**DRAFT MINUTES**
**MHCC TECHNICAL SYSTEMS SUBCOMMITTEE**
**Via Conference Call**
**Tuesday, September 16, 2014**

**CALL TO ORDER AND ROLL CALL.**
Technical Systems Subcommittee Chairman, Mark Luttich, called the meeting to order at 1:05 p.m. The DFO announced to the Chair that a quorum was present noting that there were not enough members present representing the "Users" category and the meeting may commence. It was also noted that per the by-laws, all voting issues, including motions, would be followed-up by letter ballot to all Subcommittee members. All guests participating on the call were asked to introduce themselves. See Appendix A for the attendees list.

**OPENING REMARKS**
Pamela Beck Danner, Administrator of the Office of Manufactured Housing Program (DFO), welcomed the Subcommittee members. Ms. Danner noted that this is a meeting of the MHCC Technical Systems Subcommittee and that the meeting notice was published in the August 13, 2014 Federal Register.

Ms. Danner asked that the public, non-committee members, hold their questions until committee member have had a chance to comment.

Subcommittee Chairman Luttich thanked the committee members for their time and stated that four items were on the agenda (Appendix C) that were posted on HUD's MHCC website (hud.gov/mhs):

1. Log 85 Add new text to 3280.801
2. Log 86 Add new text to 3280.806(a)(3)
3. Action Item 1 - Supply Air Ducts Letter – Dated – May 1, 2014
4. Action Item 2 - GAO Report Recommendations on Ventilation Systems and Air Quality, HUD's Transmittal Letter Dated – January 9,2013

**1. LOG 85 – Arc Fault Breakers**

Following a discussion and clarification of procedures, there was a motion by Leo Poggione and seconded by Manuel Santana. William Freeborne pointed out that the technical merit of the proposal were not discussed.

**Motion:** Reject Log 85

**Substantiation:** Current HUD Code references the 2005 NEC throughout. The SC does not feel comfortable with the idea of adopting portions of a referenced document in only a specific section of the HUD code.

Mr. Santana provided Log items 17, 18, 19, and 4 as examples of similar rejections on grounds that referenced documents should not be used in certain sections only.

**Vote: 5-1-0** (see Appendix B)

**Motion Passed.**

*In accordance with the Bylaws, this preliminary action will be followed-up by letter ballot of the entire Subcommittee.*

**2. LOG 86 – Tamper Resistant Receptacles**

Following a discussion, there was a motion by Manuel Santana and seconded by Theresa Desfosses. William Freeborne stated that, as with Log 85, the technical merit of the proposal were not discussed.

**Motion:** Reject Log 86

**Substantiation:** As with Log 85, current HUD Code references the 2005 NEC throughout. The SC does not feel comfortable with the idea of adopting portions of a referenced document in only a specific section of the HUD MHS code.

**Vote: 5-1-0** (see Appendix B)

**Motion Passed.**

*In accordance with the Bylaws, this preliminary action will be followed-up by letter ballot of the entire Subcommittee.*

**3. ACTION ITEM 1 (AI-1): SUPPLY AIR DUCTS LETTER**

*Prior to discussion, the subcommittee members were instructed by the DFO to review the materials provided and ultimately propose action to the Full MHCC at its meeting in December 2014.*

Manuel Santana provided background and an overview of the information contained in AI-1. Mr. Santana directed the SC's attention to the *Federal Register* that was attached to the submitted material submitted to the section regarding circulating air systems. Mr. Santana stated that this section deals with the construction of duct work and the materials with which it can be made out of and that there are two major issues with the new requirements:

***Federal Register***
Vol. 78, No 236 / Monday, December 9, 2013 / Rules and Regulations 73989

24 CFR § 3280.715(a)(1)

1. "Class 1 air ducts and air connectors must be located at least 3 feet from the finance bonnet or the plenum."

2. "Furnace supply plenums must be constructed of metal that extends a minimum of at least 3 feet from the heat exchanger measured along the centerline of airflow."

Rick Hanger also noted that the IRC added the restriction of a maximum resistance of 250°F as well.

Mr. Santana explained that the difference in class is fire resistance (Class 0, Class 1, and Class 2). The change that was published in the Federal Register was that Class 2 ducts are not allowed. In the previous code Class 2 ducts were prohibited from being within 3 ft of the furnace bonnet or the plenum. Class 2 ducts are no longer allowed and no longer used in manufactured housing construction. This issue is *now* Class 1 ducts are prohibited from being within 3 ft from the furnace bonnet or the plenum.

If you think of Class 0 as metal duct and Class 1 as fiberboard duct, in order to comply with this new requirement, you cannot have your insulated duct board within 3 ft of the furnace.

Ultimately, it is a constructability issue as the requirement could potentially add 6 ft of insulated duct board for no additional benefit. As an example, a furnace that goes up into the attic – the duct work going from the heat exchanger into the attic for 3 ft has to be made of metal. This requirement forces the use of metal duct work above the insulation in the attic and, additionally, that area of duct will need to be insulated. The issue is the same with duct work that goes underneath the dwelling.

DFO Danner asked if this was an unintended consequence.

The new requirement was an attempt to improve the fire resistance of the home and the air duct suppliers were having difficulty providing a solution to the requirement given the space available in manufactured housing.

Mr. Santana suggested that the best approach would be to propose revised language with substantiation to recommend to the full Committee.

Tim O'Leary provided additional information regarding regionally sensitive issues with Class 0 and Class 1 duct work regarding IAQ. The difference between Class 0 and Class 1 is fire resistance of the materials. Fiberglass itself is fire resistant but is considered Class 1 because the paper backing, and the materials associated with it, can be combustible. Manufacturers in the Northwest typically use metal duct work and all of the requirements in the Northwest for manufactured homes include using a metal elbow on a crossover joint effectively eliminating problem of the 3 ft requirement. The problem is manufacturers who use duct board for their supply plenum in a warm/moist environment and then install air conditioning or a heat pump (most manufacturers do not include air conditioners or heat pumps unless they are delivering to the South). This increases the amount of bulk water that is in the air stream. Mr. O'Leary stated that some fiberglass materials will promote mold growth and wanted to draw attention to this issue that might also require partial redesign.

William Freeborne requested clarification on the last sentence of paragraph 3 of the MHCC letter dated May 1, 2014:

> "During this interim period, manufacturers will be required to provide Class 1 air ducts and connectors within 3 feet of the furnace bonnet or plenum as required by the final rule and will be allowed to use Class 0 or Class 1 furnace supply plenum within 3 feet of the heat exchanger."

This means, for now, manufacturers *are* permitted to use Class 1 exclusively.

Following the discussion, there was a motion by Theresa Desfosses and seconded by Rick Hanger.

> **Motion:** Assign AI-1 Supply Air Ducts Letter to a Task Force consisting of Manuel Santana (Chair), Debra Blake, and Tim O'Leary to review and submit a proposal to the full Committee.
>
> **Vote: 5-0-0** (see Appendix B)
>
> **Motion Passed.**
>
> *In accordance with the Bylaws, this preliminary action will be followed-up by letter ballot of the entire Subcommittee.*

Mark Weiss requested the members on the call be included on the distribution list for this action item.

Kevin Kauffman (AO) informed Mr. Weiss that once the proposed change language had been created by the Task Force, it would be assigned a Log ID number and would be publically available on HUD's website. He also informed Mr. Weiss that the ballot would be made available on the HUD website as soon as it was finalized. HUD confirmed that this is correct.

## 4. ACTION ITEM 2 (AI-2): GAO REPORT RECOMMENDATIONS ON VENTILATION SYSTEMS AND AIR QUALITY

*Prior to discussion, the SC members were instructed by the DFO to review the two recommendations suggested by the GAO Report listed in the letter to the MHCC from Henry S. Czauski, Acting Deputy Administrator, Office of Manufactured Housing Programs dated January 9, 2013 and propose action to the Full MHCC at its meeting in December 2014.*

Manuel Santana suggested that Log Items 59, 30, 33, and 25 all deal with indoor air quality and includes ASHRAE 62.2 as an option.

Tim O'Leary also supported ASHRAE 62.2 by stating that there have been a plethora of studies on IAQ particularly in energy-efficient homes—if you tighten up a house, you increase the risk for IAQ problems. ASHRAE 62.2 was written by the American Society of Engineers, the nationally recognized group regarding engineering systems. ASHRAE 62.2 is *the authority* for fresh air coming into a tight home.

William Freeborne iterated that the issue is testing, and the report is asking the MHCC to re-examine the whole-house ventilation testing requirement.

Mark Wiess cautioned that the MHCC is operating under a code system that requires a balance between costs and other issues. At a minimum the costs/benefits needs to be reviewed.

Mark Luttich informed the SC that IRC 2012 for *site-built* homes requires tight homes, heat exchanger, and on-site blower door tests and that some jurisdictions are adopting IRC 2012.

DFO Danner stated the IECC (2009, 2010, and 2015) is being reviewed by local jurisdictions around the country to decide which version should be adopted and that does bring in the issue of blower-door tests; and that DOE is also looking at IECC 2015 to see if it is appropriate for manufactured homes.

Mr. Santana stated that none of the international codes require mechanical ventilation when you have natural ventilation; however, HUD code has always required mechanical ventilation in addition to natural ventilation. Mr. Santana reiterated that the MHCC recommended that HUD include ASHRAE

62.2, which is the foremost standard in IAQ, as an option for manufacturers that wanted to use it for IAQ and whole-house ventilation.

It was the consensus of the SC that the GAO report needed to be reviewed and outline what report requests from HUD that the MHCC has not already addressed.

Mr. Luttich asked if Congress provided authority to DOE to review and write the standards.

Lois Starkey replied that IAQ is not specifically addressed – the authority has been given to establish energy standards that are comparable to the IECC. There is nothing on the docket addressing IAQ and that IAQ does not fall with the purview of DOE at this time.

Mr. O'Leary stated that testing of equipment is dependent on the type of equipment installed to accommodate whatever ventilation standards are necessary. HUD rules currently are a sizing standard. ASHRAE 62.2 would be better standard for the manufacturer because you can set it up for each individual home. He further opined that as far as the testing goes, the standard should include what the actual exhaust needs to be not what the size of the equipment should be. In his experience, in-plant testing is a simple, inexpensive test to verity that the equipment exhausts the amount of air required for a particular home. Not only can there be a test for the whole-house exhaust equipment, smaller areas can also be tested at the factory.

Following a discussion that included what the SC was authorized to do and the options that are available, there was a motion by William Freeborne and seconded by Mark Luttich.

> **Motion:** Assign Action Item 2 - (GAO letter) to a Task Force consisting of Michael Lubliner (Chair), William Freeborne, and Tim O'Leary to review and translate AI-2 into 1) an in plant testing procedure and 2) any other proposed change language.
>
> **Vote: 5-0-0** (see Appendix B)
>
> **Motion Passed.**
>
> *In accordance with the Bylaws, this preliminary action will be followed-up by letter ballot of the entire Subcommittee.*

The DFO will work with the AO to set-up conference calls for Task Force use.

The DFO officially invited Tim O'Leary to join the Technical Systems Subcommittee of the MHCC as a User member.

Tim O'Leary accepted the invitation to join the Technical Systems Subcommittee under the user category.

**OPEN DISCUSSION**

Rick Mendlen – Agenda item for December meeting. Asking for the MHCC to review all of the referenced standards that are currently in place. This will include the NEC and help to resolve issues such as Log 85 and Log 86.

DFO Danner agreed that this is a big job but it needs to be done particularly since there are proposed changes including references to standards that are now out of date.

Lois Starky requested a list of items that the MHCC recommended to HUD that have not been acted on in order for the MHCC to offer help with prioritization recommendations.

DFO Danner replied that they recently received the list from the previous AO in two forms: letter ballot and by voice vote in the minutes. HUD is reviewing and will add to the log and post on the website when complete.

The Full MHCC Committee will have an in-person meeting the first week of December 2014 in Washington, DC. Monday and Friday will be travel days with the meeting occurring Tuesday through Thursday.

Chairman Luttich thanked the SC members for their time.

DFO Danner also thanked the SC members for their valuable time noting that they were all volunteers and looked forward to being very productive over the next year.

AO Kauffman will follow-up with letter ballots including all motions affording SC members the opportunity to modify/change their vote. Log Items 85 and 86 will then be forwarded to the Full Committee. The Action Items will remain with the SC until the SC has actionable items to forward to the Full Committee.

**ADJOURN**

The Technical Systems Subcommittee was adjourned at 3:05 p.m.

# APPENDIX A:
# Attendees

**SUBCOMMITTEE MEMBERS PRESENT:**
Debra Blake (G)
Theresa Desfosses (P)
William Freeborne (G)
Rick Hanger (G)
Mark Luttich (G), Subcommittee Chairman
Leo Poggione (P)
Manuel Santana (P)

**SUBCOMMITTEE MEMBERS NOT PRESENT:**
Mark Mazz (U)
Michael Lubliner (U)
James A. Demitrus (U)

**OTHER MHCC MEMBERS PARTICIPATING:**
Ishbel Dickens (U)
Timothy O'Leary (U)
Frank Walter (G)
Richard Weinert (G)

**HUD STAFF PRESENT:**
Pamela Beck Danner, Administrator of the Office of Manufactured Housing Program (DFO)
Patricia McDuffie, GTM for the AO Contract and the Meeting Planner Contract
Lane Pethel, Manufactured Housing Specialist
Teresa Payne, Deputy Administrator, Office of Manufactured Housing Program
Rick Mendlen, Senior Specialist Engineer
Angelo Wallace, Civil Engineer
Lois Starkey, MHI VP for Regulatory Matters

**PUBLIC NON-MEMBERS IN ATTENDANCE:**
Mark Weiss, Senior Vice President Manufactured Housing Association for Regulatory Reform (MHARR)
Kevin Kauffman and Tanya Akers, Home Innovation Research Labs (AO)

# APPENDIX B:
# Detailed Voting Summary

**LOG 85 – SECTION 3280.801**

**Subcommittee Teleconference Action** – Reject (5-1-0)

| MEMBER NAME | VOTE |
|---|---|
| *Mark Luttich* | *N/A* |
| Debra Blake | Y |
| Theresa Desfosses | Y |
| William Freeborne | N |
| Rick Hanger | Y |
| Leo Poggionne | Y |
| Manuel Santana | Y |

**LOG 86 – 3280.806(A)(3)**

**Subcommittee Teleconference Action** – Reject (5-1-0)

| MEMBER NAME | VOTE |
|---|---|
| *Mark Luttich* | *N/A* |
| Debra Blake | Y |
| Theresa Desfosses | Y |
| William Freeborne | N |
| Rick Hanger | Y |
| Leo Poggionne | Y |
| Manuel Santana | Y |

**ACTION ITEM 1 – SUPPLY AIR DUCTS LETTER**

**Subcommittee Teleconference Action** – Assign AI-1 Supply Air Ducts Letter to a Task Force consisting of Manuel Santana (Chair), Debra Blake, and Tim O'Leary to review and submit a proposal to the full Committee.

| MEMBER NAME | VOTE |
|---|---|
| *Mark Luttich* | *N/A* |
| Debra Blake | Y |
| Theresa Desfosses | Y |
| William Freeborne | Y |
| Rick Hanger | Y |
| Manuel Santana | Y |

**ACTION ITEM 2 – GAO REPORT**

**Subcommittee Teleconference Action** - Assign Action Item 2 - (GAO letter) to a Task Force consisting of Michael Lubliner (Chair), William Freeborne, (Producer: Dave Compost or Michael Wade), and Tim O'Leary to review and translate AI-2 into 1) an in plant testing procedure and 2) any other proposed change language.

| MEMBER NAME | VOTE |
|---|---|
| *MARK LUTTICH* | *NA* |
| DEBRA BLAKE | Y |
| THERESA DESFOSSES | Y |
| WILLIAM FREEBORNE | Y |
| RICK HANGER | Y |
| MANUEL SANTANA | Y |

**APPENDIX C:**
**Agenda**

# Technical Systems Subcommittee Teleconference

## Agenda

**September 16, 2014**
**1:00 p.m. to 4:00 p.m. (EDT)**

**Call in Number: 1-866-622-8461**
**Password: 4325434**

I. Call to Order and Roll Call

II. Opening Remarks: Chair, Mark Luttich
DFO, Pamela Danner

III. New Business – Review Items Assigned to Technical Systems Subcommittee by MHCC

- Log 85 – Add new text to 3280.801
- Log 86 – Add new text to 3280.806
- Action Item 1: Supply Air Ducts, Letter Dated – May 1. 2014
- Action Item 2: GAO Report – Recommendations on Ventilation Systems and Air Quality, Transmittal Letter Dated – January 9, 2013

IV. Open Discussion

V. Adjourn: 4:00 p.m.

## APPENDIX D:
## Proposed Changes and Action Items

Log 85 – Add new text to 3280.801

Log 86 – Add new text to 3280.806

Action Item 1: Supply Air Ducts, Letter Dated – May 1. 2014

Action Item 2: GAO Report – Recommendations on Ventilation Systems and Air Quality, Transmittal Letter Dated – January 9, 2013

3280HUD- Log #85 **Final Action:**
**(3280.801)**

**Submitter:** Vince Baclawski, National Electrical Manufacturers Association (NEMA)
**Recommendation:** or alternative proposal
§ 3280.801 Scope
(b) In addition to the requirements of this part and Part II of Article 550 of the National Electrical Code (NFPA No. 70–~~2005~~ 2011), the applicable portions of other Articles of the National Electrical Code must be followed for electrical installations in manufactured homes. The use of arc-fault breakers under Articles 210.12(A) and (B), 440.65, and 550.25(A) and (B) of the National Electrical Code, NFPA No. 70–~~2005~~ 2008 2011) is not required. However, if arc-fault breakers are provided, such use must be in accordance with the National Electrical Code, NFPA No. 70–~~2005~~ 2008 2011. Wherever the requirements of this standard differ from the National Electrical Code, these standards apply.

~~Substantiation~~: This proposal to require listed tamper resistant receptacles was previously submitted and rejected by the committee on grounds that the requirements are already included in the 2008 NEC that is proposed for adoption integrally in this approval process. However, the committee rationale can only be accurate if the scope of Subpart I in 3280.801 references the 2008 or 2011 National Electrical Code. The tamper resistant receptacle requirements do not appear in the 2005 NEC, which is the edition of the code referenced in 3280.801(b).

The intent of this proposal is to insure that the necessary requirements are in place to provide protection for young children against electrical burns in both manufactured homes and site built residential construction. The 2008 and 2011 NEC provides this protection in residential occupancies other than manufactured homes. The electrical burn incidents described in the substantiation for this proposal can occur in a residence regardless of the type of construction.

There appears to be two methods of insuring that the protection offered by tamper receptacles is provided in manufactured homes.

- add the requirement for temper resistant receptacles to 3280.806
or
- revise 3280.801(B) to update the National Electrical Code edition from 2005 to 2008 or 2011

This proposal recommends either of these options to achieve the goal of insuring that the necessary child safety feature provided by tamper resistant receptacles will be provided in manufactured homes.

Also see proposal to 3280-806(a)(3).

## Technical Systems Subcommittee Meeting Action: Reject

3280HUD- Log #86 **Final Action:**
**(3280.806(a)(3))**

**Submitter:** Vince Baclawski, National Electrical Manufacturers Association (NEMA)
**Recommendation:** § 3280.806 Receptacle outlets
a) All receptacle outlets shall be:
(1) Of grounding type;
(2) Installed according to Article 406.3 of the National electrical Code, NFPA No. 70-~~2005~~ 2011.
(3) Except when supplying specific appliances, be parallel-blade, listed tamper-resistant, 15-ampere, 125-volt, either single or duplex.

**Substantiation:** This proposal to require listed tamper resistant receptacles was previously submitted and rejected by the committee on grounds that the requirements are already included in the 2008 NEC that is proposed for adoption integrally in this approval process. However, the committee rationale can only be accurate if the scope of Subpart I in 3280.801 references the 2008 or 2011 National Electrical Code. The tamper resistant receptacle requirements do not appear in the 2005 NEC, which is the edition of the code referenced in 3280.801(b).

The intent of this proposal is to insure that the necessary requirements are in place to provide protection for young children against electrical burns in both manufactured homes and site built residential construction. The 2008 and 2011 NEC provides this protection in residential occupancies other than manufactured homes. The electrical burn incidents described in the substantiation for this proposal can occur in a residence regardless of the type of construction.

There appears to be two methods of insuring that the protection offered by tamper receptacles is provided in manufactured homes.

- add the requirement for temper resistant receptacles to 3280.806
or
- revise 3280.801(B) to update the National Electrical Code edition from 2005 to 2008 or 2011

This proposal recommends either of these options to achieve the goal of insuring that the necessary child safety feature provided by tamper resistant receptacles will be provided in manufactured homes.

Also see proposal to 3280-801.

## Technical Systems Subcommittee Meeting Action: Reject

# Action Item 1:
# Supply Air Ducts, Letter Dated - May 1, 2014

**Technical Systems Subcommittee Meeting Action:**

Assign AI-1 Supply Air Ducts Letter to a Task Force consisting of Manuel Santana (Chair), Debra Blake, and Tim O'Leary to review and submit a proposal to the full Committee.

U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
WASHINGTON, DC 20410-8000

ASSISTANT SECRETARY FOR HOUSING-
FEDERAL HOUSING COMMISSIONER

MAY 1 - 2014

Manufactured Housing Consensus Committee

Dear Committee Member:

This is in response to information received from Manufactured Housing Consensus Committee (MHCC) member Manuel Santana and others regarding expressed concerns and problems associated with compliance with the new requirements for supply air ducts in 24 CFR § 3280.715(a)(1) of the Manufactured Home Construction and Safety Standards (copy enclosed) that were published in the Federal Register on December 9, 2013. A detailed analysis of potential issues provided by Mr. Santana is attached for your review and consideration.

Specifically, manufacturers and their suppliers have encountered problems in finding workable solutions in meeting the new requirement for furnace supply plenums to be constructed of metal for a minimum of 3 feet from the heat exchanger, due to small furnace compartment spaces and smaller attic and crawl space areas than encountered in site built construction. The information provided also suggests there are no issues associated with the use of Class 1 supply air ducts and with elimination of the less fire resistive Class 2 type supply air ducts as required by the final rule.

In view of all of the above, the Department has determined that the requirement in 24 CFR § 3280.715(a)(1) for furnace supply plenums to be constructed of metal that extends a minimum of 3 feet from the heat exchanger is to be indefinitely delayed to provide industry with sufficient time to develop a workable solution to meet the requirement or until the MHCC can reassess this aspect of the rule and provide recommendations on how this matter should be resolved. During this interim period, manufacturers will be required to provide Class 1 air ducts and connectors within 3 feet of the furnace bonnet or plenum as required by the final rule and will be allowed to use a Class 0 or Class 1 furnace supply plenum within 3 feet of the heat exchanger.

If you have any additional comments or questions, please contact me at (202) 402-7112.

Sincerely,

Pamela Beck Danner
Administrator
Office of Manufactured Housing Programs

Enclosures

Analysis of New HUD Standards Revisions to 3280.715, effective 6/9/2014
04/17/14

The purpose of this paper is to identify the significant changes made to §3280.715 by the new HUD standards revisions effective June 9, 2014. This paper will evaluate their justification, impact and provide recommendations where appropriate.

Significant Changes

1. Class 2 ducts have been eliminated
2. Class 1 ducts and connectors are not allowed within 3 feet of the furnace bonnet or plenum
3. The furnace supply plenum must be constructed of metal that extends at least 3 feet from the heat exchanger.
4. Crossover duct insulation has been increased from R-4 to R-8

With respect to modern Manufactured Housing (MH) construction, Class 2 ducts are no longer used, Class 1 ducts are fiberglass board or insulated flex ducts and Class 0 ducts are aluminum or steel ducts.

Justification

Justification for the revisions provided in the Supplementary Information of the Final Rule, can be found in *Part III, This Final Rule, Section H.*

1. "Class 2 ducts were deleted because the change is consistent with the requirements of the International Residential Code for One and Two Family Dwellings, and would improve the fire safety and performance of air handling ducts by requiring the use of Class 0 or 1 ducts".
2. There was no justification provided for requiring Class 1 ducts not be allowed within 3 feet of the furnace bonnet or plenum
3. There was no justification provided for requiring that the plenum be constructed of metal for 3 feet from the heat exchanger.
4. Justification for this was to provide consistency with the IRC

Analysis and Impact

The 2012 version of the International Residential Code (IRC) and 2012 version of the International Mechanical Code (IMC) were analyzed and compared to the new HUD requirements.
The elimination of Class 2 ducts is consistent with the requirements of the IRC/IMC. To my knowledge, Class 2 ducts are no longer being used in manufactured housing.

The IRC/IMC does not have any limitations on where Class 1 ducts may be located relative to a furnace plenum or bonnet. Rather, the IRC/IMC requires that the discharge air temperature of the equipment be limited to 250°F as a condition for the use of Class 0 or 1 ducts (see §M1601.1.1 attached). It is then the responsibility of others to ensure that the duct being installed is rated to withstand at least 250°F. Similarly, the IRC/IMC does not have any requirement as to the construction of a furnace supply plenum that extends 3 feet from the heat exchanger.

This rule will have a significant impact on all manufacturers in varying degrees. Manufactured homes are typically built with one of the following duct systems

- Downflow
  1. Singlewide units with aluminum ducts, no crossovers
  2. Multiwide units with aluminum ducts and round flex duct crossovers
  3. Single wide units with rigid insulated ducts and no crossovers
  4. Multiwide units with rigid insulated ducts with round flex duct crossovers
- Upflow
  1. Singlewide units with a rigid insulation plenum connected to round flex duct, no crossovers
  2. Multiwide units with a rigid insulation plenum connected to round flex duct and crossovers

Singlewide units with downflow furnaces and aluminum ducts will be affected by Item #3 in the significant changes listed above. Item #3 is the requirement for a metal supply plenum that extends 3 feet from the heat exchanger. §3280.702 defines a plenum as "an air compartment which is part of an air distribution system to which one or more ducts or outlets are connected". This can be interpreted to mean that the duct cannot be taken as part of the plenum since one or more ducts are not connected to it. If a plenum is taken to be separate from ducts then it is not possible to install a metal plenum that extends 3 feet between the heat exchanger and the duct below as the furnace heat exchanger and the duct are only separated by the depth of the floor joists. In order to comply with this requirement, the ducts will have to be installed approximately 2' below the underside of the joists.

Multiwide units with downflow furnaces and aluminum ducts and round flex duct crossovers will be affected by items #2, 3 and 4 of the significant changes listed above. It is considered best practice to install the crossover duct directly underneath the furnace. When this is done, (assuming the flex duct can be taken to be the supply plenum) the flex duct will have to be replaced with a round metal duct for a distance necessary to comply with the 3 feet supply plenum from the heat exchanger requirement. Once this distance is reached, the metal duct will need to be extended an additional 3 feet to comply with the requirement that a Class 1 duct cannot be within 3 feet of a furnace supply bonnet or plenum. All portions of the metal duct crossover that is exposed to outside air must be insulated to R8 minimum per item #4 of the significant changes listed above.

Singlewide units with downflow furnaces and rigid insulated ducts will be affected by items #2 and 3 in the significant changes listed above. Item #2 prohibits Class 1 ducts from being within 3 feet of the furnace plenum. This means that a metal duct will have to be installed directly underneath the furnace plenum for a distance of 3 feet in both directions. Similar to the discussion above, the requirement for a 3 feet metal supply plenum will be difficult to accomplish as it will require the ductwork to be placed approximately 2' below the underside of the joists.

Multiwide units with downflow furnaces, rigid insulated ducts and round flex crossovers will be affected by items #2, 3 and 4 of the significant changes listed above. This scenario combines the difficulties listed for the other scenarios above. There will need to be metal duct run for 3 feet in both directions under

the furnace, the crossover (if allowed to serve as the plenum) will need to be metal for 3 feet from the heat exchanger followed by 3 feet minimum until it can be connected to an insulated flex duct. All portions of the metal duct crossover that is exposed to outside air must be insulated to R8 minimum.

Singlewide and multiwide units with an upflow furnace are typically equipped with a plenum made from rigid insulated duct material, round insulated flex duct is connected to the plenum. This scenario will be affected by items #2, 3 and 4 from the significant changes listed above. The supply plenum will need to be fabricated from metal for 3 feet from the heat exchanger. All ducts leading away from the supply plenum for 3 feet in all directions will have to be metal before transitioning to round insulated flex duct. All exposed metal ductwork will need to be insulated to R-8 minimum.

With respect to potential solutions, clarification of the new requirements and the definition of a plenum will be required before any proposed solution can be finalized. The revised standard do not allow for a Class 1 duct to be within 3 feet of the furnace plenum, there is no mention of Class 1 ducts being allowed in this range as long as the inside of the duct is lined with a Class 0 material. The same applies to the requirement for a metal 3 feet supply plenum from the heat exchanger to the duct, the standards don't mention that this can be a metal duct encased in Class 1 material.

There is a proposed solution for the downflow scenario with rigid insulated duct. It includes opening the rigid duct and lining it for 3 feet in each direction with a metal duct, then resealing the rigid insulated duct. This solution is dependent on the issues above being clarified.

As of the date on this paper there are no practical solutions to the upflow scenario.

Conclusion and Recommendations

It is not clear from the comments in the preamble what caused HUD to restrict use of Class 1 ducts within 3 feet of bonnets of plenums or require a metal supply plenum to extend 3 feet from the heat exchanger. No data of incidents of fire caused by Class 1 ducts connected to plenums or bonnets within 3 feet.

The IRC addresses fire safety of the ducts by limiting the air discharge temperature to 250°. Based on information received from one major supplier of equipment approved for installation in manufactured housing, air discharge temperatures for their products range from 155°F to a high of 210°F for high efficiency equipment.

Rigid insulated duct board currently used by this manufacturer is listed as Class 1 and for max 250°F operating temperature.

With air discharge temperature not being an issue, it is questionable how the use of Class 0 duct near the plenum or bonnet would improve fire safety. There are no open flames in fuel burning equipment, all combustion takes place inside the heat exchanger. The likelihood of flames getting into the duct

system is slim to none and would only be an issue with deterioration of the heat exchanger housing due to the lack of maintenance and periodical inspections by qualified service personnel. Electrical equipment does not produce any flames.

The industry and its suppliers have not come up with a viable solution to comply with the new requirements, especially for upflow systems common in the industry. Metal portions of duct systems, especially when also used for air conditioning, must be insulated to prevent condensation. One supplier's solution for down flow systems is to insert metal sleeves into existing Class 1 duct components, by cutting open the duct board and resealing it once insertion is complete. This solution may not comply with the new requirements since it is unclear if a Class 1 material is allowed within 3 feet of the plenum even if the interior is lined with a metal (Class 0) duct.

All proposed solutions currently being considered increase fabrication complexity, parts and pieces, cost as well as the opportunity for mistakes. I believe that implementation of these new rules carry the risk of lowered energy efficiency of the system due to constraints in the air flow and likely introduction of leakage points due to increased joints and connections. Increased duct leakage outside of the pressure envelope has been identified as contributing to moisture problems in humid climate zones. There are many obstacles and risks with no tangible benefits.

I recommend that HUD delay enforcement of the metal supply plenum required 3 feet from the heat exchanger and prohibition of Class 1 ducts within 3 feet of the furnace bonnet or plenum. I believe that HUD needs to reconsider the substantiation of making these changes and if HUD elects to proceed with implementation, do so only after issuing guidelines or an interpretative bulletin to eliminate disparate enforcement among the industry's third parties.

I, Storage Water Heaters with Input/ Ratings of 75,000 BTU per hour or less, ANSI Z21.10.1–1998 with addendums Z21.10.1a–2000, and Z21.10.1b–1992, except that for oil-fired units. CF=1.0, Q=total gallons of oil consumed and H=total heating value of oil in BTU/ gallon.

| Storage capacity in gallons | Recovery efficiency | Standby loss |
|---|---|---|
| Less than 25 | At least 75 percent. | Not more than 7.5 percent. |
| 25 up to 35 | 00 | Not more than 7 percent. |
| 35 or more | 00 | Not more than 6 percent. |

* * * * *

(f) *Oil-fired heating equipment.* All oil-fired heating equipment must conform to Liquid Fuel-burning Heating Appliances for Manufactured Homes and Recreational Vehicles, UL 307A–1995, with 1997 revisions, and be installed in accordance with Standard for the Installation of Oil Burning Equipment, NFPA 31–01 (incorporated by reference, see § 3280.4). Regardless of the requirements of the above-referenced standards, or any other standards referenced in this part, the following are not required:

* * * * *

■ 32. Revise § 3280.711 to read as follows:

**§ 3280.711 Instructions.**

Operating instructions must be provided with each appliance. The operating and installation instructions for each appliance must be provided with the homeowner's manual.

■ 33. Amend § 3280.714 as follows:

■ a. Add "(incorporated by reference, see § 3280.4)" immediately following "Heat Pump Equipment" in paragraph (a)(1) introductory text and immediately following "Heat Pump Appliances" in paragraph (a)(2); and

■ b. Revise paragraphs (a)(1)(i) and (ii).

The revisions read as follows:

**§ 3280.714 Appliances, cooling.**

(a) * * *

(1) * * *

(i) Electric motor-driven unitary air-cooled air conditioners and heat pumps in the cooling mode with rated capacity less than 65,000 BTU/hour (19,045 watts), when rated at ARI standard rating conditions in ARI Standard 210/240–89, Unitary Air-Conditioning and Air-Source Heat Pump Equipment, must have seasonal energy efficiency (SEER) values not less than as specified in 10 CFR Part 430, Energy Conservation Program for Consumer Products: Central Air Conditioners and Heat Pumps Energy Conservation Standards.

(ii) Heat pumps must be certified to comply with all requirements of the ARI Standard 210/240–89, Unitary Air Conditioning and Air-Source Heat Pump Equipment. Electric motor-driven vapor compression heat pumps with supplemental electrical resistance heat must be sized to provide by compression at least 60 percent of the calculated annual heating requirements for the manufactured home being served. A control must be provided and set to prevent operation of supplemental electrical resistance heat at outdoor temperatures above 40 °F (4 °C), except for defrost conditions. Electric motor-driven vapor compression heat pumps with supplemental electric resistance heat conforming to ARI Standard 210/240–89, Unitary Air-Conditioning and Air-Source Heat Pump Equipment, must have Heating Season Performance Factor (HSPF) efficiencies not less than as specified in the 10 CFR Part 430, Energy Conservation Program for Consumer Products: Central Air Conditioners and Heat Pumps Energy Conservation Standards.

* * * * *

■ 34. In § 3280.715, revise paragraphs (a)(1) introductory text, (a)(5)(ii), (a)(7), and (d) to read as follows:

**§ 3280.715 Circulating air systems.**

(a) * * *

(1) Supply air ducts, fittings, and any dampers contained therein must be made of galvanized steel, tin-plated steel, or aluminum, or must be listed as Class 0 or Class 1 air ducts and air connectors in accordance with UL 181–2003, Factory-Made Air Ducts and Air Connectors (incorporated by reference, see § 3280.4). Class 1 air ducts and air connectors must be located at least 3 feet from the furnace bonnet or plenum. Air connectors must not be used for exterior manufactured home duct connection. A duct system integral with the structure must be of durable construction that can be demonstrated to be equally resistant to fire and deterioration as required by this section. Furnace supply plenums must be constructed of metal that extends a minimum of 3 feet from the heat exchanger measured along the centerline of airflow. Ducts constructed from sheet metal must be in accordance with the following table:

* * * * *

(5) * * *

(ii) The manufacturer must provide installation instructions for supporting, mechanically fastening, sealing, and insulating each crossover duct. The instructions must indicate that no portion of the crossover duct is to be in contact with the ground, and must describe the means to support the duct without compressing the insulation and restricting airflow.

* * * * *

(7) Unless installed in a basement, supply and return ducts, fittings, and crossover duct plenums exposed directly to outside air, such as those under-chassis crossover ducts or ducts connecting external heating, cooling, or combination heating/cooling appliances, must be insulated with material having a minimum thermal resistance of R–8 in all Thermal Zones. All such insulating materials must have a continuous vapor barrier retarder having a perm rating of not more than 1 perm. Where ducts are exposed underneath the manufactured home, they must comply with paragraph (a)(5)(ii) of this section, and shall be listed for exterior use.

* * * * *

(d) *Supports and protection.* Ducts must be securely supported. Nails or other fasteners must not be driven or penetrate through duct walls. Where vertical ducts are installed within closets or rooms, they must be enclosed with materials equivalent to those used in the closet or room construction.

* * * * *

■ 36. In § 3280.802, revise paragraphs (a)(37) and (39) to read as follows:

**§ 3280.802 Definitions.**

(a) * * *

(37) *Receptacle* means a contact device installed at the outlet for the connection of an attachment plug. A single receptacle is a single contact device with no other contact device on the same yoke. A multiple receptacle is a device with two or more contact devices on the same yoke.

* * * * *

(39) *Utilization equipment* means equipment that utilizes electric energy for electronic, electromechanical, chemical, heating, lighting, or similar purposes.

* * * * *

# Action Item 2:
# GAO Report - Recommendations on Ventilation Systems and Air Quality, Transmittal Letter Dated - January 9, 2013

**Technical Systems Subcommittee Meeting Action:**

Assign Action Item 2 - (GAO letter) to a Task Force consisting of Michael Lubliner (Chair), William Freeborne, and Tim O'Leary to review and translate AI-2 into 1) an in plant testing procedure and 2) any other proposed change language.

**U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT**
WASHINGTON, DC 20410-8000

OFFICE OF HOUSING

January 9, 2013

Manufactured Housing Consensus Committee
c/o Robert Solomon, Project Manager
National Fire Protection Association
1 Batterymarch Park
Quincy, MA 92619-7471

Dear Committee Member:

At the request of Congress, the Government Accounting Office (GAO) recently completed a review of the ventilation systems and air quality in manufactured homes. The final GAO 13-52 report entitled, "Manufactured Housing Standards: Testing and Performance Evaluation Could Better Ensure Safe Indoor Air Quality" was issued October 24, 2012.

The GAO Report made the following two recommendations:

> To better ensure that air ventilation systems in manufactured homes perform as specified and meet the HUD code, we recommend that HUD develop an appropriate method to test and validate the performance of the ventilation system as part of the HUD certification process.
>
> To ensure that its specification for airflow continues to be appropriate, we recommend that HUD reassess the assumptions for the whole-house ventilation specification, working with the MHCC, to determine the appropriate rates, taking into consideration current natural air infiltration, to achieve the whole-house ventilation performance, considering the expected impact such ventilation would have on indoor air quality.

In response to the GAO Report, the Department agreed to bring the GAO recommendations before the Manufactured Housing Consensus Committee (MHCC) for its consideration. The purpose of this letter is to transmit a copy of the GAO Report to the members of the MHCC through the Administering Organization, NFPA, for review, consideration and appropriate action.

We look forward to future discussions with the MHCC with regard to these important recommendations to further enhance and improve indoor air quality levels in manufactured homes.

Sincerely,

Henry S. Czauski
Acting Deputy Administrator
Office of Manufactured Housing Programs

Enclosure

United States Government Accountability Office

GAO

Report to Congressional Requesters

October 2012

# MANUFACTURED HOUSING STANDARDS

# Testing and Performance Evaluation Could Better Ensure Safe Indoor Air Quality


GAO-13-52

October 2012

# MANUFACTURED HOUSING STANDARDS

## Testing and Performance Evaluation Could Better Ensure Safe Indoor Air Quality

GAO Highlights

Accountability * Integrity * Reliability

Highlights of GAO-13-52, a report to congressional requesters

### Why GAO Did This Study

Since 1976, HUD has been responsible for developing construction and safety standards (the HUD Code) for manufactured homes. Concerns have been raised by Congress and others about existing HUD code requirements that are intended to ensure proper indoor air quality, including protecting occupants from potential carbon monoxide exposure. As requested, GAO examined 1) existing standards for separating air intakes and exhaust vents in both manufactured and site-built homes; 2) reasons for differences in ventilation standards for manufactured and site-built homes; and 3) the number of manufactured homes built, the distances between their air intakes and exhaust vents, and the performance of their ventilation systems. GAO reviewed documentation from HUD and building standards organizations to determine differences in requirements tied to ventilation and air quality, reviewed the rulemaking process and status of proposed updates to manufactured housing standards related to ventilation and air quality, analyzed data on the occupancy of manufactured houses subject to HUD's standards, assessed HUD's efforts to ensure compliance with certain standards, and interviewed agency officials and indoor air quality experts.

### What GAO Recommends

GAO recommends that HUD test the performance of installed ventilation systems and reassess its ventilation standards. HUD generally agreed with both recommendations and stated that it would bring them before the MHCC for consideration.

View GAO-13-52. For more information, contact Mathew J. Scirè at (202) 512-8678 or sciremj@gao.gov.

### What GAO Found

Key standards for manufactured homes provide a lower margin of safety against a carbon monoxide exposure incident than those for site-built homes, which are constructed at their permanent locations. For instance, the Department of Housing and Urban Development (HUD) Code requires a minimum 3-foot separation between air intakes and exhaust vents, while industry standards for site-built homes have required a greater distance for many years. The industry standards call for a greater separation between air intakes and exhaust vents to help reduce the risk that contaminants such as carbon monoxide will re-enter the home. Indoor air quality experts whom GAO interviewed stated that the exhaust of an improperly operating furnace combined with unique wind conditions could, in rare cases, present a risk of carbon monoxide exposure. GAO analysis shows that increasing the separation between an air intake and exhaust vents, using industry standards, can significantly dilute concentrations of contaminants.

The primary reason for the differences in ventilation standards for manufactured homes and site-built homes is the HUD Code has not been updated since 2005 and has not kept pace with standards tied to ventilation and air quality for site-built homes. For example, updates to standards for site-built homes made in 2003 requiring a greater separation between intakes and exhaust vents are only now being considered by HUD for manufactured homes. This update was recommended to HUD in 2010 by the Manufactured Housing Consensus Committee (MHCC), which is responsible for recommending proposed rule changes to HUD. Similarly, requirements for carbon monoxide detectors adopted in industry standards for site-built homes and recommended by the MHCC in 2009 have yet to be incorporated in the HUD Code. HUD did publish a proposed rule in the *Federal Register* in 2010 to update aspects of the HUD Code but has not issued a final rule because the rulemaking process is ongoing. Additional proposals, including the two above related to indoor air quality, are under consideration by HUD, but have not yet been published as proposed rules.

An estimated 5.5 million occupied manufactured homes were built under the HUD Code, according to 2009 American Housing Survey data. Although HUD retains copies of approved designs of manufactured homes, the agency does not maintain data on the actual distances between the air intakes and exhaust vents of each home. Further, once ventilation systems are installed in manufactured homes, HUD does not require manufacturers to test their performance. For example, manufacturers are not required to determine if the systems meet the requirements for the whole-house ventilation airflow rate, which quantifies the volume of air exchanged in the home over time. Without performance testing of the installed ventilation systems, HUD cannot fully ensure that the systems installed in manufactured homes are meeting performance specifications. In addition, HUD's standard for the whole-house airflow rate provided by mechanical ventilation was initially established assuming a certain level of natural air infiltration. This whole-house airflow rate standard has not changed since 1993. Air quality experts and research suggest that homes are increasingly being built with less air leakage, reducing the expected level of natural air infiltration. However, HUD has not reassessed the whole-house ventilation airflow rate standard to determine whether it continues to be sufficient to assure adequate air quality.

# Contents

GAO
Accountability * Integrity * Reliability

**United States Government Accountability Office**
**Washington, DC 20548**

October 24, 2012

The Honorable James P. Moran
Ranking Member
Subcommittee on Interior, Environment, and Related Agencies
Committee on Appropriations
House of Representatives

The Honorable John W. Olver
Ranking Member
Subcommittee on Transportation, Housing, and Urban Development, and Related Agencies
Committee on Appropriations
House of Representatives

The Department of Housing and Urban Development (HUD) certified manufactured homes offer a lower-cost option to traditional site-built homes. In 2010, an estimated 18 million individuals lived in manufactured homes, which are defined as transportable structures of at least 320 square feet built on permanent chassis structures.[1] Since 1976, all manufactured homes (formerly called "mobile homes") have been required to meet HUD's Manufactured Home Construction and Safety Standards (the HUD Code), the only building code that preempts state and local building codes. The HUD Code covers body and frame requirements, thermal protection, plumbing, electrical, ventilation, and other aspects of the home. Every home built to the HUD Code is identified with a red metal tag, known as the HUD certification label.

In your request, you raised concerns that the HUD Code's ventilation standards, particularly the separation distance between fresh air intakes and exhaust vents that is intended to assure that contaminants do not reenter a home, may not be keeping pace with standards for site-built homes. For this review, we examined 1) existing standards for separating air intakes and exhaust vents in both manufactured and site-built homes; 2) reasons for differences in ventilation standards for manufactured and site-built homes; and 3) the number of HUD manufactured homes built,

[1]This estimate is from the U.S. Census Bureau's 2010 American Community Survey (ACS). The margins of error for these estimates are +/- 87,000.

including the distances between their air intakes and exhaust vents, and the performance of their ventilation systems.

## Scope and Methodology

To examine standards associated with the separation distance between air intakes and exhaust vents in homes, we collected and analyzed information on existing standards for home ventilation systems. Specifically, we collected and analyzed documentary information on construction and safety standards for manufactured homes and interviewed representatives from HUD to ascertain how such standards were developed. Likewise, we collected information on commonly-accepted industry standards for site-built homes and the evolution of those standards. We also interviewed subject area experts performing research on ventilation and air quality issues for manufactured homes to understand factors affecting the indoor air quality of manufactured and site-built homes. Further, we contacted state administrative agency officials in 5 of the 37 states that administer manufactured housing consumer programs for information on indoor air quality complaints. We chose administrative agencies in New York, Pennsylvania, Tennessee and Texas based on different climate zones and numbers of placed manufactured homes. We added Utah because carbon monoxide poisoning had allegedly occurred in a manufactured home. We selected states with relatively high numbers of manufactured homes, using data from the Census Bureau's 2010 Manufactured Homes Survey. Additionally, we compared different separation distances between air intakes and exhaust vents and the potential for carbon monoxide exposure using modeling methods from the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). Appendix I contains a more detailed description of our comparison.

To assess the rationale for having different ventilation standards for manufactured and site-built homes, we collected documentary information and contacted officials from HUD, industry associations, and organizations that set building standards. Specifically, we identified the reasons behind the differences in ventilation standards for manufactured versus site-built homes, the evolution of these standards over time, and the current status of new or revised standards that have been proposed for manufactured homes.

To determine the number of manufactured homes that have been built to HUD standards, we analyzed U.S. Census Bureau estimates on the number of occupied manufactured homes built since 1975 and relevant characteristics of the homes. We assessed the reliability of the Census

Bureau's 2009 American Housing Survey and 2010 American Community Survey by reviewing information on the data and interviewing knowledgeable officials on the quality of the data. We determined the data were sufficiently reliable for the purposes of this report. To identify and obtain available data on the design and performance of ventilation systems in manufactured homes, we sought information from HUD on the distances between intake and exhaust vents and the performance of the ventilation systems. We also contacted officials from industry associations, researchers, and companies in the manufactured home industry to identify common design and performance specifications that they used for manufactured homes. Further, we collected information from organizations that conduct testing and certify ventilation systems for manufactured homes.

We conducted this performance audit from December 2011 through October 2012 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

# Background

## HUD Oversight and Standards for Manufactured Homes

HUD is responsible for enforcing the federal manufactured home construction and safety standards that it established under The National Manufactured Housing Construction and Safety Standards Act of 1974.[2] The act authorized HUD to develop construction and safety standards for manufactured homes and to oversee the enforcement of the standards through inspections and review of building plans. HUD developed the Manufactured Housing Construction and Safety Standards, commonly known as the HUD Code, basing them in substantial part on the National

[2]Pub. L. No. 93-383, Title VI.

Fire Protection Association (NFPA) standards for manufactured homes (NFPA 501).[3] The HUD Code was implemented in 1976.[4]

Because a manufactured home can be moved from one state to another, the HUD Code is applied nationwide and preempts state and local codes. As a result, state and local building authorities may not apply their own codes to manufactured homes for components covered by the HUD Code, such as ventilation systems. Unlike site-built homes, which are constructed at their permanent locations, manufactured homes are constructed in factories and must have a permanent chassis so that they can be moved on wheels to retailers or consumers in different states and localities, where they are placed on temporary or permanent foundations. Manufactured homes differ from modular homes, which are another type of prefabricated home and are often designed and constructed by the same manufacturers that construct manufactured homes. Like site-built homes, modular homes are built to state and local building codes. But unlike manufactured homes that are required to be moved to the site and remain on wheeled chassis, modular home sections or modules are transported on truck beds and assembled on site.

The 1974 act was amended by the Manufactured Housing Improvement Act of 2000 to create a balanced consensus process for establishing and revising manufactured home building standards.[5] The amendment established the Manufactured Housing Consensus Committee (MHCC), a federal advisory committee established to provide recommendations to the HUD Secretary on new standards and revisions of current standards.

The MHCC consists of voting members representing seven producers or retailers of manufactured housing; seven representatives of consumer interests, such as owners of manufactured homes; and seven general interest and public official members. In addition to construction and safety standards, the MHCC also develops proposed model installation

[3]NFPA is a nonprofit organization that focuses on the prevention of fire and other hazards through codes and standards, research, training, and education. First published in 1940, NFPA 501 Standard for Manufactured Housing establishes minimum criteria for manufactured homes and is updated periodically. The NFPA has a HUD contract to provide administrative, managerial, and technical support to the MHCC.

[4]24 C.F.R. Part 3280.

[5]Pub. L. No. 106–569, Title VI.

standards for the manufactured housing industry. Two-thirds of MHCC members must approve a proposal before the committee recommends it to HUD.

As part of the oversight of manufactured homes, HUD approves certain state agencies and private third-party entities to inspect manufactured housing plants and determine whether manufacturers are complying with the HUD Code. Each manufacturer contracts with two types of third-party entities, a Design Approval Primary Inspection Agency (DAPIA) and In-plant Production Primary Inspection Agency (IPIA). DAPIAs review and approve all home designs, design changes, and each plant's quality assurance manuals. To ensure that homes comply with the HUD Code, manufacturers contract with IPIAs to approve and monitor their quality control programs by inspecting each home at some stage of production in the plant. IPIAs issue the HUD label that is attached to each section of the home upon completion (see fig. 1).

**Figure 1: HUD Label**


Source: HUD.

## Ventilation Standards Used for Manufactured Homes

Builders of manufactured homes, as well as site-built and modular homes, are designing more tightly constructed homes that have less natural air infiltration in order to reduce energy costs for consumers. Without proper ventilation, a home's occupants may be exposed to a buildup of harmful contaminants, such as carbon monoxide,

**Federal Efforts to Improve Indoor Air Quality**

**HUD's Healthy Homes Program**
Promotes research, assessment and intervention methods, and public education of housing-related health hazards, such as mold, dampness, and poor indoor air quality.

**Department of Energy's Indoor Air Quality Project**
Aims to reduce ventilation energy demands without compromising indoor air quality, improve ventilation standards, and enable energy-efficient building practices.

**Environmental Protection Agency**
Regulates toxic chemicals and promotes healthy indoor air quality in homes, schools, and large buildings.

**Centers for Disease Control**
Promotes public health in homes, schools, and workplaces and monitors carbon monoxide-related illness and death.

**Consumer Product Safety Commission**
Works to ensure the safety of consumer products, including furnaces and carbon monoxide detectors, through voluntary and mandatory standards, recalling products, and researching potential product hazards.

**National Institute of Standards and Standards**
Researches indoor air quality in buildings, including the ventilation of manufactured homes.

**Occupational Safety and Health Administration**
Publishes guidance on indoor air quality in commercial and institutional buildings.

formaldehyde, and mold.[6] In addition to the HUD Code, multiple federal agencies have an interest in and have made efforts to improve indoor air quality in buildings.

To prevent indoor contamination and compensate for less natural air in manufactured homes, the HUD Code requires a whole-house ventilation system consisting of either mechanical ventilation or systems combining mechanical and passive ventilation.[7] Mechanical ventilation uses fans and ducts to bring fresh air into the home or draw contaminated air to the outdoors. Passive ventilation takes place naturally through windows, doors, and other air leakage sites. One common mechanical ventilation approach uses an outdoor air intake that is connected to the air distribution system return duct and that carries fresh air into the home whenever the furnace fan operates. Another approach uses a whole-house exhaust fan, which draws contaminants from the home to the outdoors. In both cases, the system releases air to the outdoors through an exhaust vent, preventing the build-up of contaminants indoors. Although mechanical ventilation is becoming more common, most older site-built homes have relied on passive ventilation.

To help ensure that contaminants that accumulate indoors are adequately vented out of the home and replaced with fresh outside air, the HUD Code requires a certain whole-house ventilation airflow rate. This rate specifies the volume of air that should be "replaced" over time—that is, fresh air drawn into the ventilation system as contaminated air is expelled. HUD requires an airflow rate of least 0.035 cubic feet per minute for each square foot of interior floor space or its hourly average equivalent. The ventilation system is required to produce between 50 and 90 cubic feet per minute to achieve this whole-house airflow rate.[8]

[6]Carbon monoxide is particularly hazardous because it is colorless, odorless, and tasteless. According to Centers for Disease Control (CDC) estimates, from 1999 to 2004 an average of 439 persons died annually from unintentional, non-fire-related carbon monoxide poisoning. CDC estimates from 2000 to 2009 show that about 78 percent (53,039) of carbon monoxide exposure-related incidents occurred in the home.

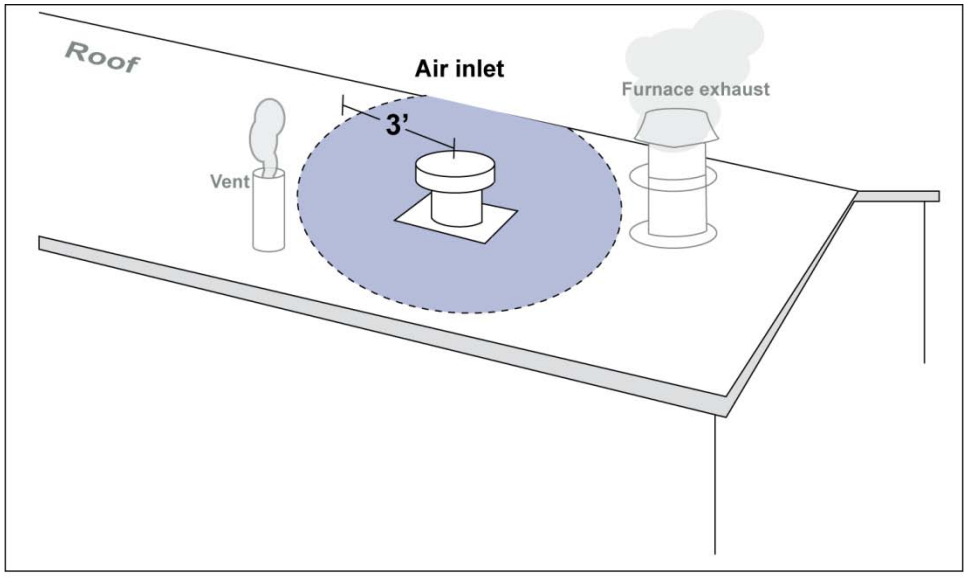
[7]24 C.F.R. § 3280.103(b)

[8]24 C.F.R. § 3280.103(b).

## Ventilation and Air Quality Standards Differ between Manufactured and Site-Built Homes

Standards exist for separating air intakes and exhaust vents in both manufactured and site-built homes, but standards for the two types of homes differ. Since 1976, HUD's ventilation system specifications for manufactured homes have required that any fresh air intake be at least 3 feet from any exhaust vent—for example, from a gas furnace exhaust or plumbing system vent. (See fig. 2.)

**Figure 2: HUD Code's Separation Requirement for Fresh Air Intakes and Exhaust Vents, 2012**




Source: GAO.

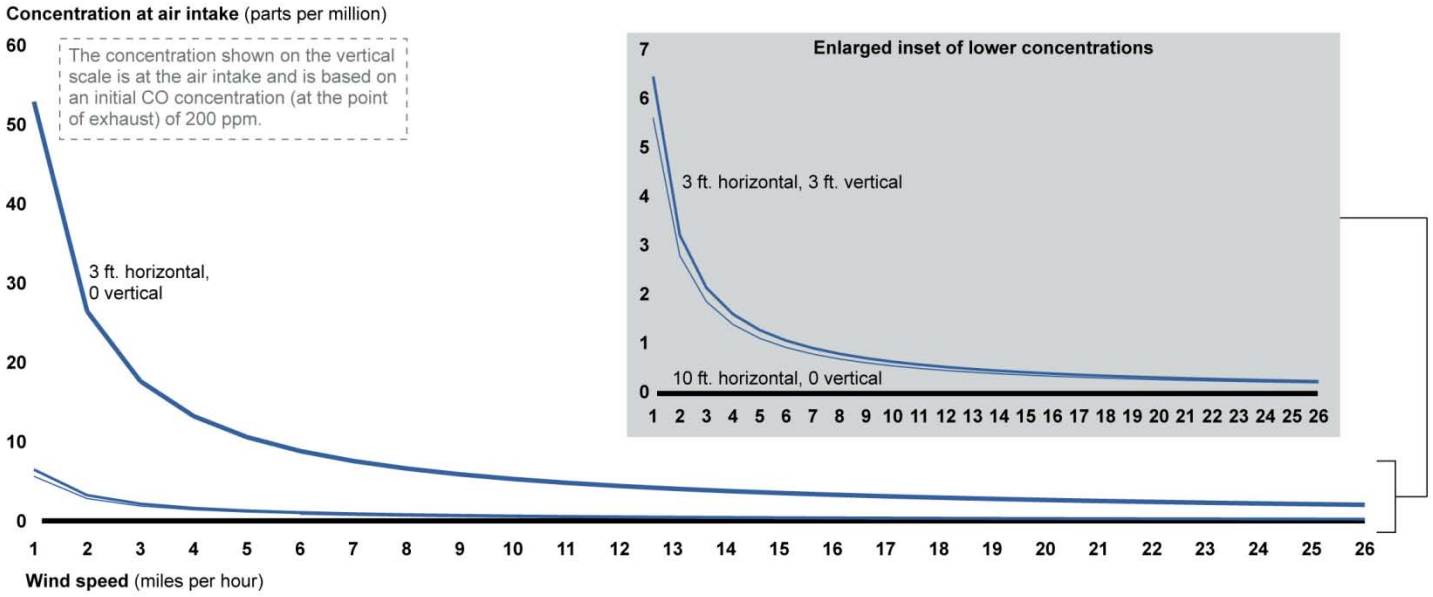
Compared with the HUD Code, industry standards commonly used for site-built homes recommend a greater distance between air intakes and exhaust vents. State and local building codes commonly cite generally accepted ventilation standards from ASHRAE and the International Residential Code (IRC). Specifically, ASHRAE requires a 10-foot horizontal separation between any air intake and exhaust vent. Additionally, IRC requires either a 10-foot horizontal separation or a minimum vertical separation of 3 feet if the horizontal separation is less than 10 feet.

Industry standards that address the separation distance between air intakes and exhaust vents were created to reduce the possibility that contaminants in the exhaust, such as carbon monoxide, would reenter the building. Experts associated with testing and establishing ventilation

standards said that increasing the distance between the air intakes and exhaust vents would improve the margin of safety, making it less likely that contaminants, such as carbon monoxide, could reenter the home. Experts explained, however, that such an event would occur rarely and would require a combination of several factors. They noted that the exhaust of a properly functioning furnace would contain relatively low levels of carbon monoxide (e.g. less than 4 parts per million (ppm)). They also noted an improperly functioning furnace, however, could produce hazardous carbon monoxide levels that, coupled with unique wind conditions, could result in carbon monoxide gas reentering a home through a fresh air intake. Because carbon monoxide is produced by incomplete combustion in fuel-burning devices such as gas furnaces, contamination is most likely in homes utilizing combustible fuels for heating and with an outdoor air intake connected to the air distribution duct system.

Our analysis of scenarios involving the dispersion of exhaust containing carbon monoxide demonstrated that the contaminant was less likely to reenter a building when the separation distance between an air intake and exhaust vent was increased. Using calculations recommended by ASHRAE, we quantified the difference in contaminant concentrations at the air intake as a function of wind speeds for various exhaust vent to air intake separations. As shown in figure 3, across a range of wind speeds, contaminant concentrations at air intakes placed either 10 feet horizontally or 3 feet horizontally and 3 feet vertically from an exhaust vent are less than contaminant concentrations that would be expected at an air intake separated just 3 feet horizontally (HUD Code requirement) from an exhaust vent. The figure also shows that the effect of separation distance on concentration levels is particularly evident at low wind speeds. For example, in a light 1 mph wind, exhaust with a carbon monoxide concentration of 200 parts per million (ppm) would be diluted to approximately 50 ppm at an air intake separated 3 feet horizontally from the exhaust vent. Increasing the separation between the exhaust vent and air intake to either 10 feet horizontally or 3 feet horizontally and 3 feet vertically in a 1 mph wind results in carbon monoxide concentrations of less than 10 ppm at the air intake.

**Figure 3: Air Intake Contaminant Concentration at Different Wind Speds for Various Exhaust Vent to Air Intake Separations**




Source: GAO analysis based on the *ASHRAE Handbook of Fundamentals*.

Note: The lines shown in the figure were generated using an exhaust-to-intake dilution calculation, based on recommendations from ASHRAE members, with parameters typically found in manufactured housing. Among the parameters used in our scenario, we assumed a capped exhaust vent with a diameter of 4 inches, which emitted exhaust at a speed of 1000 feet per minute, and which contained a CO concentration of 200 parts per million (ppm). The dilution levels determined by use of the calculation will vary based on changing these and other parameters. See Appendix I for a more detailed discussion of our use of the ASHRAE dilution equations.

These results were consistent with statements made by indoor air quality experts that increasing the distance between air intakes and exhaust vents reduces the concentration of contaminants such as carbon monoxide from reentering a home.

Concerns about the risk of carbon monoxide reentering the fresh air intake of a manufactured home were presented to the MHCC in July 2009, including an explanation of the differences between current industry standards and the HUD Code. That is, the MHCC viewed a presentation prepared by an individual who claimed an incident of carbon monoxide reentering a home built to the existing HUD Code requiring a separation distance of 3 feet.

HUD officials told us that the agency, in its oversight capacity for the Manufactured Housing Program, had not received any reports, other than the incident described above, either directly or from state administrative

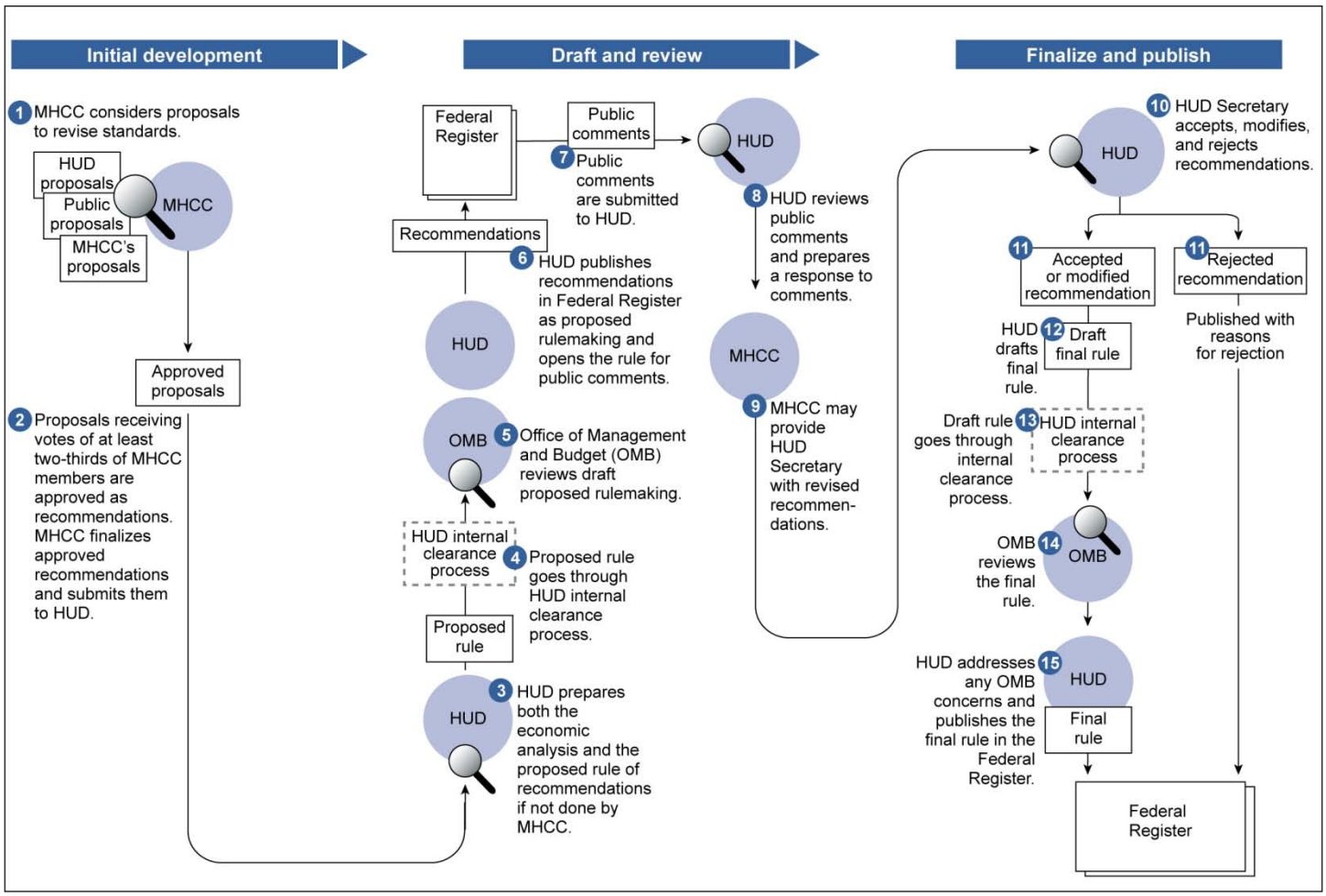
agencies, on cases of carbon monoxide reentering manufactured homes through fresh air intakes. We also contacted several state administrative agencies in the five states we reviewed, all of which stated that they had not received reports from consumers of any incidents of carbon monoxide reentering a home through a fresh air intake. HUD has not conducted or sponsored research to determine an appropriate separation distance between the fresh air intakes and exhaust vents since the HUD Code was established in 1976, according to HUD officials. However, HUD has sponsored research related to whole-house ventilation that discusses airflow rate issues.

Industry standards also call for carbon monoxide detectors in all site-built and modular homes. These detectors are not intended to be used as a measure of, or to test for, adequate indoor air quality but are a safety device to warn occupants in the event of a dangerous build-up of carbon monoxide gasses in the air. IRC and ASHRAE have required carbon monoxide detectors for residential site-built and modular homes since 2009 and 2010, respectively. While the MHCC has recommended this standard be required for all new manufactured homes, it is not yet a requirement in the HUD Code.

## Updates to the HUD Code on Key Standards Related to Ventilation and Air Quality Lag behind Industry Standards for Site-Built Homes

As of April 2012, HUD officials stated they were reviewing 84 MHCC recommendations on changes to the HUD Code. However, time delays associated with considering updates to the HUD Code continue to exacerbate differences between standards for manufactured and site-built homes. These include MHCC recommendations and proposed changes related to ventilation and indoor air quality that HUD has begun considering to bring the HUD Code in line with industry standards. However, HUD's process for considering and approving proposed changes, which includes development and consideration of proposed changes by the MHCC, can take many years (see fig. 4). Despite the outstanding proposed changes that are being considered, HUD has not adopted any changes to the HUD Code since 2005. Another set of proposed updates to the HUD Code were published in the *Federal Register* in 2010, and a final rule is currently under review at HUD, according to HUD officials. Further, other proposed updates being considered by HUD have not yet been published in the *Federal Register* as proposed updates to the HUD Code. These include MHCC safety designated items related to air quality and ventilation.

**Figure 4: GAO Analysis of HUD Processes for Updating the HUD Code**




Source: GAO analysis of HUD information.

MHCC recommended in 2010 that HUD increase the separation distance between air intakes and exhaust vents. HUD officials said that HUD is now considering this recommendation to increase the separation distance toward industry standards, which were modified in 2003. The requirements for this separation distance in the HUD Code have remained unchanged since 1976, when HUD first established the HUD Code. We found that IRC and ASHRAE standards on ventilation were periodically updated about every 3 years.

Specifically, in the 2003 version of its residential ventilation standards, ASHRAE stated several reasons for the need to update the standards, including:

- recognition by government agencies on ties between indoor air quality and health effects;
- increasingly more energy-efficient, air-tight homes being constructed;
- increased concerns over residential indoor air quality and ventilation; and
- the importance of adequate whole-house ventilation to improve air quality.

According to HUD officials, HUD is currently considering the MHCC recommendation to increase the distance between the air intakes and exhaust vents to a 3-foot vertical separation if the horizontal distance is less than 10 feet. MHCC developed the proposal after hearing the public testimony in July 2009 alleging that exhaust from a vent reentered a manufactured home through the air intake and caused carbon monoxide poisoning. MHCC made the recommendation to HUD in April 2010, but as of August 2012, HUD had not published a proposed rule in the *Federal Register*. A HUD official explained that HUD had received and is considering the MHCC recommendation to revise the current separation distance required between air intakes and exhaust vents. That is, HUD has not completed its internal clearance process – step 4 in figure 4.

HUD is also considering an MHCC recommendation to require installation of carbon monoxide detectors for all new manufactured homes. MHCC made this recommendation in December 2009. Similarly, HUD officials stated that HUD has not completed the economic analysis or drafted the proposed rule for this recommendation. As we have seen, other organizations that set industry standards already have this requirement—the IRC since 2009 and ASHRAE since 2010.

The Manufactured Housing Improvement Act of 2000 established a 1-year time limit for HUD to publish decisions on MHCC recommendations in the *Federal Register*.[9] HUD's website states that statutory language

[9]Pub. L. No. 106-569 requires the Secretary of HUD to either accept, reject, or modify proposed changes to the HUD Code within 1 year and publishing the decisions for notification or further comment in the *Federal Register*.

requiring the MHCC to submit recommendations to HUD in the form of a proposed rule, including an economic analysis, is impractical.

HUD explains that the MHCC does not have the technical expertise to present HUD with a rule package that meets the requirements of the *Federal Register* and the Administrative Procedure Act. HUD collects the necessary supporting information and then prepares the proposed rule. According to HUD, proposals that the MHCC recommends are then subject to a review and clearance process—which can be lengthy—first within HUD and then are subject to review and approval by the Office of Management and Budget. We plan to assess these rulemaking issues, including options for accelerating the process, in future work.

We also observed several administrative challenges facing the Manufactured Housing Program. For example, NFPA temporarily suspended its administration of the MHCC in May 2012, citing that HUD had not yet paid invoices supporting the committee. Later, NFPA officials stated they had resumed the function for administering the MHCC after HUD paid the outstanding funds due. Further, MHCC members we spoke to told us that HUD's Office of Manufactured Housing was understaffed and lacking in resources, possibly contributing to delays in updating the standards. HUD officials stated that the Manufactured Housing Program and its processes can be labor intensive. The program has 10 authorized staff positions. The office has been run by an Acting Deputy Administrator since July 2011. The Administrator position has been vacant since 2010.

Industry officials also told us that the federal rulemaking process for manufactured housing was slow because manufactured housing was not a priority for HUD. We found the priority given the program is unclear. HUD's strategic plan does not include the manufactured housing program among those contributing to HUD's priority goal of promoting healthy, energy-efficient, and affordable buildings.

## Millions of Manufactured Homes Have Been Built under the HUD Code but HUD Has Not Tested the Performance of Installed Ventilation Systems

HUD does not maintain data on the number of manufactured houses built or the distances between vents and air intakes of homes designed with an outdoor air intake connected to the air distribution system. American Housing Survey estimates showed that in 2009 many of the approximately 6.8 million occupied manufactured homes had been built under the HUD Code. Specifically, about 5.5 million of these units had been built after 1975.[10] The 3-foot separation requirement between air intakes and exhaust vents has been in effect since 1976 and thus applied to these homes. According to the American Housing Survey, about half (52 percent) of occupied manufactured homes used electricity as their main heating source, and most of the remaining 48 percent used a combustible fuel source.[11] As we have mentioned, experts said carbon monoxide exposure—although rare—is most likely in homes that use a combustible fuel source, or nearly half of the manufactured homes identified in the survey.

According to HUD officials, although it does not have data on the actual distances between vents and air intakes of constructed homes, HUD retains copies of all DAPIA approved design packages, which include requirements for this separation. As validated by DAPIAs, designs of manufactured homes are developed with the intent of meeting the HUD Code. Two large manufacturers we spoke to, which accounted for about 60 percent of the market, stated that they did not track the distances between vents and air intakes of each home, but that their homes met HUD standards—that is, the distances were at least 3 feet for homes with air intakes.

### Data on the As-Installed Performance of Ventilation Systems in Manufactured Homes are Limited

Furthermore, we found that the HUD Code does not require testing of the performance of the ventilation system, including the resulting whole-house airflow rate of homes, either at the plants or once the homes are put in place. HUD officials told us that the DAPIAs review designs to help ensure the performance of ventilation systems meets the HUD Code. In particular, DAPIAs ensure that designs include the required exhaust fans to move a certain volume of air that should achieve the specified whole-

[10]The relative margins of error for these estimates are between 4.41 and 13.70 percent.

[11]Estimates are from the Census Bureau's 2009 American Housing Survey. The margins of error are between 1.40 and 4.70 percent.

house airflow rate.[12] HUD officials stated that IPIAs are not required to test the whole-house airflow rate either in the plant or in the field because the HUD Code does not require it. In contrast, the HUD Code does require the inspection and testing of other specified features, such as gas lines, smoke alarms installed at the factory, and plumbing systems.[13]

Air quality experts we spoke with emphasized that a variety of factors could impact the whole-house airflow rate. For example, one expert said duct leakage and friction could result in airflow losses. Therefore, an approved design may assume a certain airflow rate for an exhaust fan, but the quality of construction could reduce the whole-house airflow rate upon installation. Additionally, several studies by the Department of Commerce's National Institute of Standards and Technology (NIST) indicated that the whole-house airflow rate of manufactured homes depended on how often the fans were operated, as well as weather and climate factors. In 2008 and 2010 NIST reported that some airflow rates in a test home were below levels specified in the HUD Code. Because HUD does not require testing to validate the performance of ventilation systems, specifically the resulting whole-house airflow rates, it does not know how the systems are performing or whether they meet HUD specifications.

Cooperative research in 2003 involving HUD and the Manufactured Housing Research Alliance concluded that it was unclear how well whole-house ventilation systems in manufactured homes performed with respect to the HUD Code's whole-house airflow rate performance specification.[14] According to the study and HUD officials, identifying a typical airflow rate for manufactured homes is challenging because factors such as temperature, wind, location of the home, and construction type have varying impacts on the natural infiltration in similar homes. The study recommended that HUD:

[12]24 C.F.R. § 3280.103 (b). The HUD Code also requires mechanical ventilation systems to have a manual control and for the instructions to encourage consumers to operate the system whenever the home is occupied. 24 C.F.R. § 103(b)(4), (6).

[13]24 C.F.R. § 3280.706(l)(8), 3280.208(f), 3280.612.

[14]The Manufactured Housing Research Alliance is now named the Systems Building Research Alliance. The mission of this nonprofit organization is to develop new technologies to enhance the value, quality, and performance of both manufactured and modular homes.

- conduct further research to develop a testing method to determine whether specifications for ventilation design and performance were being met, and
- publish guidelines for achieving the required airflow rate in manufactured homes in a best practices manual to be created for the industry.

As of August 2012, MHCC was considering a proposal to adopt an industry standard for residential ventilation that includes testing to ensure that ventilation systems meet performance specifications. Requirements for testing the ventilation system after installation were incorporated in ASHRAE's ventilation standards for residential homes in 2003. The current proposal with the MHCC includes testing the delivered airflow of the system, using an airflow measuring device to confirm the airflow of the system.

HUD officials acknowledged that the recommendations from the 2003 study had not been implemented and cited funding issues as reasons for not implementing them. According to HUD officials, HUD has not received negative reports on indoor air quality in manufactured homes that occurred as a direct result of the whole-house ventilation systems. However, without testing of the actual whole-house airflow rates of recently manufactured homes, HUD cannot know whether these homes, as built, meet HUD's requirement of 0.035 cubic feet per minute for each square foot of interior floor space. Still, the ventilation standards establish standards for airflow, not air quality, although the required airflows are intended to enhance air quality in the home.

Measuring the actual airflow achieved by installed ventilation systems would not only permit HUD to know whether its standards are being met, but also permit HUD to better understand the potential impact ventilation systems may have on indoor air quality. In the next section we discuss limitations in HUD's standard.

## The HUD Code Airflow Rate Is Based on Standards and Research from 1993

We found that the performance specifications for the whole-house airflow rate in the HUD Code were based on industry standards and assumptions from nearly 20 years ago. As we stated earlier, HUD has not tested these performance specifications as manufactured homes are built and installed. In 1993, HUD first set a standard for the whole-house airflow

rate, basing it on the ASHRAE standards from 1989 and ventilation research by NIST and the U.S. Department of Agriculture's Forest Products Laboratory.[15] The original whole-house airflow rate requirement aimed at replacing about one-third of the air in a manufactured home with fresh air each hour (that is, 0.35 total air changes per hour). As part of this requirement, HUD also assumed natural infiltration would account for 0.25 air changes per hour and required mechanical ventilation to provide the remaining 0.1 air changes per hour. Therefore, the HUD Code in 1993 specified that each manufactured home shall be provided with mechanical whole-house ventilation having a minimum capacity of 0.035 cubic feet per minute for each square foot of interior space in order to achieve a minimum rate of 0.1 air changes per hour. In 2005, HUD removed the natural infiltration assumption but kept the same rate for mechanical ventilation.

Since 1993, HUD has continued to specify a mechanical whole-house ventilation airflow rate of least 0.035 cubic feet per minute for each square foot of interior floor space or its hourly average equivalent.[16] Air quality experts emphasized that homes have continued to be built with less leakage and greater energy efficiency. Thus, a home built in 1993 and a home built in 2012 may both meet the HUD whole-house airflow rate standard (that relates only to ventilation achieved through mechanical means) but may not achieve the same level of air quality. Nonetheless, HUD has not reconsidered the appropriateness of its standard in achieving an acceptable level of air quality, nor specified an acceptable level of air quality. Without further research and testing of its whole-house airflow rate standard, HUD may not know the effect of new design and construction practices on the overall ventilation performance and air quality of manufactured homes.

## Conclusions

Current standards used for site-built and modular homes offer a greater margin of safety against carbon monoxide exposure than the HUD Code standards used for manufactured homes. While carbon monoxide

[15]As of 2010, ASHRAE requires specific fan flow rates depending on the floor area, the number of bedrooms, and the number of occupants rather than the fixed airflow rate of 0.35 air changes per hour.

[16]24 C.F.R. § 3280.103(b). In 2005 the HUD Code also first required exhaust fans to produce between 50 and 90 cubic feet per minute to achieve this airflow rate.

exposure resulting from exhaust reentering the home through an air intake is unlikely, air quality experts we spoke to maintain that industry standards already required for site-built homes offered a greater margin of safety to prevent carbon monoxide from reentering a home than the HUD Code does for manufactured homes. Our analysis also confirmed that increasing the separation distance between air intakes and exhaust vents to industry standards decreased the likelihood of carbon monoxide reentering the home. Further, industry standards for site-built homes call for the use of a carbon monoxide detector whereas the HUD Code does not. In response, the MHCC has forwarded safety-designated recommendations to HUD to update the HUD Code to address concerns over the separation distance between air intakes and exhaust vents and the lack of a requirement for carbon monoxide detectors in manufactured homes.

The differences between the HUD Code and industry standards related to home ventilation and indoor air quality are due to the regulatory procedures and time it takes HUD to consider and implement proposed updates. Although we observed proposals aimed at maintaining similar standards for manufactured and site-built homes, proposed updates for manufactured homes lagged behind those made by industry for site-built and modular homes. HUD's process for adopting changes to the HUD Code involving considerable time for proposals to be considered by the MHCC and HUD has resulted in a lack of action even on safety-related proposals that the MHCC has put forth, including increasing the separation requirement for air intakes and exhaust vents and requiring carbon monoxide detectors. Although MHCC has submitted several recommendations to HUD, HUD has not implemented any changes to the HUD Code since 2005, so actual implementation of recent updates may be years away. We will explore rulemaking and other issues with the Manufactured Housing Program in further work.

HUD does not maintain data on the actual separation distances between the fresh air intakes and exhaust vents, but does retain copies of designs with DAPIA approval, indicating they comply with the HUD Code. We noted that 5.5 million occupied manufactured homes were built since the HUD Code took effect with a 3-foot separation requirement, and almost half of manufactured homes built use combustible furnace fuels. However, we found limited data available related to the installed performance of the ventilation systems of manufactured homes constructed and placed. HUD does not require manufacturers to test the performance of the ventilation systems installed in manufactured homes to determine whether the systems actually meet their performance

specifications. Further, while the HUD Code specifies certain inspections and tests to validate many other features of manufactured homes, HUD does not require manufacturers to conduct performance testing of the ventilation system, specifically the required whole-house ventilation airflow rate. Other research efforts have previously voiced similar concerns over uncertainties as to whether the performance specifications of the ventilation system were being met in manufactured homes. Ultimately, without testing the whole-house airflow rate for constructed manufactured homes, either in the factory or the field, HUD and others cannot be assured as to whether the airflow is ventilating the home as specified.

We also found that the current HUD code performance specification for the whole-house ventilation airflow rate is based on standards and research from nearly 20 years ago. Since then, air quality experts and research suggest that the industry has improved the construction of manufactured homes. To the extent that manufactured homes continue to be built tighter and more energy efficient, mechanical ventilation of homes becomes more important for ensuring indoor air quality. HUD's whole-house airflow rate standard for mechanical ventilation of 0.035 cubic feet per minute per square foot of living space has remained unchanged. Without further assessment of the impact that potential changes in natural air infiltration have on whole-house ventilation, HUD cannot be certain of the air quality in manufactured homes.

## Recommendations for Executive Action

To better ensure that air ventilation systems in manufactured homes perform as specified and meet the HUD Code, we recommend that HUD develop an appropriate method to test and validate the performance of the ventilation system as part of the HUD certification process.

To ensure that its specification for airflow continues to be appropriate, we recommend that HUD reassess the assumptions for the whole-house ventilation specification, working with the MHCC, to determine the appropriate rates, taking into consideration current natural air infiltration, to achieve the whole-house ventilation performance, considering the expected impact such ventilation would have on indoor air quality.

## Agency Comments and Our Evaluation

We provided a draft of this report to HUD for review and comment. HUD's Acting Assistant Secretary for Housing-Federal Housing Commissioner provided written comments that are discussed below and presented in

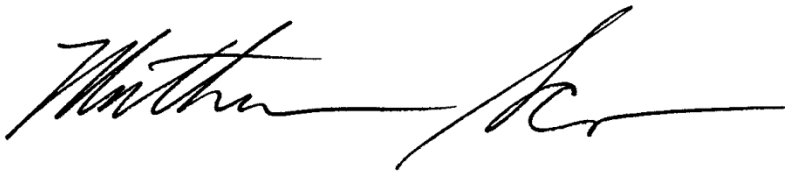
Appendix II. HUD also provided technical comments that were incorporated as appropriate.

HUD agreed with both recommendations, noting that it would bring them before the MHCC for consideration. HUD also said, however, that it would require additional funding and resources. Specific to our recommendation that HUD develop an appropriate method to test and validate the performance of the ventilation system as part of the HUD certification process, HUD agreed that such testing and validation could improve the accuracy of system performance. But HUD also questioned the need for such testing, given that the current systems were designed and approved by private design professionals. HUD further noted that no documentation existed showing that ventilation systems in manufactured homes did not meet current standards. But as our report points out, HUD lacks such documentation because it does not systematically test the systems. HUD also stated that it would be impractical to conduct testing at the factory for multi-section units. However, testing of the whole-house airflow rate could occur in the field as well as at factories, when practicable.

We also recommended reassessing the assumptions for the existing whole-house ventilation airflow rate specification. HUD agreed that a reassessment of the assumptions used to determine the appropriate rate could have a positive impact on indoor air quality. HUD also said that it would need to balance changes in these requirements against costs incurred by manufacturers and consumers. As we noted in the report, the existing whole-house ventilation airflow rate requirement (0.035 cubic feet per minute per square foot of living space) is based on assumptions for natural air infiltration dating back to 1993. HUD noted in its technical comments that no evidence existed to support the argument that the ventilation standards for manufactured homes were less effective than industry standards. Further, HUD said that its standards provide rates of mechanical ventilation that are comparable to those provided by industry standards. However, without further assessment of the impact that potential changes in natural air infiltration have on whole-house ventilation, HUD cannot be certain of the air quality in manufactured homes. Reassessing assumptions made nearly 20 years ago would help determine whether HUD's required whole-house ventilation airflow rate continues to ensure that manufactured homes are properly ventilated.

We are sending copies of this report to appropriate congressional committees and the Secretary of Housing and Urban Development. The report also is available at no charge on the GAO website at http://www.gao.gov.

If you or your staff have any questions about this report, please contact me at (202) 512-8678 or sciremj@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made major contributions to this report are listed in appendix III.



Mathew J. Scirè
Director,
Financial Markets and Community Investment

# Appendix I: Comparison of Different Separation Distances Between Air Intakes and Exhaust Vents and Impacts on Potential Carbon Monoxide Exposure

Reentry of exhaust occurs when exhaust leaving its vent finds its way to an air intake and gets pulled back into the home. The common mitigation practice is to provide adequate horizontal or vertical separation between the exhaust vent and the air intake such that any reentered air is diluted to a greater extent by the time it reaches habitable areas of the home.

In their Handbook of Fundamentals, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) provides methods for modeling the diluting effect of an exhaust stream mixing with open air. ASHRAE officials we spoke with told us that these methods can be used to assess solutions to various ventilation problems including exhaust air reentry scenarios. Therefore, we used these techniques on a simple model of a manufactured home to analyze how much carbon monoxide in the exhaust stream of the furnace in the home could be diluted by the time it reached an air intake of the home. We analyzed different scenarios involving various separation distances between the exhaust vent and the air intake to see what effect separation distance produced on the amount of dilution provided by open air mixing.

Dilution of contaminants occurs through mixing of the exhaust stream with fresh air as the stream leaves its vent, enters open air, is affected by the wind, and spreads away from the vent, dispersing contaminants in the stream as it progresses. In general, dilution increases with increasing wind speed, as might be expected, because a stronger airflow will aid in dispersing contaminant particles, and is inversely proportional to both the speed with which the exhaust stream is coming out of the vent, as well as the size of the vent opening. This makes sense because increasing exhaust speed and increasing vent size, naturally, competes against dilution by putting more contaminant into the air.

However, the mixing is not straightforward, as many factors can influence how much dilution takes place. For example, the airflow closer to the ground can be disrupted by obstacles such as trees and buildings, inducing turbulence in the flow. At roof level, vents and even the pitch of the roof can further complicate the flow, creating a mix of eddies and zones where the air might get recirculated and trapped near the roof, thus restricting the dilution effect. This is sometimes the case at lower exhaust speeds and lower wind speeds, where the exhaust plume will not have the momentum to rise very high or get dispersed very quickly by the wind and may get pushed down and remain near roof level and the air intake.

In implementing their model, ASHRAE assumes the air intake is positioned directly downwind of the exhaust vent and then allows for a

variety of parameters to specify the geometries involved; for example the height of the roof, the horizontal and vertical separation distances between the exhaust vent and the air intake, and the size of the exhaust vent opening. In addition, ASHRAE allows for specifying characteristics of the exhaust stream, such as the speed with which the exhaust is exiting the vent, and the initial concentration of a contaminant within the stream at the vent opening. Finally, ASHRAE models the flow of the air through a number of factors that include the wind speed, the downwind, cross-wind, and vertical spread of the plume as it progresses downstream, and the turbulence intensity of the air, which is controlled by a factor that allows for specifying the roughness of the terrain over which the air will be flowing.

In our analysis, we used three different scenarios for separation distances between the air intake and exhaust vent—3 foot horizontal, 10 foot horizontal, and 3 foot horizontal with a 3 foot vertical separation. Table 1 also shows the specific parameters we used in our analysis. These included a manufactured home with a roof height of 10 feet and an exhaust vent diameter of 4 inches. We used an initial carbon monoxide concentration in the exhaust stream of 200 ppm, which experts have told us could occur in the exhaust stream of a malfunctioning furnace.

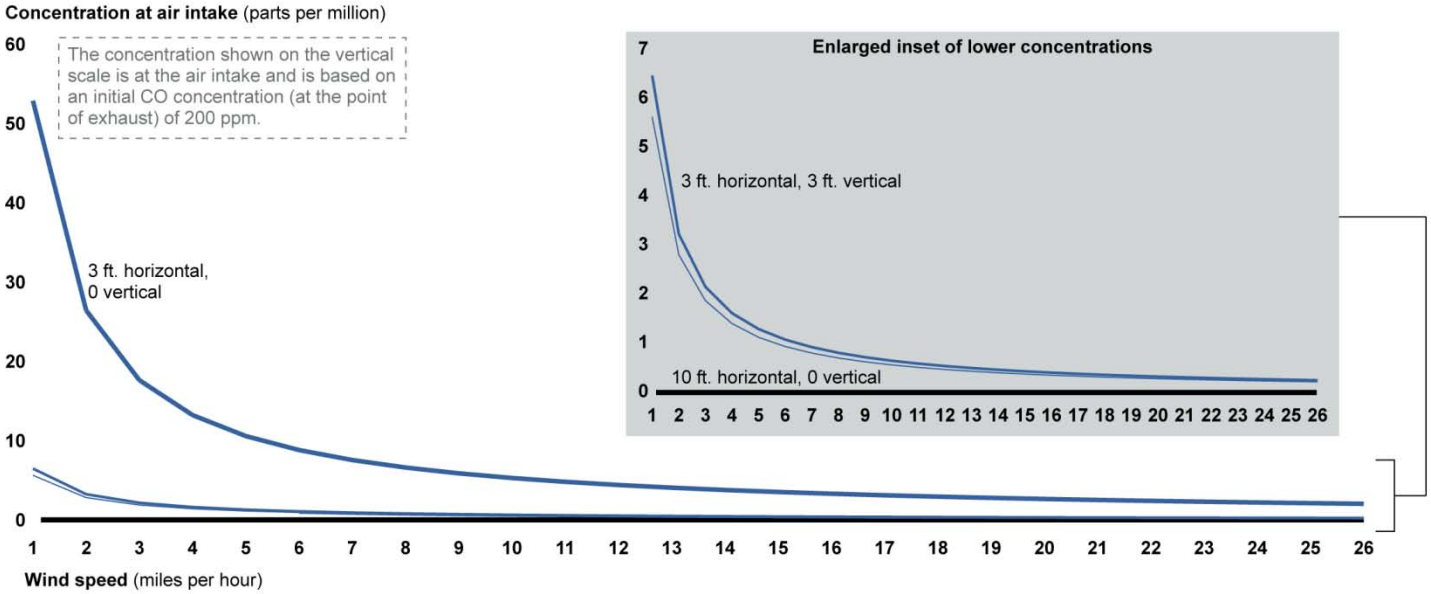
**Table 1: Parameters Used in Our Analysis**

| Parameter | Value | Notes |
|---|---|---|
| Height of the roof | 10 ft | Height of the roof off the ground at the gutter. |
| Horizontal distance between the exhaust vent and the air intake | Variable | We assessed cases with horizontal separation distances of 3 feet and 10 ft. |
| Vertical separation distance between the exhaust vent and the air intake | Variable | We assessed cases of no separation (0) and a separation of 3 feet. |
| Diameter of the exhaust vent opening | 4 inches | Diameter of the exhaust vent opening. We considered the exhaust vent to be capped. |
| Exhaust stream speed | 1000 feet per minute (fpm) | ASHRAE representatives mentioned 100-2000 fpm are typical values for residential furnaces. |
| Initial carbon monoxide concentration | 200 ppm | Concentration at the exhaust vent opening of an assumed carbon monoxide component in the exhaust stream. |
| Wind speed | Variable | We assessed scenarios varying the wind speed from 1 to 26 mph (about 88 to 2288 fpm). |
| Roughness factor | 2.132 | Characterizes airflow over the terrain. This is the value ASHRAE specifies for a suburban setting. For comparison purposes, a flat desert would have a value of 0.03 while an urban setting would have a value of 6.0. |

Source: GAO analysis based on the ASHRAE Handbook of Fundamentals.

Figure 5 represents the results of our analysis and illustrates contaminant concentration at the air intake as a function of wind speeds for various exhaust vent to air intake separations. Here it can be seen that increasing the horizontal separation to 10 feet or adding a 3 foot vertical separation to the 3 foot horizontal separation reduces the concentration at the air intake more than the 3 foot horizontal separation alone does. For example, in a light 1 mph wind, exhaust with a carbon monoxide concentration of 200 ppm would be diluted to approximately 50 ppm at an air intake separated 3 feet horizontally from the exhaust vent. Increasing the separation between the exhaust vent and air intake to either 10 feet horizontally or 3 feet horizontally and 3 feet vertically in a 1 mph wind results in carbon monoxide concentrations of less than 10 ppm at the air intake.

**Figure 5: Contaminant Concentration at Air Intake for Different Wind Speeds and Various Exhaust Vent to Air Intake Separations**




Source: GAO analysis based on the *ASHRAE Handbook of Fundamentals*.

# Appendix II: Comments from the Department of Housing and Urban Development

U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
WASHINGTON, DC 20410-8000

ASSISTANT SECRETARY FOR HOUSING-
FEDERAL HOUSING COMMISSIONER

SEP 28 2012

Mr. Mathew J. Scire
Director
Financial Markets and Community Investment
Government Accountability Office
441 G Street, NW
Washington, DC 20548-0001

Dear Mr. Scire:

Thank you for the opportunity to respond to the Government Accountability Office (GAO) draft report GAO-13-52 of September 17, 2012, entitled, "Manufactured Housing Standards: Testing and Performance Evaluation Could Better Ensure Safe Indoor Air Quality,"(GAO-13-52). This letter conveys the Department of Housing and Urban Development (HUD) response to the audit.

**Recommendation:**

HUD develops an appropriate method to test and validate the performance of the ventilation system as part of the HUD certification process.

**HUD Response:**

HUD agrees that the development of new methods to test and validate performance of ventilation systems could improve the accuracy of system performance; however, current systems are designed and approved by private design professionals to meet existing standards for each home design and HUD has no documentation to support that ventilation systems do not meet current standards. The development of new methods to test and validate the performance of ventilation systems by HUD will require additional funding and resources to accomplish and would be impractical to conduct at the factory for multiple section units. However, the Department is agreeable to bringing the recommendation before the Manufactured Housing Consensus Committee (MHCC) for consideration.

**Recommendation:**

HUD reassesses the assumptions for the whole-house ventilation specification, working with the MHCC, to determine the appropriate rates, taking into consideration current natural air infiltration, to achieve the whole-house ventilation performance, considering the expected impact such ventilation would have on indoor air quality.

**HUD Response:**

HUD agrees that a re-assessment of the assumptions for whole-house ventilation specification to determine appropriate rates could benefit the impact on indoor air quality. However, HUD notes that the current range of rates for whole-house ventilation of 50 cfm minimum to 90 cfm maximum is already comparable to those recommended by the Industry Standard, ASHRAE 62.2, for residential buildings of similar size and area. Any potential benefits obtained by changes to the current requirements for whole-house ventilation would need to be balanced against the costs incurred by the manufacturers and the consumers. HUD would require additional funding and resources to adopt GAO's recommendations. The Department is agreeable to bringing the recommendation before the MHCC for consideration.

We appreciate the efforts of the GAO to review testing and performance evaluation to ensure safe indoor air quality.

Sincerely,

Carol J. Galante
Acting Assistant Secretary for Housing-
Federal Housing Commissioner

# Appendix III: GAO Contact and Staff Acknowledgements

## GAO Contact

Mathew J. Scirè, (202) 512-8678 or sciremj@gao.gov

## Staff Acknowledgments

In addition to the contact named above, Andy Finkel (Assistant Director), Mike Armes, James Ashley, Tim Bober, Bill Carrigg, Emily Chalmers, Pamela Davidson, Juliann Gorse, Barry Kirby, John McGrail, Marc Molino, and Nadine Garrick Raidbard, made key contributions to this report.