WHITE PAPER

Residential Exhaust Makeup Air: Explanations and Solutions

Prepared for:

Systemair

10048 Industrial Blvd.

Lenexa, KS 66215

www.systemair.net

Hamid Massali, Engineering Manager

Mark Wald, Product Manager

Prepared by:

ABT Systems, LLC

726 East Maple Street

Annville, PA 17003

www.abtsystems.us

Armin Rudd, Principal

June 24, 2015

[This page left blank]

Contents

List of Figures ..... **iv**
List of Tables ..... **iv**
Definitions ..... **v**
1 Introduction and Background **1**
2 Building Code and Standard Review **1**
2.1 2012 International Residential Code 1
2.2 2015 International Residential Code 2
2.3 ASHRAE Standard 62.2-2013 2
3 House Depressurization in Relation to House Airtightness and Exhaust Air Rate **3**
4 Exhaust Makeup Air Systems **6**
4.1 Passive Makeup Air Supply 6
4.2 Mechanical Makeup Air Supply 6
4.3 Compensating Range Hood 6
4.4 Dedicated Outdoor Air System 7
5 Best Practice Options **7**
5.1 Use of Central Space Conditioning System to Temper Outdoor Air 7
5.2 Conditioning Exhaust Makeup Air 11
5.2.1 Sensing of Exhaust Airflow 11
5.2.2 Electric Resistance Heating of Exhaust Makeup Air 12
5.2.3 Dehumidification of Exhaust Makeup Air 12
6 Conclusions **14**
References **14**

List of Figures

Figure 1. Extent of house depressurization potential due to exhaust airflow; this also shows the amount of makeup air required to balance a measured depressurization 5
Figure 2. Duct sizes required to use passive air inlets for exhaust makeup air 8
Figure 3. Exhaust makeup heating required to achieve 55^oF to 65^oF delivered air temperature for a range of exhaust airflow rates and outside air temperatures 13

List of Tables

Table 1 Tempering of outdoor air with indoor air to keep mixed air temperature above 55^oF 9
Table 2. Summary of responses and literature from furnace manufacturers regarding minimum return air temperature 10
Table 3. Tempering the moisture level of outdoor air by mixing with indoor air 11

Definitions

ACH	air changes per hour
ACH50	air changes per hour at 50 Pascal pressure differential
AHU	Air handler unit
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers (www.ashrae.org)
CFM50	Cubic feet per minute at 50 Pascal test pressure differential
ICC	International Code Council (www.iccsafe.org)
IECC	International Energy Conservation Code
IMC	International Mechanical Code
IRC	International Residential Code
Pa	Pascal; SI unit of pressure (equivalent to one Newton per square meter)
RH	relative humidity

ABT Systems, LLC ‖ 726 E. Maple St. ‖ Annville, PA 17003 ‖ 717.867.0123 ‖ www.abtsystems.us

1 Introduction and Background

Makeup air is outdoor air that is intentionally supplied within a building structure to make up for air that is removed by combustion venting or mechanical exhaust. Combustion venting can be mechanically forced or by natural draft. If combustion venting is by natural draft, it is critical that exhaust makeup air be provided to avoid back-drafting of combustion products. Back-drafting of natural draft combustion appliances can occur with relatively small negative pressures (5 Pa [0.02" w.c.]) within a building enclosure with respect to outdoors. Such negative pressures can be caused by natural stack effect when it is cold outside or by fans that exhaust air from the interior, such as: kitchen range hood, dryer, bath/toilet room fans, and non-direct vent forced draft combustion appliances. Even if there are no natural draft combustion appliances indoors, provision for exhaust makeup air can still be important to avoid other problems. For example, pulling humid outdoor air inwards through the building enclosure where moisture can contact cool surfaces and cause mold and rot; or drawing contaminated air inward from soil beneath the house, or from a garage, crawlspace, attic, or attached dwelling.

Besides the aforementioned building science reasons for providing exhaust makeup air, building codes are now requiring it. Requirements for residential exhaust makeup air are relatively recent, so how to deal with it is new to the homebuilding industry. The first kitchen exhaust makeup air requirements came out in the 2009 International Residential Code (IRC). The 2012 IRC began to put limits on building enclosure air leakage. While limiting building enclosure air leakage is good practice, mechanical exhaust within tighter building enclosures can cause problematic negative pressures, hence, the companion requirements for exhaust makeup air.

This document will review the current code requirements, provide more detailed discussion regarding the impacts of building airtightness and exhaust flow rates on building depressurization, and discuss a number of ways to provide exhaust makeup air along with the pros and cons.

2 Building Code and Standard Review

2.1 2012 International Residential Code

The 2012 IRC (IRC 2012) requires that the building thermal envelope of dwellings be constructed to limit air leakage. It requires testing to meet a requirement of 3 air changes per hour (ACH) or less at 50 Pascal pressure differential (ACH50) in climate zones 3 through 8, and 5 ACH50 or less in climates zones 1 and 2. Related to the house air leakage limit is a requirement for exhaust makeup air when kitchen range hood exhaust is greater than 400 cfm.

> **M1503.3 Kitchen exhaust rates.** Where domestic kitchen cooking *appliances* are equipped with ducted range hoods or down-draft exhaust systems, the fans shall be sized in accordance with Section MI507.4.
> **M1503.4 Makeup air required.** Exhaust hood systems capable of exhausting in excess of 400 cubic feet per minute (0.19 m^3/s) shall be provided with makeup air at a rate approximately equal to the exhaust air rate. Such makeup air systems shall be equipped

with a means of closure and shall be automatically controlled to start and operate simultaneously with the exhaust system.

The IRC Chapter 24, Fuel Gas section also requires makeup air for clothes dryer exhaust exceeding 200 cfm.

> **G2439.4 (614.5) Makeup air.** Installations exhausting more than 200 cfm (0.09 m^3/s) shall be provided with *makeup air*. Where a closet is designed for the installation of a clothes dryer, an opening having an area of not less than 100 square inches (0.0645 m^2) for *makeup air* shall be provided in the closet enclosure, or makeup air shall be provided by other *approved* means.

2.2 2015 International Residential Code

The 2015 IRC (IRC 2015) added additional kitchen exhaust makeup air requirements having to do with air dampers and the location of the supplied exhaust makeup air.

> **M1503.4 Makeup air required.** Exhaust hood systems capable of exhausting in excess of 400 cubic feet per minute (0.19 m^3/s) shall be mechanically or naturally provided with makeup air at a rate approximately equal to the exhaust air rate. Such makeup air systems shall be equipped with not less than one damper. Each damper shall be a gravity damper or an electrically operated damper that automatically opens when the exhaust system operates. Dampers shall be accessible for inspection, service, repair and replacement without removing permanent construction or any other ducts not connected to the damper being inspected, serviced, repaired or replaced.
>
> **M1503.4.1 Location.** Kitchen exhaust makeup air shall be discharged into the same room in which the exhaust system is located or into rooms or *duct systems* that communicate through one or more permanent openings with the room in which such exhaust system is located. Such permanent openings shall have a net cross-sectional area not less than the required area of the makeup air supply openings.

Equipment manufacturers are gearing up to offer new equipment, and the homebuilding industry in general is working to design and install exhaust makeup air systems. At the same time, new code change proposals are being submitted to continue to improve the requirements. One such change proposal for the 2018 IRC code IRC suggests that only the amount of exhaust air above 400 cfm be supplied by the exhaust makeup air system, not the entire exhaust air rate. As will be shown further in this report, at code levels of airtightness, 5 and 3 air changes per hour at 50 Pa pressure differential (ach50) depending on the climate zone, significant building depressurization will occur at exhaust air rates much lower than 400 cfm.

2.3 ASHRAE Standard 62.2-2013

ASHRAE Standard 62.2-2013 (ASHRAE 2013) is a standard written in mandatory language for adoption by building codes, but it is not a building code. Section 6.4 Combustion and Solid-Fuel Burning Appliances of Standard 62.2 requires exhaust makeup air when the two largest exhaust fans in the house exceed 0.15 cfm/ft^2 of floor area in the occupiable space. What that means in comparison to the IRC 400 cfm criteria is that 400 cfm exhaust in a house with less than 2667 ft^2 floor area would have more than 0.15 cfm/ft^2 (400 cfm/0.15 cfm/ft^2=2667 ft^2) and therefore would be required to provide exhaust makeup air where natural draft combustion appliances or solid-fuel (wood) burning appliances are located inside. Standard 62.2 does not require exhaust makeup air for any reason other than for natural draft combustion safety, even though the

Standard does include language for prohibiting or minimizing air transfer from adjoining garages and dwellings. Standard 62.2 does not differentiate between houses with varying degrees of airtightness, although, as shown in Figure 1 that certainly does have a significant impact on depressurization potential.

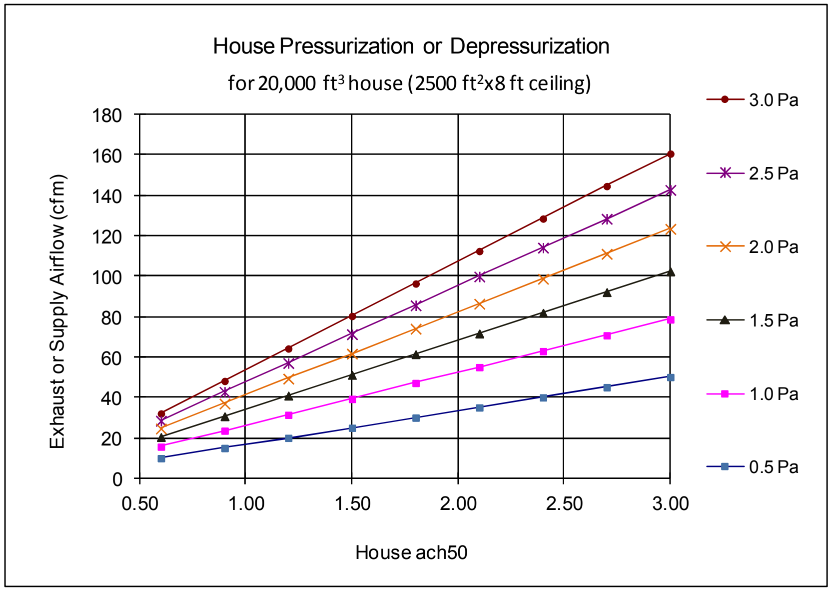
> "Where atmospherically vented combustion appliances or solid-fuel burning appliances are located inside the pressure boundary, the total net exhaust flow of the two largest exhaust fans (not including a summer cooling fan intended to be operated only when windows or other air inlets are open) shall not exceed 15 cfm per 100 ft2 (75 L/s per 100 m2) of occupiable space when in operation at full capacity. If the designed total net flow exceeds this limit, the net exhaust flow must be reduced by reducing the exhaust flow or providing compensating outdoor air. Gravity or barometric dampers in non-powered exhaust makeup air systems shall not be used to provide compensating outdoor air. Atmospherically vented combustion appliances do not include direct-vent appliances."

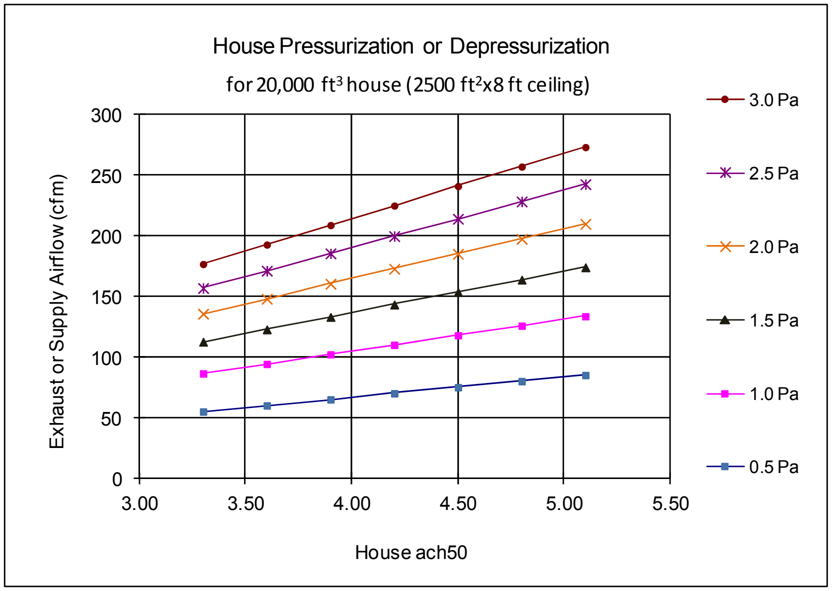
3 House Depressurization in Relation to House Airtightness and Exhaust Air Rate

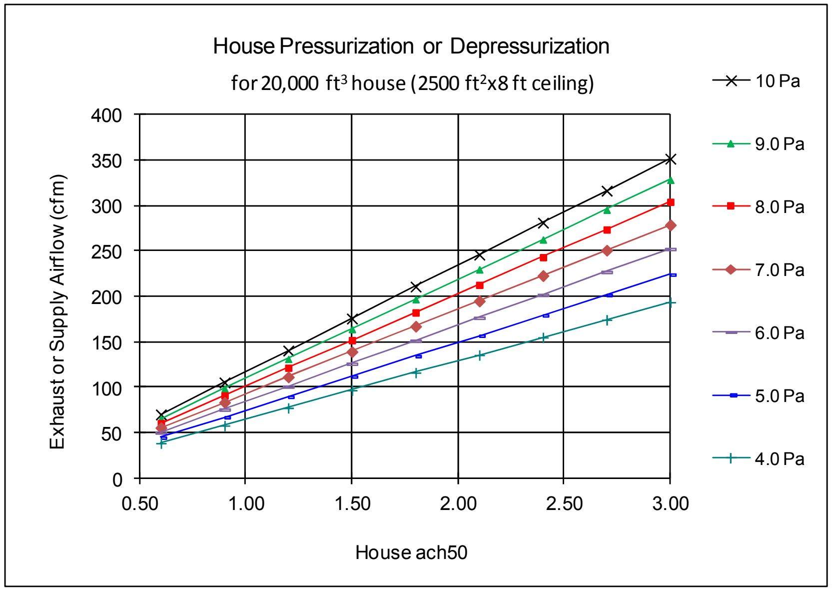
The six charts shown in Figure 1 were created for a typical 2500 ft^2, 8 ft ceiling house. They show the extent of house depressurization potential due to exhaust airflow, and can also be used to find the amount of makeup air required to balance a measured depressurization. For example, referring to the upper-left chart of Figure 1, 160 cfm of exhaust (typical for a dryer) would depressurize a 3 ach50 house about 3 Pa with respect to outdoors, while, referring to the upper-right chart of Figure 1 the same 160 cfm would depressurize a 5 ach50 house only about 1.5 Pa. Referring to the upper-right chart again, 270 cfm exhaust (typical for a dryer plus a 110 cfm master bathroom exhaust fan) would depressurize a 5 ach50 house about 3 Pa.

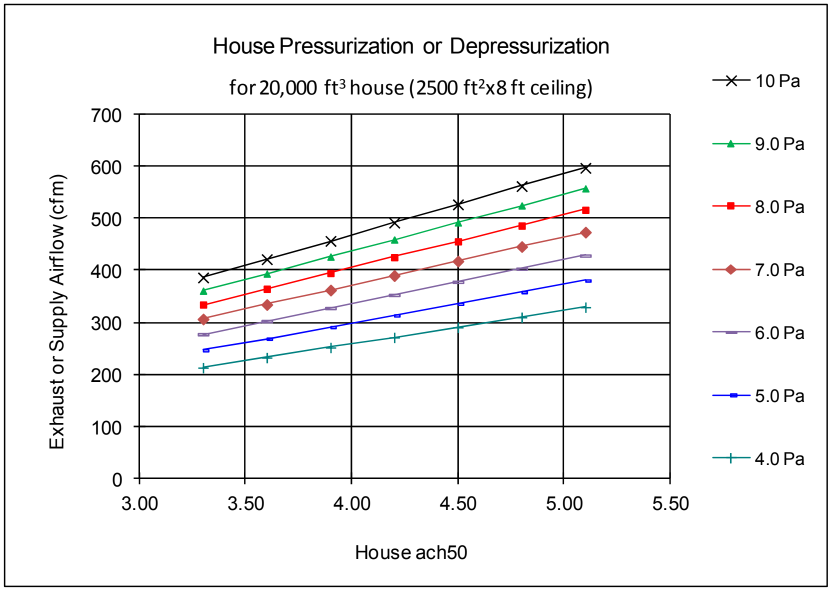
The middle charts of Figure 1 show depressurization between 4 and 10 Pa. Referring to the middle-left chart, a 110 cfm bathroom exhaust fan or kitchen range hood would depressurize a 1.5 ach50 house about 5 Pa, whereas it would take 225 cfm to depressurize a 3 ach50 house to the same 5 Pa. Clearly natural draft appliances should not used in 1.5 to 3 ach50 houses with typical exhaust fan usage without exhaust makeup air. The middle-right chart shows that 375 cfm will depressurize a 5 ach50 house to 5 Pa. This appears to be a basis for the IRC code limit of 400 cfm exhaust before requiring exhaust makeup air, however, the same 375 cfm will depressurize a 3 ach50 house more than 10 Pa.

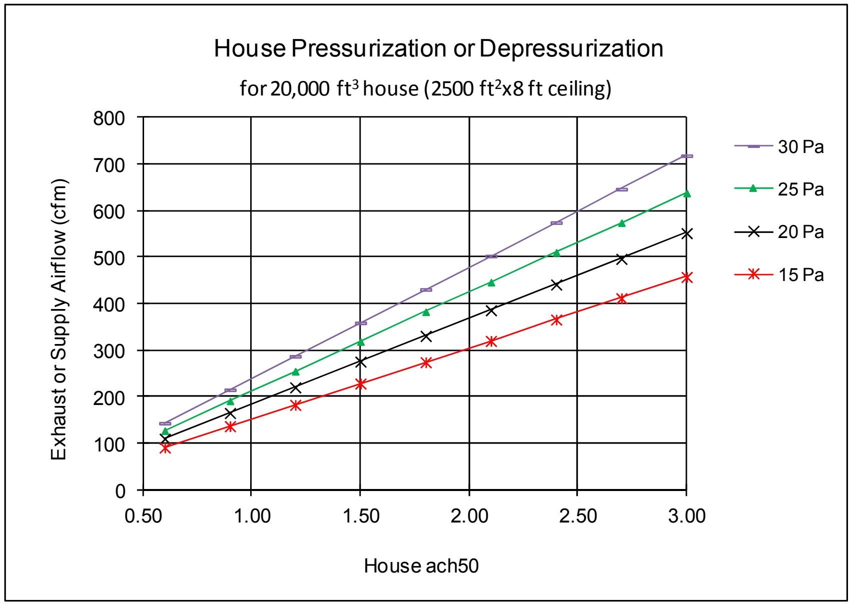
Gourmet kitchens with high airflow range hoods are becoming more common. The lower charts show that a 600 cfm cooktop exhaust would depressurize a 3 ach50 house about 25 Pa, and a 1200 cfm cooktop exhaust would depressurize a 5 ach50 house 30 Pa. Besides moisture and contaminant transfer issues, those pressures could back-draft even forced-draft combustion appliances. Clearly, exhaust makeup air is necessary in those cases. How and where to supply that makeup air without causing comfort problems is a question that will be addressed in following sections.


House Pressurization or Depressurization
for 20,000 ft³ house (2500 ft²x8 ft ceiling)
Exhaust or Supply Airflow (cfm)
House ach50
3.0 Pa
2.5 Pa
2.0 Pa
1.5 Pa
1.0 Pa
0.5 Pa


House Pressurization or Depressurization
for 20,000 ft³ house (2500 ft²x8 ft ceiling)
Exhaust or Supply Airflow (cfm)
House ach50
3.0 Pa
2.5 Pa
2.0 Pa
1.5 Pa
1.0 Pa
0.5 Pa


House Pressurization or Depressurization
for 20,000 ft³ house (2500 ft²x8 ft ceiling)
Exhaust or Supply Airflow (cfm)
House ach50
10 Pa
9.0 Pa
8.0 Pa
7.0 Pa
6.0 Pa
5.0 Pa
4.0 Pa


House Pressurization or Depressurization
for 20,000 ft³ house (2500 ft²x8 ft ceiling)
Exhaust or Supply Airflow (cfm)
House ach50
10 Pa
9.0 Pa
8.0 Pa
7.0 Pa
6.0 Pa
5.0 Pa
4.0 Pa



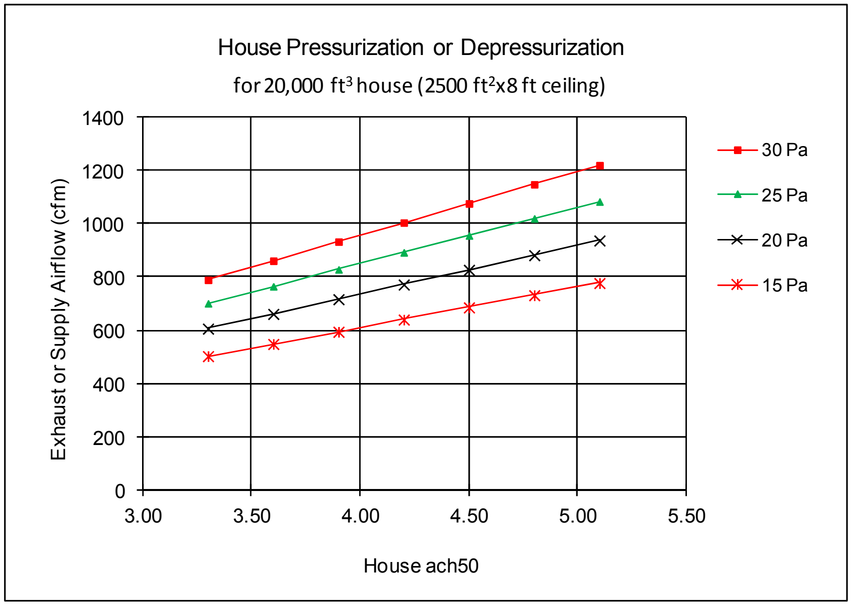


Figure 1. Extent of house depressurization potential due to exhaust airflow; this also shows the amount of makeup air required to balance a measured depressurization

4 Exhaust Makeup Air Systems

There are a number of ways to provide exhaust makeup air, but the residential equipment industry is far from mature in this regard. The following sections give a brief summary and examples of some of these ways.

4.1 Passive Makeup Air Supply

The code allows for passive exhaust makeup air supply as opposed to active mechanical exhaust makeup air supply, but there are limitations to the passive solution which make it mostly unworkable. Figure 2 shows outdoor air duct sizes required with a passive makeup air system to limit house depressurization to below the natural draft combustion safety level of 3 to 5 Pa. While large intake or exhaust grilles are not unusual on commercial buildings, the required duct size for airflow above about 150 cfm in a passive makeup air system goes beyond the maximum 8- to 10-inch diameter sizes seen on homes. Even if interior depressurization was allowed to go up to forced-draft combustion safety limits of about 25 Pa, passive makeup air duct sizes go above 10 inch for airflow above 400 cfm.

4.2 Mechanical Makeup Air Supply

Mechanical makeup air supply is fan-forced. Providing exhaust makeup air through mechanical means has many advantages. It allows the opening to outdoors to be much smaller and allows the air to be tempered via mixing with indoor air, or actively heated, cooled, dehumidified, and filtered. Depending on the design decisions and extent of conditioning, the exhaust makeup air can be delivered directly to the space in which the exhaust fan is located, or it can be delivered to the central space conditioning air distribution ducts to be further tempered and delivered with operation of the central air handler unit (AHU).

As with ducts sizes for passive makeup air supply, there are practical limits to tempering outdoor air by mixing it with indoor air. Table 1 shows that, with an indoor temperature of 70^{o}F a mixing ratio of 1 part inside air and 1 part outside air only works down to an outside air temperature of 40^{o}F to stay above 55^{o}F delivered temperature. To stay above 55^{o}F delivered temperature when it is 10^{o}F outside would require a 4:1 mixing ratio. That means that the outside air fraction can only be 20% and the fan must be five times larger than what would be required to deliver just the outside air. Of course ducting complications, first cost, and operating cost are directly related to that increased airflow.

The foregoing has shown that the passive and mechanical air mixing means of providing exhaust makeup air have significant short-comings and are really not practical beyond 100 to 200 cfm.

4.3 Compensating Range Hood

The most ideal approach from both an energy and comfort perspective is to provide the exhaust makeup air within the exhaust hood itself as much as possible. That type of system is referred to as a compensating range hood. These are commonly available for commercial type kitchens, but are mostly not intended for price competiveness and aesthetic requirements of residential applications. Compensating range hoods supply outdoor air within the range hood design. The design is such that the supplied outdoor air picks up cooking contaminants as it flows into and out of the cooking contaminant plume. The outdoor air volume flow rate is typically designed to be about 80% to 90% of the exhaust air volume flow rate in order to maintain a slight negative pressure at the exhaust device. That leaves only 10% to 20% of the total exhaust airflow rate to be made up by another exhaust makeup air strategy.

Commercial kitchen range hoods have specific requirements that do not exist in residential codes, such as for handling of grease, cooktop temperature, broiler use, side and front hood overhang dimensions relative to the cooking surface, and clearance dimensions. Typical commercial range hoods meeting code will extend at least six inches past the sides of the cooktop and between one and two feet in front of the cooktop. This makes the range hood very large and bulky compared to most residential range hoods. Some companies are willing to customize the compensating range hood design to make them more acceptable and appealing in residential environments. Where such a solution is feasible it should be considered.

4.4 Dedicated Outdoor Air System

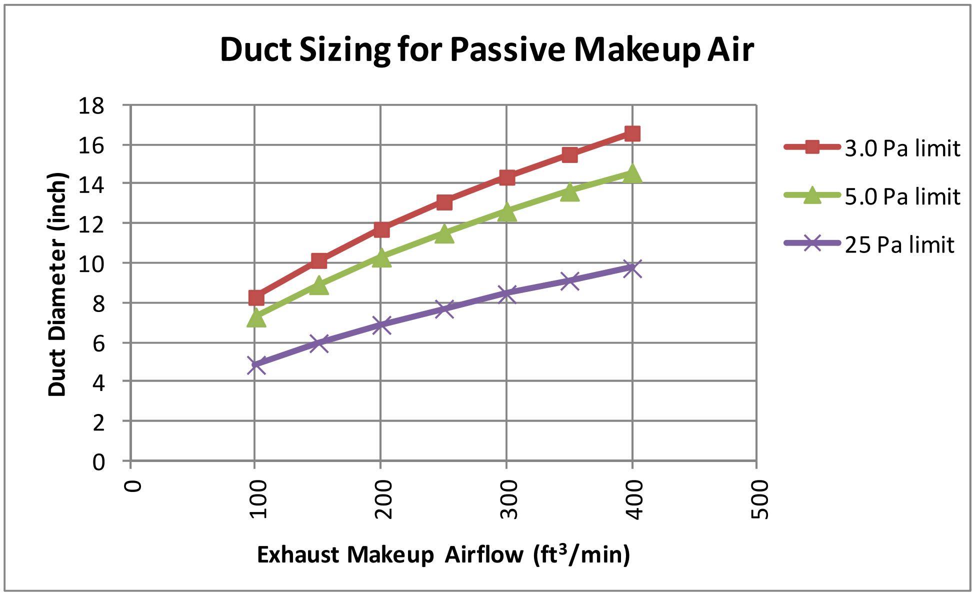
Dedicated Outdoor Air Systems (DOAS) are common in commercial and industrial buildings where large amounts of exhaust air must be replaced with conditioned outdoor air. DOAS systems have all the capability needed to monitor the conditions of incoming outdoor air and condition that air to specific design conditions, including room neutral conditions which would be ideal in most residential situations. The problem applying them in residential applications is that they are expensive and large, and are often only available in much larger capacity than needed. Manufacturers generally design purpose-built DOAS systems to a specific airflow, and may stage multiple DOAS units to adjust for varying exhaust airflow rather than vary a specific DOAS unit airflow. Compared to commercial building systems, residential exhaust makeup air requirements are relatively small, and used more intermittently, often from less than 400 cfm to 1200 cfm depending on the range hood fan setting and the operation of other exhausts such as a dryer or bathroom exhaust fan.

5 Best Practice Options

Utilization of compensating range hoods and DOAS equipment would be ideal, but is largely impractical due to the relative cost and unavailability of residentially-oriented models. Mechanical, fan-forced makeup air supply is a practical and effective solution, especially for 400 cfm and greater air flow requirements, since the supply air can be filtered and actively conditioned before being delivered by ducts to the space from where the exhaust is removed.

5.1 Use of Central Space Conditioning System to Temper Outdoor Air

When high tempering ratios are needed, it becomes obvious to try to use the central space conditioning system and its inherent high recirculation airflow rate to accomplish this. Referring once again to Table 1, an outdoor air fraction of 14% will keep the mixed air temperature above 55°F down to -30°F outdoors. In order to keep furnace heat exchangers from corroding due to condensation of gas combustion moisture, 55°F is a limit set for mixed air return temperature by most gas furnace manufactures. A summary of that is shown in Table 2. However, there are also limitations to using the central space condition system to temper outside air. For example, 14% outdoor air fraction is only 280 cfm for a 5-ton cooling system. Obviously, active conditioning will be necessary for 400 cfm of exhaust makeup air.



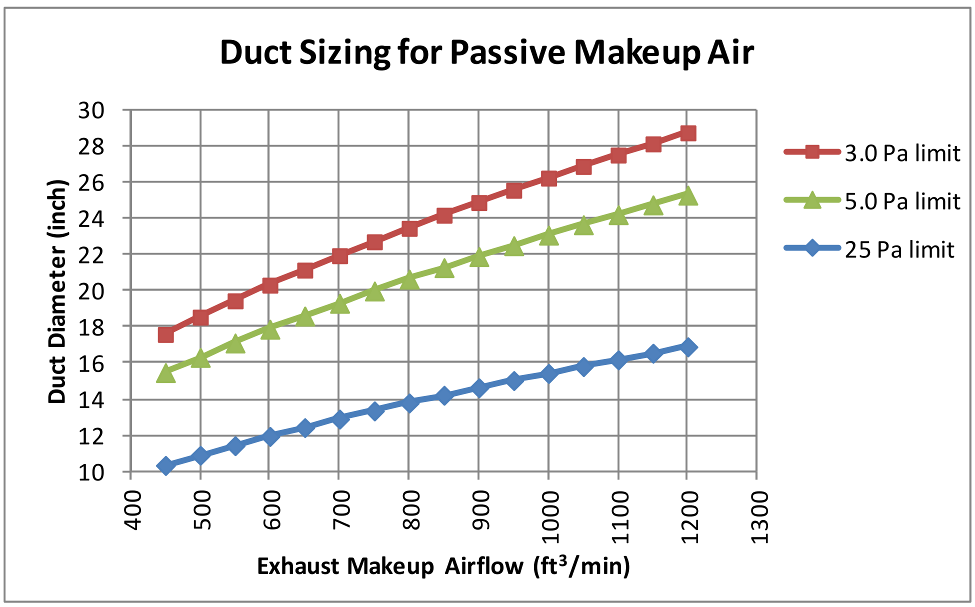


Figure 2. Duct sizes required to use passive air inlets for exhaust makeup air

Table 1 Tempering of outdoor air with indoor air to keep mixed air temperature above 55°F

Indoor setpoint temperature:			70	F				
	Mixed Air Dry-bulb Temperature (F)							
	At listed tempering ratio of inside air to outside air							
Outside Air Drybulb Temp (F)	6.00	5.00	4.00	3.00	2.50	2.00	1.50	1.00
	At listed outside air fraction							
	0.14	0.17	0.20	0.25	0.29	0.33	0.40	0.50
55	68	68	67	66	66	65	64	63
50	67	67	66	65	64	63	62	60
45	66	66	65	64	63	62	60	58
40	66	65	64	63	61	60	58	55
35	65	64	63	61	60	58		
30	64	63	62	60	59			
25	64	63	61	59				
20	63	62	60	58				
15	62	61	59					
10	61	60	58					
5	61	59						
0	60	58						
-5	59	58						
-10	59							
-15	58							
-20	57							
-25	56							
-30	56							

A similar mixed air explanation can be made related to moisture in outdoor air. When outdoor air is humid, mixing it with drier indoor air can reduce the discomfort level. However, a more important impact to understand is avoidance of condensation in cool ducts. If humid exhaust makeup air is injected into the central space conditioning system ducts without the central fan operating, there is a high risk of condensation in those ducts after the end a cooling cycle. This is illustrated in Table 3. 75°F and 50% relative humidity (RH) inside equates to a 55°F dew-point temperature. Since cooled air leaves the cooling coil near saturated conditions, 55°F is also a typical temperature of supply ducts after a cooling operation ends. If outdoor air with a dew-point temperature above 55°F continues to be introduced into those ducts, condensation will occur and lead to fungi growth in the ducts. Across the humid south and southeast, outdoor dew-point temperatures of 75-78°F are typical day and night in summer, and higher after daytime rainfall. Table 3 values show that high mixing ratios of at least 6 parts inside air to 1 part outside air are needed to reduce the risk of condensation in cooling ducts. The ducts will eventually warm up, however, how long it takes for that to happen is a rather unpredictable part of the risk assessment depending on where the ducts are located and the time-varying heat gain they experience.

Table 2. Summary of responses and literature from furnace manufacturers regarding minimum return air temperature

	Minimum return air temperature (°F) (during heating)			
Manufacturer	Any operation	Intermittent operation	Continuous operation	Other brands included
American Standard	55			Trane
Carrier		55	60	Bryant
ICP		55		Tempstar, Heil, Comfortmaker, Arcoaire, KeepRite
Johnson Controls	55			York, Coleman
Lennox		55	60	
Nordyne	50			Westinghouse, Tappan, Kelvinator, Grandaire, Frigidaire, Philco, Gibson, Intertherm, Miller, Maytag
Rheem	55			

Because central residential space conditioning equipment is not designed for handling large percentages of outdoor air, adverse effects should be expected for outdoor air flow rates greater than 200 cfm mixed via the central space conditioning system. Therefore, the use of the central space conditioning system equipment to temper supply air is not practical for residential exhaust makeup air flow rates greater than 200 cfm.

Table 3. Tempering the moisture level of outdoor air by mixing with indoor air

Parts inside air:	1.0	2.0	3.0	6.0	9.0
Parts outside air:	1.0	1.0	1.0	1.0	1.0
OA fraction:	0.50	0.33	0.25	0.14	0.10
	Mixed Air Dew-point Temperature (F)				
Outside	**At Indoor Dew-point Temperature**				
Dew-point	(75F/50%)	(75F/50%)	(75F/50%)	(75F/50%)	(75F/50%)
(F)	**55**	**55**	**55**	**55**	**55**
80	68	63	61	59	58
79	67	63	61	58	57
78	67	63	61	58	57
77	66	62	61	58	57
76	66	62	60	58	57
75	65	62	60	58	57
74	65	61	60	58	57
73	64	61	60	58	57
72	64	61	59	57	57
71	63	60	59	57	57
70	63	60	59	57	57
69	62	60	59	57	56
68	62	59	58	57	56
67	61	59	58	57	56
66	61	59	58	57	56
65	60	58	58	56	56

5.2 Conditioning Exhaust Makeup Air

When the exhaust makeup airflow rate is higher than 100 to 200 cfm, or when outdoor weather conditions are on the extreme cold or hot-humid side, the best practice is mechanically conditioning outdoor air close to room air conditions. In this ideal case, outdoor air can be delivered almost anywhere without comfort or condensation concern.

For most intermittent exhaust makeup air requirements in residential applications, the most practical and effective equipment would include a modulating electric resistance heater inline with a dehumidifier that senses incoming humidity to remove moisture. The heater should bring the air dry-bulb temperature up to a minimum of 55^{o}F and the dehumidifier should reduce the air dew-point temperature to a maximum of 55^{o}F.

5.2.1 Sensing of Exhaust Airflow

There are a number of ways to sense and signal when there is exhaust air that need to be made up. A common way is to use a current sensor that closes a switch when the electrical current passing through the sensor exceeds a given threshold. Similar on/off-type controls include an airflow “sail” switch in the airstream or a pressure switch that detect when the exhaust fan turns on and close a switch sending an electrical signal to turn on the makeup air fan.

However, single-speed on/off-type control is coarse because it does not take into consideration different levels of exhaust airflow. Better performing systems can track just how much exhaust makeup air is needed to balance the actual exhaust airflow. For example, a more sophisticated system can employ a current transducer rather than a current switch. The current transducer can help the system infer the exhaust airflow rate by sending a signal proportional to the current being drawn by the exhaust fan rather than just closing a switch when given current threshold is passed. Equipment that is designed to interpret the proportional signal and provide a proportional response will perform better because it will not deliver more makeup air than necessary.

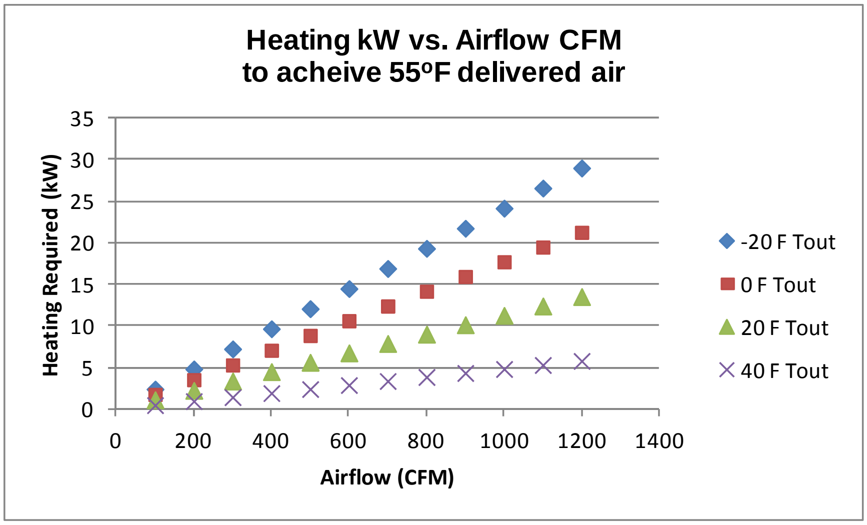
Controlling the makeup airflow rate by sensing and responding in real-time to house pressure with respect to outdoors gets to the real heart of the issue and is the most sophisticated and highest performing. Because of the greater expense, this type of system can be found in commercial buildings but is rare in residential applications.

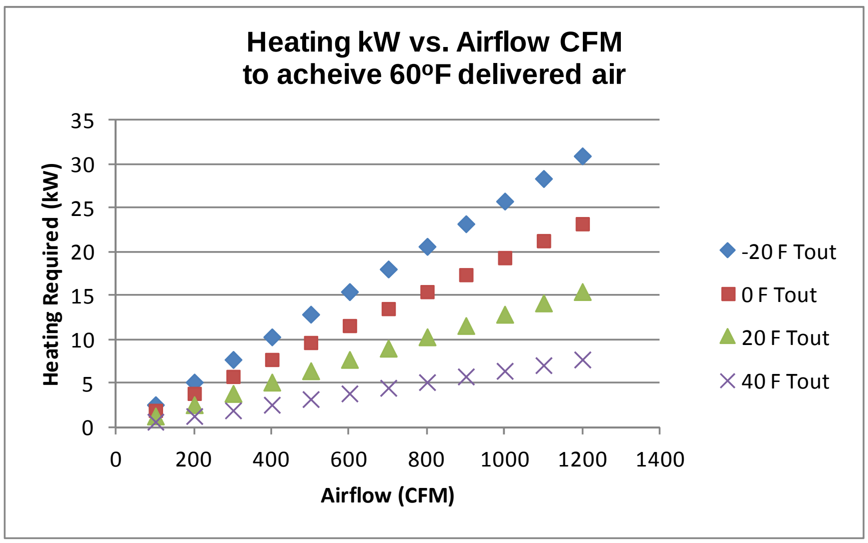
5.2.2 Electric Resistance Heating of Exhaust Makeup Air

Electric resistance heat is relative easy and inexpensive to control compared to other heating methods such as hot water. The amount of electric resistance heat can be staged by relays, or power can be "pulsed" by rapid cycling of solid-state power relays to provide a desired supply air temperature. The charts in Figure 3 show how much exhaust makeup heating is required to achieve a 55-65^{o}F delivered air temperature for a range of exhaust airflow rates and outside air temperatures. Referring to the top chart in Figure 3, to deliver 400 cfm of 55^{o}F air when it is 20^{o}F outdoors requires about 5 kW of electric resistance heat. To deliver 1,150 cfm of 55^{o}F air when it is 0^{o}F outdoors requires about 20 kW of electric resistance heat.

5.2.3 Dehumidification of Exhaust Makeup Air

Residential scale dehumidifiers are available in the 200-500 cfm range that will automatically sense the incoming air dew-point temperature and turn on the dehumidifier compressor to remove moisture. Such a dehumidifier installed inline after the electric resistance heater should be installed in humid climates. The dehumidifier outlet air can be 10 to 30^{o}F warmer than the incoming air due to the added heat of condensation and the compressor and fan heat. Therefore, care should be taken to deliver the air in such a way that it will not cause discomfort. Injecting the air into the central system supply plenum and interlocking the central system fan with the dehumidifier fan can work well. This strategy complies with the 2015 IRC location requirement as long as there is sufficient airflow from the central system to the room where the exhaust fan is located. Since the exhaust fan of concern is usually a range hood, and the kitchen is connected to the main common area, this is usually not an issue. As ideal as an in-line dehumidifier may be, currently available equipment can handle air flow rates up to only about 500 cfm. Residential exhaust makeup air flow rates are commonly much greater than 500 cfm. Residential range hoods are typically used very intermittently, though, and the temporary increase in space temperature and humidity can be corrected by the central cooling system after the range hood exhaust is de-energized.





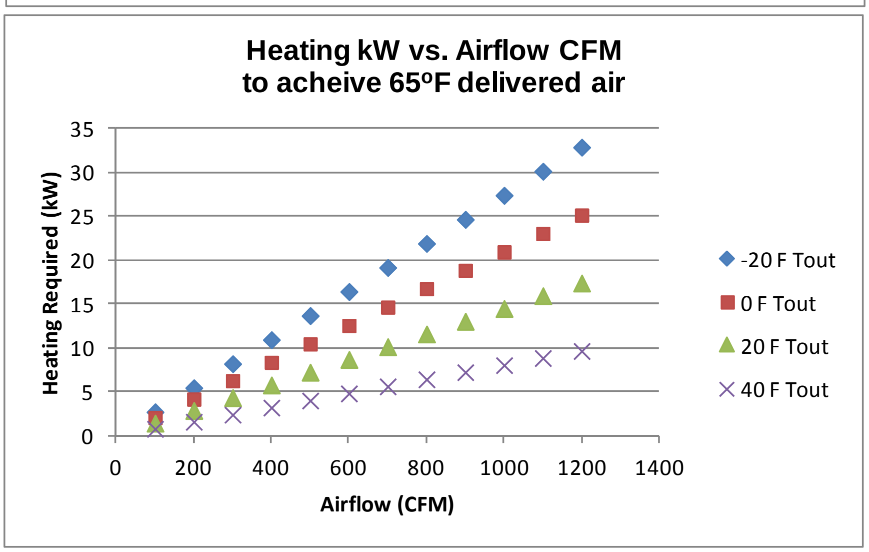


Figure 3. Exhaust makeup heating required to achieve 55°F to 65°F delivered air temperature for a range of exhaust airflow rates and outside air temperatures

6 Conclusions

Residential scale exhaust makeup air systems are becoming more prevalent due to new code requirements and to avoid depressurization concerns in homes. The International Residential Code requires exhaust makeup air when kitchen range hood exhaust is greater than 400 cfm. For the tightness of construction that is common for many of today's homes, significant building depressurization will occur at exhaust air rates much lower than 400 cfm when not properly compensated by makeup air. Even a 5 Pa (0.02 in. w.c.) depressurization can lead to back-drafting of appliance vent systems and other adverse effects. As little as 600 cfm exhaust would depressurize a 3 ach50 house about 25 Pa, and a 1200 cfm cooktop exhaust would depressurize a 5 ach50 house about 30 Pa. Moisture and contaminant transfer issues aside, those pressures could back-draft even forced-draft combustion appliances. Clearly, exhaust makeup air is necessary to compensate larger exhaust systems in today's tighter homes.

The code allows for passive exhaust makeup air supply as opposed to active mechanical exhaust makeup air supply, but exhaust makeup air delivered by passive or mechanical mixing systems have limitations that make them mostly impractical or ineffective beyond 100-200 cfm. Compensating range hoods combined with a small amount of exhaust makeup air, or DOAS equipment, although functionally ideal systems, are costly large commercial products that are generally out of range for most residential applications.

Mechanically fan-forced, filtered, conditioned and proportionally-controlled makeup air to balance the rate of exhaust is a practical and effective solution for residential exhaust makeup air. Proportional control of the makeup air fan to provide just the right amount of makeup air to balance the exhaust air, eliminating depressurization, is superior to single-speed on/off control of the makeup air fan. The makeup air must be ducted and supplied to a location that has sufficient free-air connection to where the exhaust air is removed. Conditioning the exhaust makeup air by proportionally controlled electric heating in cold weather, and by dehumidification in humid weather where such equipment is available to handle the required system air flow rate and associated conditioning capacities, is recommended.

References

2012 International Residential Code®, International Code Council, Inc., Country Club Hills, IL. First Printing: May 2011, Second Printing: February 2012, ISBN: 978-1-60983-042-7 (soft-cover edition), ISBN: 978-1-60983-041-0 (loose-leaf edition).

2015 International Residential Code®, International Code Council, Inc., Country Club Hills, IL. First Printing: May 2014. ISBN: 978-1-60983-470-8 (soft-cover edition), ISBN: 978-1-60983-469-2 (loose-leaf edition).

ANSI/ASHRAE Standard 62.2-2013. Atlanta, GA. ISSN 1041-2336