Assessment of Pressure, Indoor Humidity, and Energy Impacts of Kitchen Ventilation Systems on Florida Homes

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Research Questions:

What are the potential pressures induced indoors with reference to outdoors by kitchen exhaust systems with and without kitchen make-up air?

What is the impact on indoor humidity, pressure, and energy consumption in Florida homes with an air tightness of at least 5 ACH50 resulting from high capacity kitchen exhaust and powered make-up air systems (*ACH50 is described below.*)

Code Relevance:

There is particular concern that the Florida Building Code does not adequately address the potential for increased indoor air environmental problems associated with unbalanced exhaust air in tightly constructed homes. It is not the intent of this project to result in encouraging low kitchen exhaust flows that would be ineffective at capturing and removing cooking effluent, but rather provide adequate make-up air. It is expected that kitchen exhaust flow rates should continue to be determined as appropriate by Code and engineers for effective capture for each specific application.

A modification to the current mechanical code may be warranted. The current mechanical code permits high kitchen exhaust air flow rates up to 799 cfm before pressure relief is required if there are no gas combustion appliances in the home. If there are gas combustion appliances, then make-up air is required when kitchen exhaust exceeds 399 cfm. While kitchen exhaust fans typically have limited operation on a daily basis, they move a lot of air from the home very quickly. Little is known about resulting indoor humidity and building pressures from kitchen exhaust system operation. Current code does not adequately account for house tightness and can result in poor cooking effluent capture (resulting in poor IAQ) and extreme depressurization in very tight homes with kitchen exhaust systems of 100 cfm or greater.

Figure 1 below shows that very high indoor pressures are possible in very tight homes. The red arrows point out that house depressurization of 120 Pa (0.48 In WC) could result with an airflow of 790 cfm. This airflow amount is low enough such that code would not require make-up air. The orange arrows point out that house depressurization of 390 cfm could result in about 35 Pa (0.14 In WC) without make-up air. An airflow of 390 cfm is low enough that the current code does not require make-up air.

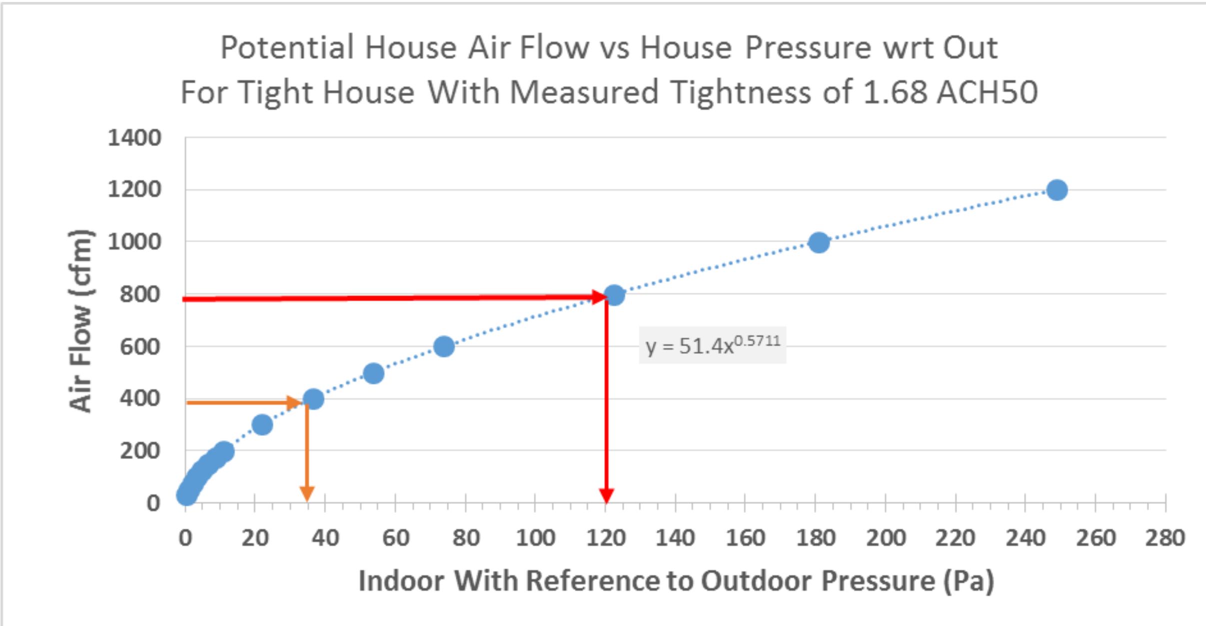

Figure 1 Air flow versus pressure for a tight home shows that 248 Pa (0.99 In WC) can result from an exhaust fan capable of moving 1200 cfm.

Defining the Problem:

Recent versions of the Florida Building Code have addressed the most significant building envelope and HVAC issues that contributed to higher energy use and indoor humidity (such as building air leakage, duct leakage and proper AC equipment sizing). The unintended consequences of these energy conservation measures have brought about a need to address IAQ in more tightly constructed buildings. In Florida, natural air infiltration has declined dramatically in recent decades. House tightness is measured using a blower door test assembly and is quantified as air changes per hour at 50 pascals of pressure or ACH50. Typical new homes have declined in air leakage from approximately 20 ACH50 in the 1950s to about 6 ACH50 in recent years. The new Florida 5th Edition (2014) Code will require that newly constructed houses be tested for envelope air leakage, not permitting leakage in excess of 5 ACH.

Tight homes with high flow kitchen exhaust fans without adequate make-up air are more likely to result in poor indoor air quality than those with adequate make-up air. This is due to lack of available pathways for outdoor air to be pulled into the home that will create greater home depressurization and static pressure for the fan to pull against resulting in lower air flow than intended. Diminished exhaust flow can result in poor cooking effluent capture and poorer IAQ. Field study has documented a tight home under 2 ACH50 (houses tightness curve shown in Figure 1) that was depressurized to -42.9 Pa from solely operating the kitchen exhaust. The homeowner indicated that the kitchen exhaust did not adequately remove smoke during high temperature stir-fry cooking activities.

There is also particular concern in cases where homes have high capacity kitchen exhaust rates on the order of 400-1200 cfm. High capacity kitchen exhaust systems can be very effective at removing unwanted cooking heat, steam, odors and particulates. However, significant house depressurization may diminish the exhaust fan flow rates and potentially diminish capture effectiveness as is likely the case of the previously mentioned stir-fry cooking capture problems. High capacity kitchen exhaust systems and substantial runtime of other mechanical exhaust systems will result in depressurization of the home which increases infiltration rates, increased potential for higher indoor RH, greater potential for moisture damage, increased space conditioning energy use, and increased potential of transported pollutants into the conditioned space from outside (such as radon, various particulates, and volatile airborne compounds from attached garages). With an increased emphasis on tighter homes, exhaust ventilation rates will also result in greater negative pressure differentials that may potentially be large enough to limit combustion gases from drafting effectively to outdoors.

There is a need, therefore, to identify methods of improved humidity control in homes to prevent moisture-related occupant health problems as well as preservation of building materials. It is of course also essential that humidity control be achieved in ways that are energy-efficient and cost-effective.

Scope of Work:

A literature review will be completed that will seek information on residential kitchen exhaust and make-up air systems including: available range of exhaust flow rates at the maximum hood setting, fan efficacy (cfm/watt), and costs of equipment. Information on the frequency and elapsed time of use of kitchen exhaust fans will also be sought after in existing published work.

Measured impacts on indoor RH and energy will be completed in a building that is at least 5 ACH50 or tighter as measured by blower door tightness test method. Measurements of indoor RH, indoor main body pressure with reference to outdoor, and energy consumption will be made under the proposed test configurations shown in Table 1 below. Table 1 shows the proposed testing configurations at three different exhaust flows and location of make-up air termination. Fan powered make-up air will be tested in two different supply locations. One make-up location will be at the kitchen exhaust hood with complete capture and no make-up air spillage into the room. The second make-up location will be into the main body living area away from the kitchen exhaust. The make-up air flow will be adequate to minimize indoor depressurization with reference to outdoors to no more negative than -5 Pa when the kitchen exhaust is operating.

Table 1. Proposed Kitchen Exhaust Test Configurations

Test Configurations			
Test #	Exhaust cfm	Make-up capture at exhaust hood	Make-up to main body (no kitchen hood capture)
1	400	Yes	No
2	400	No	Yes
3	800	Yes	No
4	800	No	Yes
5	1200	Yes	No
6	1200	No	Yes

Assuming a contract start by late summer, work will first begin on literature review and installation of kitchen ventilation equipment, meters, sensors, and datalogger set up. Testing will be rotated on a schedule of 5-10 days each, depending upon weather, throughout a period of about six to seven months. This will allow an evaluation of impacts under different weather conditions.

In addition to the test configurations in Table 1, the following short-term testing and analysis will be completed:

- Determine impacts of no make-up air upon the indoor pressure and kitchen exhaust flow rates.
    - Simulated analysis matrix will be performed to evaluate the flow versus house pressure characteristics for kitchen exhaust flow ranging from 100 cfm- 1200 cfm in houses with ACH50 ranging from 1 ACH50 to 7 ACH50.
    - The impact of static pressure impact upon kitchen exhaust flow rates will also be evaluated to the extent possible based upon available data.
- Determine duct size of passive, non-powered, make-up air vent required to minimize indoor depressurization with reference to outdoors to no more negative than -5 Pa when the kitchen exhaust is operating.

Expected Outcome and Impact on the Code:

Building codes and various national programs are requiring specific levels of building tightness and mechanical ventilation. It is expected that ventilation rates in new Florida homes will increase and that the indoor RH is likely to increase. It also expected that new homes will become tighter and more likely to become negatively impacted by unbalanced exhaust flows.

The data collected from the proposed experiments will be examined to characterize the impact of likely test cases. The results will help inform the code making body towards consideration of requiring pressure relief of kitchen exhaust systems at lower flow rates than the Code currently requires. The research will also provide information that will help form estimates of installation and operational costs of implementing different passive and powered make-up air designs.

A final report will be prepared that explains the purpose, methods, and results of the research. The final report will include impacts of test cases upon indoor humidity and energy use. The report will also provide guidance on kitchen make-up air design and any justifiable recommendations towards code changes addressing when and how much make-up air should be required in homes. As a result of this research, Florida Code may be improved to take into account cost-effective and energy-efficient building practices that maintain safe building pressure and airflow balance across the envelope.

Budget:

Budget total is $40,128 and covers all costs for labor, test materials, and overhead.

PROPOSAL TITLE: Assessment of Indoor Humidity, Pressure and Energy Impacts of Kitchen Exhaust Ventilation In Homes

Period of Performance: 09/01/15 TO 05/31/16

ver.101614

LABOR COST	FB Rate	BASE HOURLY RATE	HOURS	SALARY & WAGES	FRINGE BENEFITS	TOTAL COSTS	FSEC Cost Share	Agency Funding Requested
Program Manager/Professor	Fac/Staff	$72.70	8	$582	$166	$748	$0	$748
Sr. Research Engr-Scientist/Ass't Prof.	Fac/Staff	$41.08	403	$16,555	$4,735	$21,290	$0	$21,290
Research Engr-Scientist	Fac/Staff	$35.28	257	$9,067	$2,593	$11,660	$0	$11,660
Subtotal Labor Costs:				**$26,204**	**$7,494**	**$33,698**	**$0**	**$33,698**
TRAVEL								
Travel (out of state)						$0	$0	$0
Travel (in-state)						$452	$0	$452
Travel (foreign)						$0	$0	$0
					Subtotal Travel:	**$452**	**$0**	**$452**
OTHER EXPENSE:								
Materials & Supplies (specify below)						$1,362	$0	$1,362
Printing/photocopying of project reports and related delilverable documents & materials						$0	$0	$0
Overnight mail & postage for project reports and related deliverable docs & materials						$0	$0	$0
Computer Charges (monitoring, database mgmt.)						$968	$0	$968
					Subtotal Other Expense:	**$2,329**	**$0**	**$2,329**
EQUIPMENT:								
--none						$0	$0	$0
					Subtotal Equipment:	**$0**	**$0**	**$0**
TOTAL DIRECT COSTS:						**$36,480**	**$0**	**$36,480**
O/H Rate:	10.0%							
Base for Indirect Costs						$36,480	$0	$36,480
INDIRECT COSTS:						**$3,648**	**$0**	**$3,648**
TOTAL PROPOSED COSTS:						**$40,128**	**$0**	**$40,128**
							Cost Share:	**0.0%**

Details of Materials and Supplies:

4 Air Fans	$901
Duct materials	$299
electric control materials	$162
Total Materials & Supplies	**$1,362**