., garage, workshop, laundry room), back to the return air inlet(s). These remote supplies act just like supply leaks to the outdoors. If this pressure or the pressure above is greater than -3.0 and there is a combustion appliances or there is a wood stove or fireplace (wood or gas) that draws any portion of its combustion air from the area that it is located, then repair will be very important. This is due to the possibility of backdrafting and spillage.

8. CLOSED MASTER BEDROOM EFFECT ON THE WHOLE HOUSE: Closed the master bedroom door, with only the air handler fan on.

9. Measure the pressure difference mainbody of the house WRT outdoors.

- This is the effect of closing just the master bedroom door on the rest of the entire house. If this door is closed for long periods of time it may causes all sorts of problems in the areas of health , safety, durability, comfort and increased energy use due to in creased infiltration.

10. Close all interior bedroom, utility, laundry, basement and bath doors, with only the furnace or air conditioner fan on.

11. Measure the pressure difference mainbody of the house WRT outdoors.

- This is the pressure effect of all doors closed upon the main body of the house. If there is no pressure effect it might mean the house is too leaky to register any pressure or that the house has free egress of air flow back to the return air inlet(s). **Note:** If there was positive pressure recorded due to return leaks and now there is no pressure difference, then door closure pressure effect is the same as the pressure effect of the dominate return duct leak to the outdoors.

• If there is a negative pressure, there is an indication that there is not free egress for the air supplied to the closed rooms. If the pressure is greater than -1.0 pa and doors are closed for long periods of time in a climate having a considerable cooling season and air conditioning is used, then pressure relief is needed. If the pressure is greater than -2.0 pa in a cold climate, having a small cooling requirement, then pressure relief may be needed. If there is a combustion appliance, fireplace or wood stove in the mainbody of the home and it draws any portion of its combustion air from the area where it is located and there is pressure recorded greater than -3.0 pa then pressure relief is needed.

NOTE OF CAUTION: These pressures assume that the venting of combustion appliances or fireplaces are sized correctly, terminate properly and that there are no constrictions or venting problems whatsoever. If there are any questionable areas about the venting or combustion air for these appliances then there can be no negative pressure difference caused by the closing of interior doors.

12. CLOSED DOOR PRESSURE EFFECT ON THE CLOSED ROOM: Measure the pressure difference; closed rooms WRT mainbody of the house.

When measuring closed door pressures remember that the reference point is the mainbody of the house ***not the outdoors.*** *If you want to know what the room is s to outdoors you can direct measure it. When there is little or no wind and the pressure taken mainbody WRT outdoors in the step just before this one is a sure number you can add mainbody WRT outdoors to closed room WRT mainbody and that will be the closed room WRT outdoors.*

• If there is a negative pressure difference, there is an indication that the return air inlet in the closed room is drawing more air from the room than is being supplied to it. If there is a fireplace, wood stove, or vented combustion appliance inside the room the pressure should be measured, room WRT outdoors. If the negative pressure is greater than -3.0 pascals (ie. -3.5), pressure relief is needed.

• If there is a **positive pressure** difference then there is an indication that this room might have no return air inlet or the return air inlet is drawing less air from the room than is being supplied to the room. If this pressure is greater than 2.0 pa then there may be a need for pressure relief in a cold climate if the room is going to be closed for long periods of time.

13. Maximum Depressurization Test, turn on all exhaust fans leaving the air conditioning or furnace fan on and leave all the interior doors closed. Use a smoke generator and check to see which way air is flowing across the door of each room that is closed. If air is blowing out of the closed room into the mainbody of the house leave that room closed. The pressurization is forcing air out of the building. If air is being drawn into the closed room then open that rooms' door. Something in the room wants to draw air from the vented appliances, let it. Next, go into the combustion appliance zone (CAZ) and close the door behind you. If air is being drawn out of the CAZ and into the mainbody of the house, then open the door. Something in the mainbody wants to draw air from the CAZ and vent pipes, let it at them.

14. Measure the combustion appliance zone (CAZ) WRT outdoors. We will call this pressure measurement pressure #1.

Next, turn off the air handler fan leaving on the exhaust fans and close all interior doors having no exhaust fans and open all that do. Leave the CAZ door as in the last test.

15. Measure the CAZ WRT outdoors. We will call this pressure measurement pressure #2

Next, either open or close the CAZ to house door so it is opposite from the test you just did.

16. Measure the CAZ WRT outdoors. We will call this pressure measurement pressure #3.

The greatest negative pressure of these three measurements CAZ WRT outdoors is the maximum depressurization for the CAZ.

If there is a combustion appliance that draws any portion of its combustion and dilution air from the CAZ and the CAZ is depressurized greater than -3.0 pa., then pressure relief is needed before or in conjunction with any work that is to be done on the house.

If there are vented appliances in the CAZ, combustion safety testing should be conducted with the above maximum depressurization configuration.

17. Measure draft in all combustion appliances that are not sealed combustion or are designed to have positive draft. (Vent WRT CAZ) This testing is to be conducted after five minutes of run time in order to let the appliances come to steady state.

This measurement is done by drilling a 5/16 or 1/4" hole in the vent pipe two feet up from the draft hood or diverter.

Place a static pressure probe in the hole in the vent pipe and attach a tube to the manometer. This measurement is the pressure difference inside the vent pipe WRT the combustion appliance zone (CAZ). The vent pipe tube is connected to the top tap of the manometer and the lower tap is open to the CAZ. If there is a disconnected or rusted out flue pipe that leaks, it should be repaired before testing is done, when possible.

Minimum Acceptable draft is: outside air temperature. **Over 80** degrees Fahrenheit draft must be greater (lower)than **-1.0 pascal, 60 to 80 degrees** draft must be greater (lower) than **-2.0 pascals, 40 to 60 degrees** draft must be greater (lower) than **-3.0 pascals, 20 to 40 degrees** draft must be greater (lower) than **-4.0 pascals** and **below 20 degrees** draft must be greater (lower) than **-5.0 pascals. Remember,** draft pressures are measured after 5 minutes of furnace or water heater operation.

GAS APPLIANCES

If draft pressures are found to be less than acceptable, then an inspection of the vent and chimney for blockage should be done and repairs made. To determine if it is blockage or pressure induced spillage, or backdrafting open the CAZ to the outdoors. If the draft becomes acceptable it was pressure, if nothing changes blockage should be investigated. **An appliance should never spill combustion gases more than one minute under any condition.**

18. Carbon Monoxide testing should be conducted right after draft to assure none of the appliances are producing more than 100 ppm in the combustion gases. If any appliance is greater than 100 ppm, it should be repaired as soon as possible.

19. Measure the pressure difference between the mainbody of the house WRT outdoors.

- This will be the effect of all exhaust fans and doors closed on the mainbody of the house.

20. Open the interior doors and re-measure the pressure mainbody WRT outdoors. This will be the effect of all exhaust fans on the whole house.

- If there is a negative pressure difference greater than -3.0 pa during either of these tests and there are combustion appliances, coupled to the interior air of the mainbody then pressure relief is necessary.

NOTE OF CAUTION: The pressure above assumes that the venting of these appliances is sized correctly, terminates properly and that there are no constrictions or venting problems whatsoever. If there are any questionable areas about the venting or combustion air for these appliances then there can be no negative pressure difference mainbody WRT outdoors.

21. Turn off all the exhaust fans, and leave on just the attic powered vent fan(s).

• Measure the pressure difference house WRT outdoors. If there is pressure recorded in the house caused by the attic powered ventilator fan(s) repair is necessary. This may be accomplished by increasing the ventilation area of the attic and air sealing the attic to house interface.

If there is a furnace or gas water heater in the attic and the attic is operating at a negative pressure; attic WRT outdoors; then backdrafting and spillage may be an issue.

If this is the case, these fans should be removed or disconnected. If they can't be removed or disconnected, make sure that the increase in free area from the attic to outdoors is large enough to take the attic WRT outdoors to zero. Caution should be taken to assure that these fans cannot cause this free area to be decreased over time by drawing dirty air through a screen of small mesh. The screen or small mesh acts as a filter and becomes blocked. If birds, bugs or bats getting into the attic is a major issue, disconnecting or removing the fans may be the best measure.

22. Turn off the attic vent fan(s) and turn on the crawlspace vent fan(s).

Repeat the above measurement. House WRT outdoors.

If there is pressure recorded in the house caused by the vent fan(s) then repair is necessary. This can be accomplished by increasing the ventilation area of the crawlspace and sealing the crawlspace to house interface. If there is a furnace or gas water heater in the crawlspace and the crawlspace is operating at a negative pressure relative to outdoors then backdrafting and spillage may be an issue. Every issue discussed with attic power ventilators, applies to crawlspaces.

Even small return duct leaks in the crawlspace that have vented combustion appliances can become hazardous. This is due to the possibility of spillage and backdrafting caused by these fans. The return duct is usually located at the top of the crawlspace and the hot flue gases will rise and collect around the return ducts.

SOLUTIONS TO PRESSURE PROBLEMS

Each driving force can affect the house in the areas of health, safety, durability, comfort, and affordability. Our understanding of how each driving force is dealt with can make all the effects positive rather than negative. All six can be controlled and must be. The following will be a short discussion on each and the methods we can use to control them. ***Weather, house and homeowner all demand that they be taken into consideration when choosing a solution. All solutions don't work in all areas of the nation, nor do they fit every house or homeowner life style.***

WIND

From the 70s' until now we have developed more products for air sealing the leak sites found in houses than there are holes. Wind is not going to stop, so our sealing cannot. We need to get houses even tighter. The cry across the land, and rightly so, has been to insulate right, make them tight and then ventilate them. Primarily wind is dealt with by sealing up the holes. Stop the outside air from getting in. Landscaping to shield the house is also used in many windy areas to reduce the effect of wind on the house.

STACK

Stack, as with wind, is being reckoned with by sealing the holes in the building.

COMBUSTION PROCESS

The combustion process as a driving force, although small, demands attention. Pre-fab fireplaces are installed in many houses across

the nation. Masonry fireplaces have a smaller market share. Combustion air inlets leave much to be desired. Fireplaces, wood stoves, atmospheric drafting gas and oil fired heating appliances installed in housing today, all need air for combustion. Fireplaces need about 200 to 400 CFM, where water heaters and furnaces need much less. The supply for a large portion of their air comes from the house. How might we control this desire for inside air? Another issue is other driving forces competing for their air. Many of the driving forces are competing for the same air. The air in the house is their lust. There is not enough to go around. Backdrafting and spillage may be the result of this competition. A few methods to protect and control the combustion process are listed below.

- Make-up air by fans or by holes in the building where the homeowner understands their use and importance and will not turn off the fans nor will they seal the make-up holes

- Sealed combustion appliances

- Power drafting fans that are designed for use with the combustion appliance, fireplace or wood stove

- Airtight fireplaces and wood stoves

- Relocation or replacement

EXHAUST FANS AND APPLIANCES

For every cubic foot of air that goes out of the house one cubic foot of air must come in. Remember, air is like crooked men, rivers, teenagers and cheap labor, it always seeks the least line of resistance. When exhaust devices draw air out of the house the largest portion of that air comes in through the first largest available holes. Exhaust fans don't care if these hole are vent pipes and chimneys. Dirty or polluted air is just fine by them. Fireplaces, wood stoves and atmospheric appliances are often much weaker than fans. There really isn't any competition so it's an unfair fight. Fireplaces might win over vented water heaters, causing them to spill and backdraft, but they can't win very often against the exhaust equipment of today. Control of exhaust fans and appliances is hard at it's best. Below are a few control methods.

Make-up air by fans and holes in the building

De-rating fans by reducing their flow. (baffles in the duct, reducing flow by eliminating higher fan speeds)

DUCT LEAKAGE BOTH SUPPLY AND RETURN

There are only two approaches to control duct leakage problems. Seal them up if they are a problem. Pressure relief is another approach if they are inside the building and they are causing pressure problems. Problems such as backdrafting, spillage and moisture can be caused by ducts leaking inside the building. Often pressure relief can be used to remove the pressure problem caused by leaking ducts. Undercutting doors, transfer grills and ducts all have worked to let duct leak air out of confined spaces inside the conditioned space of the house.

INTERIOR DOOR CLOSURE

Interior doors and central return systems cause large pressure differences in houses. Removing the doors or installing returns in each room seem to be out of the picture in many houses. Doors are being closed for long periods of time for privacy and to keep pets and small children out of rooms. The air handler fan runs about 40 to 60% of the time in a house that has no major problems. Closing interior doors increases infiltration rates which increases the run time of the air handler fan. The air delivered to the bedrooms is forced out of the house through all the cracks and holes in the bedroom. The return in the mainbody of the house then starves for the lost supply air. The return then enters into "the big" competition for air.

There are several methods used to create a return air path for the delivered room air to get back to the return air inlet. These paths can be designed in advance or retrofitted into any house. Sound transmission should be a consideration when choosing a remedy for pressure related problems. Privacy often is a high priority when dealing with the master bedroom. A list of the most often used pathways follows. (see illustrations attached)

- 1. Pass over transfer ducts can be installed in attics. These ducts should be air tight and insulated right if this option is chosen.

- 2. Pass under transfer ducts can be installed in basements, crawlspaces and tuck-under garage. These ducts should be air tight and insulated when located in vented crawlspaces and tuck-under garages.

- 3. Transfer grille, above doors, should always assure that building air leakage is not increased by penetrations through the walls.

- 4. Walls can be used as a transfer. Never use any portion of the building as a return air path that has venting, piping or wiring in the cavity. Top and bottom plates of the walls should be sealed with a long life seal, such as mastic used to seal ducts.

- 5. Door transfers work well. Sound transfer should be discussed with the homeowner before this option is used.

- 6. Undercutting the door will work in some houses but often it is not enough relief by itself.

- 7. Reducing flow to rooms by installing balancing dampers. Comfort should be of concern when choosing reduction of flow to the room.

- 8. Reducing flow to the house by air handler fan speed. Caution should be taken to assure this is the proper approach and will not hurt the equipment in any way.

- 9. Adding supply(s) in the fireplace wood stove or Combustion Appliance Zone can reduce negative pressures that may cause spillage and back drafting. Caution should be taken to assure adding supply will not cause comfort problems in any other part of the house.

- 10. Transfer duct system that transfers air from more than one room into a junction box and then back to the central return. This system should be airtight and insulated right.

- 11. In some houses removing a door may be acceptable. (ie., basement to house, dining room to main body, etc.)

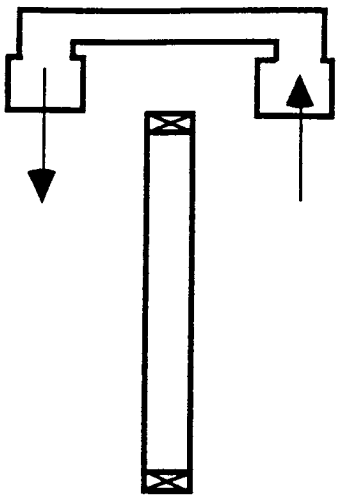
- 12. Adding return(s) to room(s) that have supply delivered may be the approach for many houses. Again, airtight and insulated right.

- 13. Installing make-up air by adding holes in the building or by a fan. This application should be discussed with the home owner to assure that the hole(s) are not sealed or the fan is not turned off. This option has been used in garages but should be used with caution when weather may not permit.

Many of these solutions or a combination of them can be used in most houses.

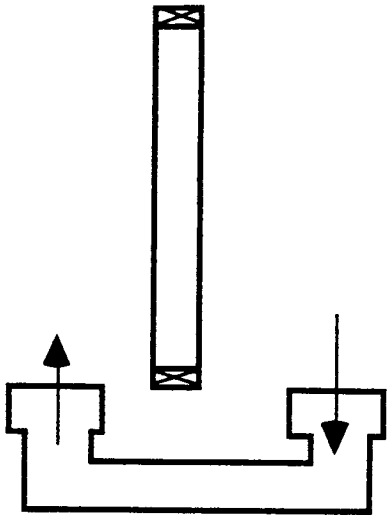
CONCLUSION: Caution should be taken when investigating "MAD-AIR" and pressure balancing a house. This paper is only a guide line and should never be used to replace sound engineering practice or common sense. This paper was intended to be used by experienced diagnostic persons, to test for and reduce the effects of "MAD-AIR." This paper is to be used with a system approach to all testing and repairs that are intended to produce a healthy, safe, durable, comfortable and energy efficient house or building.

1



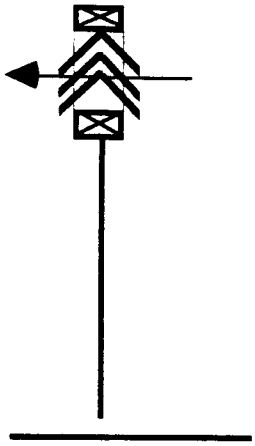
PASS OVER TRANSFER

2



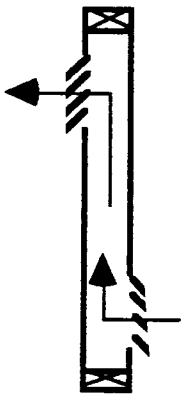
PASS UNDER TRANSFER

3



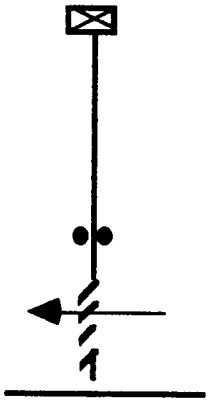
TRANSFER ABOVE DOOR

4



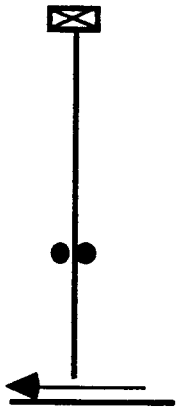
WALL TRANSFER

5



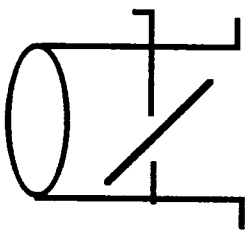
DOOR TRANSFER

6



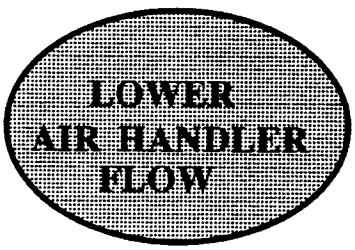
UNDERCUT

7

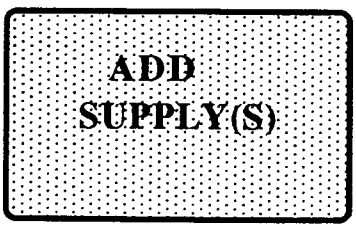


BALANCING DAMPERS

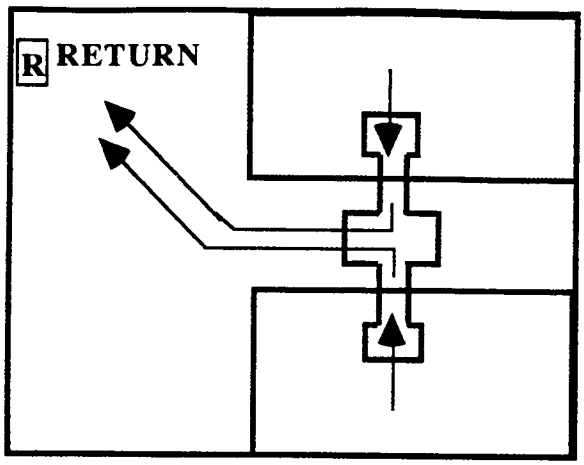
8



9

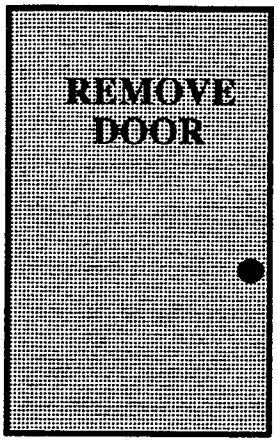


10

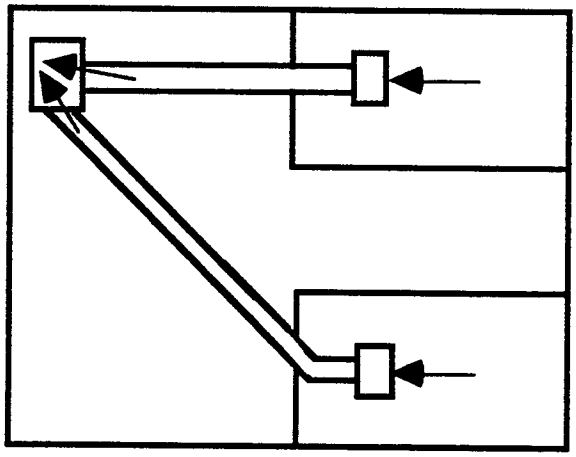


TRANSFER
DUCT SYSTEM

11



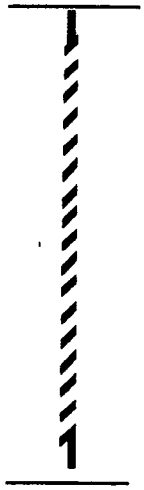
12



ADD RETURN(S)

13

14



Louvred Door

NON-DUCTED METHODS OF RETURN AIR PATHS

SUPPLY DUCT	MIN. AIR PATH AREAS	LOUVERED TRANSFER GRILLES (dimensions in inches, WxH)	
Diam. in In.	**Sq. In.**	**Duct Diam.**	**Stamped Steel**	**Extruded Aluminum**
4	25.1	5.7	6x8, 8x6, 12x4, 14x4, 16x4, 18x3, 20x3	
5	39.3	7.1	12x6, 20x4, 30x3, 10x8	
6	56.6	8.5	6x16, 8x12, 10x10 12x8, 30x4	10x6, 16x4, 8x8, 12x6, 18x4
7	77.0	9.9	6x20, 8x16, 10x12 12x10, 36x4	10x8, 20x4, 14x6 12x8, 16x6, 10x10
8	100.5	11.3	6x25, 8x20, 10x16 12x14, 30x6	18x6, 14x8
9	127.2	12.7	8x25, 10x20, 12x16 14x14, 16x14, 35x6	12x12, 24x6, 18x8, 14x10
10	157.1	14.1	8x36, 10x24, 12x20, 14x8, 16x18, 18x14, 20x14, 24x12, 25x12, 36x8	18x12
12	226.2	17.0	10x36, 12x30, 14x24, 16x24 18x20, 20x18, 24x16, 25x16 30x12, 36x10	24x12, 36x8, 30x10, 20x24 18x18, 24x14, 20x16
14	307.9	19.8	14x36, 16x36, 18x25, 20x24 24x20, 30x16, 36x14	30x12, 20x18
16	402.1	22.6	20x30, 24x25, 30x20, 36x18	

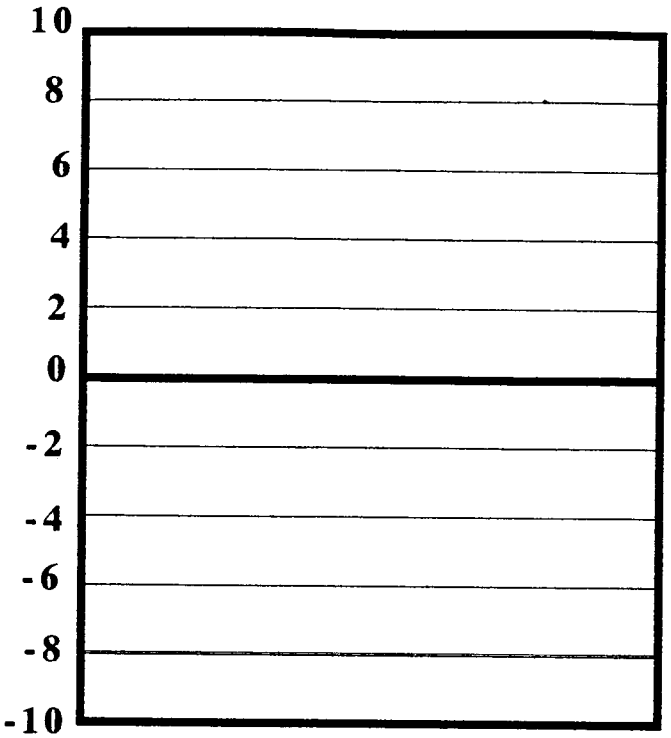
INSTRUCTION FOR USE: Start by identifying the diameter of the supply duct delivering air to a closeable room. This table gives the size of the non-ducted return air path. **EXAMPLE:** If a supply duct is 6" in diameter, the components of a ceiling transfer duct would be the following: The transfer grille could be any of the dimensions, from 6x16 to 30x4, and the diameter of the transfer duct would be 8.5" or greater. A through the wall transfer grille would have the same grille options, but the wall cavity passageway could be just 56.6 sq.in., which is smaller than the overall grille area.

METHODS FOR CONTROLLING
THE EFFECTS OF DRIVING FORCES (PRESSURE)
ON RESIDENTIAL HOUSING

DRIVING FORCE	CONTROLS
1. WIND	• Landscaping • Seal Bldg. Holes • Pressurization
2. STACK	• Seal Bldg. Holes
3. COMBUSTION	• Airtight Doors (FP/WS) • Outside Combustion Air • Sealed Combustion • Power Venting • Relocate/Replace
4. DUCT LEAKAGE	• Seal Bldg/Duct Holes • Pressure Relieve
5. INTERIOR DOOR CLOSURE	• Pass Over Transfer • Pass Under Transfer • Transfer over Door • Through Wall Transfer • Through Door Transfer • Undercut Door(s) • Balancing Damper(s) • Lower Air Handler Flow • Add Supply(s) • Transfer Duct System • Remove Door(s) • Add Return(s) • Add a Hole or Make-up Fan • Louvred Door
6. EXHAUST FANS DRYERS ATTIC/CRAWL FANS CENTRAL VACUUMS COOK TOP FANS	• Make-up Fan • De-Rate Fan (Reduce flow) • Make Hole(s) in Bldg. • Remove/Relocate (Dryer) • Seal Attic/Crawl to House and increase vent area • Power Venting

PREDICTING PRESSURE BALANCING NEEDS

House WRT Outside



▬ **Dominant Duct Leak**

● **Master Bedroom Door Closed**

▭ **All Interior Doors Closed**

○ **Maximum Depressurization**

1. Place a clear plastic sheet over this page.

2. Mark each pressure measured for each of the tests above. (use symbols)

3. Any pressure caused by duct leakage should be brought to zero by repair.

EXAMPLE: Dominant Duct Leak= 2.0
Master Bedroom Door Closed = 0.0
All Interior Doors Closed= -4.0
Maximum Depressurization= -10.0

Move the plastic so that the Dominant Duct Leak (2.0) is located at zero, because that's where you want it after repair. As you can see all pressures got more negative. Master Bedroom Door Closed is now -2.0, All Interior Doors Closed now is -6.0 and Maximum Depressurization is -12.0. This house has never experienced this before you fixed the ducts.

4. Can pressure relieving just the Master bedroom bring the house to an acceptable pressure in the fireplace zone? Move the plastic sheet up until Master Bedroom Door Closed is located at zero, because that's where you want it by pressure relief. Did it bring the pressure into a safe zone? No, All Interior Doors Closed is now -4.0 and Maximum Depressurization is -10.0.

5. Can pressure relieving the rest of the doors make the zonal pressures safe? Move the plastic sheet up until All Interior Door Closed is at zero. Maximum Depressurization is still at -6.0. The exhaust fans will also need to be dealt with to make this house safe.

The pressures will often be much worse than this sheet predicts because the house will get tighter by sealing the ducts. In the example above, we know what needs to be done if the house does not get tighter by duct repair. We know we will have to do the above repairs and pressure relief as a minimum approach. We will also predict further relief will need to be done if the house were to get tighter.

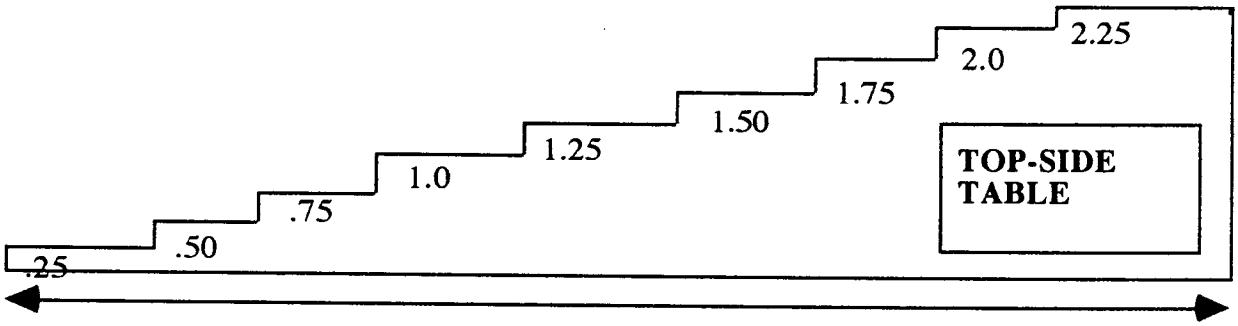
DOOR TEMPLATE CALCULATING FREE AREA OR HOLE SIZE FOR PRESSURE BALANCING AND ZONE LEAKAGE

WHAT IS THE DOOR TEMPLATE USED FOR?

How much should I undercut this door? How large of a transfer grill do I need to put in this room? If I add a crack to a door for calculating zone leakage, how do I figure the hole size added by cracking the door? These types of questions gave birth to the door template. The door template was designed to simplify calculating needed free area for free egress of air from room to room or room to mainbody when pressure balancing a house. It was also developed to calculate the hole size added to crawlspace, attic, garage and room doors for calculating zone leakage.

HOW THE TEMPLATE IS USED

The template is notched starting a 1/4 inch (.25) and increases to 2 1/4 inches (2.25).
Make the template out of wood or lexan and not out of plexiglas, otherwise it will break.



14" long, spread each step evenly over the 14"

There are tables on the left side and back of the template. The **TOP-SIDE** table is used for doors where when cracked open you are not adding any hole to the bottom of the door, (Example: bedroom doors or doors having no threshold). The **TOP-SIDE-BOTTOM** table is used on those that the doors opens to where there is no bottom under the door. (Example: attic doors that open into an attic having no floor, a garage or basement door that opens over a step or a crawlspace door that opens and has no surface under the door once opened, it opens into space. First step, The template is slid between the door an the jam until you reach the desired pressure you are trying to accomplish by adding a hole. Look across the top of the table and fine the width of your door, next, look down the left column under height and find the height of your door, now, look across where the width and height intersect, multiply this number by the notch number for the crack you added to the door.

EXAMPLE: You open the crack in the door to the 1.50 notch, the width of the door is 30" and the height is 6'8" so the intersecting number is 89.5 on the **TOP-SIDE** table. 1.50 x 89.5= 134.25 square inches. If you were going to undercut the door you would need to cut off 5" or add a transfer grille having 134.25 sq.in. of free space. The same process is done for either table used. **DOORS HAVING A SADDLE THRESHOLD ARE NOT COVERED BY THESE TABLES.** The way to use the template on these doors is to use the **TOP-SIDE** table as stated above and add the area of the door bottom that becomes free area once off the threshold.

DOOR TEMPLATE TABLES

DOOR	WIDTH								TOP-SIDE
Height	18"	24"	28"	30"	32"	34"	36"	38"	40"
2'0"	28.5	30.0	31.0	31.5	32.0	32.5	33.0	33.5	34.0
3'0"	40.5	42.0	43.0	43.5	44.0	44.5	45.0	45.5	46.0
4'0"	52.5	54.0	55.0	55.5	56.0	56.6	57.0	57.5	58.0
5'0"	64.5	66.0	67.0	67.5	68.0	68.5	69.0	69.5	70.0
6"0"	76.5	78.0	79.0	79.5	80.0	80.5	81.0	81.5	82.0
6"4"	80.5	82.0	83.0	83.5	84.0	84.5	85.0	85.5	86.0
6'8"	84.5	86.0	87.0	87.5	88.0	88.5	89.0	89.5	90.0
6'10"	86.5	88.0	89.0	89.5	90.0	90.5	91.0	91.5	92.0
7'0"	88.5	90.0	91.0	91.5	92.0	92.5	93.0	93.5	94.0
8"0"	100.5	102.0	103.0	103.5.	104.0	104.5	105.0	105.5	106.0

DOOR	WIDTH						TOP-SIDE-BOTTOM		
Height	18"	24"	28"	30"	32"	34"	36"	38"	40"
2'0"	33.0	36.0	38.0	39.0	40.0	41.0	42.0	43.0	44.0
3'0"	45.0	48.0	50.0	51.0	52.0	53.0	54.0	55.0	56.0
4'0"	57.0	60.0	62.0	63.0	64.0	65.0	66.0	67.0	68.0
5'0"	69.0	72.0	74.0	75.0	76.0	77.0	78.0	79.0	80.0
6'0"	81.0	84.0	86.0	87.0	89.0	90.0	91.0	92.0	93.0
6'4"	85.0	88.0	90.0	91.0	92.0	93.0	94.0	95.0	96.0
6"8"	89.0	92.0	94.0	95.0	96.0	97.0	98.0	99.0	100.0
6'10"	91.0	94.0	96.0	97.0	98.0	99.0	100.0	101.0	102.0
7'0"	93.0	96.0	98.0	99.0	100.0	101.0	102.0	103.0	104.0
8'0"	105.0	108.0	110.0	111.0	112.0	113.0	114.0	115.0	116.0

NATURAL FLORIDA RETROFIT, INC
P.O. BOX 560301, MONTVERDE, FLORIDA 34756-0301
Phone (407) 469-2173 Fax (407) 469-3551

FIREPLACE AND EXHAUST EQUIPMENT OPERATION

HEALTH AND SAFETY WARNING

While testing your house, your fireplace was also tested during our maximum depressurization test. This test was done with all your interior doors closed, heating and air conditioner fan(s) and all the exhaust equipment (e.g.. bath/kitchen vent fans, central vacuum, dryer, cook top fans, etc.) operating. Under these circumstances, the fireplace could have a difficult time drafting. That is, the smoke could be drawn back into the house causing smoke damage and possible injury to your family.

The measured pressure was _____pascals negative.

Very seldom, if ever, would all the interior doors and exhaust fans be on during the same time. However, ***EXTREME CAUTION*** should be taken when using any exhaust equipment and the fireplace at the same time. Our tests indicate that this could result in a hazardous situation. ***NEVER,*** operate the dryer or any other exhaust equipment after going to bed when there is a fire burning (or smoldering) in the fireplace.

It is common practice of many to close bedroom doors at night. If the fireplace has been used during the evening, it is not recommended that your bedroom doors be closed for extended periods of time. The longer the fire is left to smolder, the weaker it becomes in its ability to have all its combustion gases go up the chimney. Carbon monoxide is a deadly gas that is at its highest production during the smoldering stages of a fire. If your doors are to be closed for extended periods, the smoldering fire should be removed from the fireplace.

We offer this notification in hopes of insuring the health, safety and welfare of your family no matter how you operate your home and its appliances.

_____	_____	_____	_____
Technician Signature	Date	Homeowner Signature	Date

NATURAL FLORIDA RETROFIT, INC

P.O. BOX 560301, MONTVERDE, FLORIDA 34756-0301
Phone (407) 469-2173 Fax (407) 469-3551

CONTROLLING AIR QUALITY

You are making a decision to airtighten your home in order to reduce your utility use or increase your comfort - excellent! Maintaining a good indoor air quality should be considered as well.

Airtightening your home either by sealing the shell of the house or by sealing the duct system will result in less outdoor air passing through your home. This reduction of outdoor air flowing through your home will make it necessary that you consider the following actions to help assure a good indoor environment.

1. **Remove all toxic chemicals** or materials from the living space.

2. Increase natural ventilation **when using products** that instruct you to do so as recommended by the manufacture. The simplest and most traditional method is to open **doors and windows** during and after their use.

3. Regular **use of bath and kitchen exhaust fans** to remove excess moisture and orders.

A natural ventilation rate, (outdoor air leaking into and out of your home through such places as cracks around doors, windows, walls, etc.), is taking place in your home right now. This air flow helps to flush out the home and provide some fresh air. This **should never be thought of** as an adequate air change that would enable you to use chemicals that require higher ventilation rates.

The airtightness test done on your house can provide us with an estimated natural ventilation rate. This air flow caused by building air leakage is estimated to be _____ cubic feet per minute (cfm). Our test indicates your home needs _____ cfm to maintain good indoor air quality **when there aren't any high pollutant sources.** After airtightening your home, we estimate that the natural ventilation rate will then be _____ cfm, and if this rate is less than _____ cfm, then an active ventilation strategy may be required to maintain good indoor air quality within your home.

_____	_____	_____	_____
Technician Signature	**Date**	**Homeowner Signature**	**Date**