HOME BUILDING TECHNOLOGY SERVICES, LLC

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Subject: Bath fan closed door operating conditions

SCOPE: This paper will address the functionality of a typical spot exhaust fan located in a bathroom, where the bathroom door is closed during operation. This same fan could also be used as an exhaust only, whole house ventilation system. I frequently hear comments such as:

"When the bathroom door is closed the fan can't work! Where's the air come from?"

Let's take a look. In general there is no shortage of 'beliefs' regarding exhaust only ventilation (aka: bath fan) function and many of these beliefs when looked at closely are not always 'accurate'. To examine this situation we borrowed a 3 bedroom, 2 bathroom home for our testing. We wanted to be sure we were using a home that represented modern construction in terms of overall building tightness. Exhaust only ventilation can de-pressurize tighter homes and we wanted to be able to clearly demonstrate that even when under a 'negative pressure', exhaust ventilation can still function adequately. To get a feel for the overall building tightness we first conducted a multi-point Blower Door test. Test results are as follows and are shown in 2 equivalent metrics:

- 832 CFM50
- 2.06 ACH50

To put these numbers in perspective, the ACH50 value for this home exceeds all current 2012, 2015 & 2018 IECC requirements and just missed the DOE's Net Zero Ready requirement of 2.0.

HOME CHARACTERISTICS:

This home has 2 bathrooms with one exposed to one outside wall while the other corner bathroom has exposure to 2 outside walls. I mention this to show the potential air tightness of the surfaces enclosing these rooms. The more interior wall surface area exposure, the greater the potential for being well connected to the rest of the house with respect to replacement air for the fans. Interior walls are not intentionally air sealed where outside walls are.

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TEST PROCESS: The goals was to test the fan flow starting with no replacement air restrictions and then consecutively seal off all known openings and measure the fan flow impact as well as room pressure with respect to the main body of the house outside the bathroom. We also calculated a '%' in air flow reduction for each of the multiple steps.

TEST RESULTS: Shown in steps 1-4 for each bathroom

Bathroom #1

- Area: 62.6 $^{sq}/^{ft}$
- Volume: 500.80 $^{3/ft}$
- One wall plus the ceiling exposed to the outside
- Fan rated at 110
- Tested at 85 cfm
- 77% of rated flow

Step 1 door position: **open**
Room Conditions: Bathroom door wide open, window closed and no intentional restrictions

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Bathroom #1

- Tested at 83 cfm
- 75% of rated flow
- 85-83= 2 cfm lower
- 2% flow reduction
- Room pressure: -2.1

Step 2 door position: **closed**
Room Conditions: Bathroom door closed tight, window closed and no intentional restrictions. Room does have one forced air floor diffuser and the door undercut for fan replacement air when the fan is running. The forced air supply and door undercut are not sealed.

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Bathroom #1

- Tested at 80 cfm
- 73% of rated flow
- 83-80= 3 cfm lower
- 3.5% flow reduction
- Room pressure: -4.2

Step 3 door position: **closed**
Room Conditions: Bathroom door closed tight, window closed, **forced air supply** now **sealed off** but the door undercut is still open.

Bathroom #1

- Tested at 79 cfm
- 72% of rated flow
- 80-79= 1 cfm lower
- 1.3% flow reduction
- Room pressure: -11.5

Step 4 door position: **closed**
Room Conditions: Bathroom door closed tight, window closed, **forced air supply** still **sealed off** but now the **door undercut is** also **sealed off**.

The fan is still doing 79 cfm and this is with all obvious visual paths of replacement air very well sealed off! Because 3 of the 4 walls for this bathroom are adjacent to other interior conditioned space, the replacement air is coming from these areas.

The fan cannot be exhausting 79 cfm unless 79 cfm is available!

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Bathroom #2

- Area: 42.2 $^{sq}/_{ft}$
- Volume: 337.60 $^{3/ft}$
- Two walls plus the ceiling exposed to the outside
- Fan rated at 80
- Tested at 76 cfm
- 95% of rated flow

Step 1 door position: **open**
Room Conditions: Bathroom door wide open, window closed and no intentional restrictions

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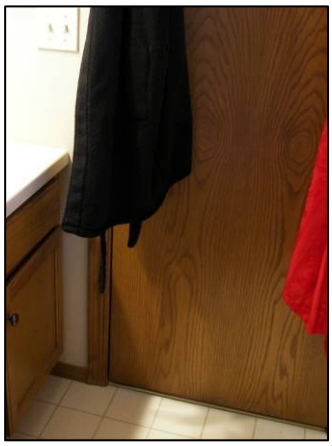
Bathroom #2

- Tested at 75 cfm
- 94% of rated flow
- 76-75= 1 cfm lower
- 1% flow reduction
- Room pressure: -1.8



Step 2 door position: **closed**
Room Conditions: Bathroom door closed tight, window closed and no intentional restrictions. Room does have one forced air floor diffuser and the door undercut for fan replacement air when the fan is running. Forced air supply and door undercut are not sealed.

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Bathroom #2

- Tested at 72 cfm
- 90% of rated flow
- 75-72= 3 cfm lower
- 4% flow reduction
- Room pressure: -3.1

Step 3 door position: **closed**
Room Conditions: Bathroom door closed tight, window closed, **forced air supply** now **sealed off** but the door undercut is still open.

Bathroom #2

- Tested at 70 cfm
- 86% of rated flow
- 72-70= 1 cfm lower
- 1.3% flow reduction
- Room pressure: -6.6

Step 4 door position: **closed**
Room Conditions: Bathroom door closed tight, window closed, **forced air supply** still **sealed off** but now with **door undercut** also **sealed off**.

The fan is still doing 70 cfm and this is with all obvious visual paths of replacement air very well sealed off! Because 2 of the 4 walls for this bathroom are adjacent to other interior conditioned space, the replacement air is coming from these areas.

The fan cannot be exhausting 70 cfm unless 70 cfm is available!

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SUMMARY: In this case you can clearly see that even when all significant sources of replacement air are intentionally sealed off from each fan, each fan was still able to deliver a very high percentage of the 'open door' starting air flow.

- Room 1 open door flow: **85 cfm**
- Room 1 room sealed off air flow: **79 cfm** = **92.9%** of starting air flow

- Room 2 'open door' air flow: **76 cfm**
- Room 2 room sealed off air flow: **70 cfm = 92.0%** of starting air flow

It's evident that this very common belief is really not accurate. In this case with both bathrooms we intentionally sealed off the largest replacement air paths, while under normal living conditions it is extremely unlikely that this would be the case. Even if these bathrooms did not have a forced air supply you can still see that there is still plenty of connection to the house for replacement air.

COMMENTS: There are many choices when it comes to selecting both spot and whole house ventilation systems. There is a large selection of 'exhaust only' bath fan products on the market that are designed and approved to provide spot and whole house ventilation function. It's obvious that with any duel function system, in order to provide the spot function, it would need to be located near the source. In most cases this would be inside a bathroom. This configuration is what frequently brings up the question about replacement air when a bathroom door is closed.

An exhaust only whole house ventilation system can be very cost effective as well. Let's look at a few whole house ventilation **system options** and **operating costs for this home**. In order to meet ASHRAE 62.2-2010 for continuous 24/7 operation, we would need a continuous rate of 58 cfm.

Ventilation system annual operating costs[1] are as follows:

- HRV system @66%^{se}: $101.00 per year (0.27 per day)
- Exhaust only[2] system: $66.00 per year (0.18 per day)
- Supply only system: $66.00 per year (0.18 per day)
- ERV system @67%/76%: $64.00 per year (0.175 per day

AUTHOR: Joe Nagan is the owner of Home Building Technology Services, LLC a consulting firm in Wisconsin and has been involved in building science research since 1985. He is widely sought after for his expertise in the design, installation & commissioning of residential mechanical ventilation systems. He is certified in mechanical ventilation through HRAI SkillTech Canada and holds many other building science related certifications as well.
Regards,
Joseph P. Nagan
Owner: Home Building Technology Services

1. ventilation operating costs calculated using REM/Rate software V15.4.2 based on electrical cost of 0.1311 per kwh and 0.8558 per therm.
2. exhaust only systems not recommended where natural draft combustion appliances are present, open hearth products are present, or in homes without soil gas protection