Effect of Mastic on Duct Tightness in Energy Efficient Manufactured Homes – Thomas Hewes Oregon Department of Energy

INTRODUCTION

Over the last 18 years the Northwest manufactured housing industry and the region's utilities have maintained a partnership aimed at developing and marketing energy efficient manufactured homes throughout the Pacific Northwest. The Northwest Energy Efficient Manufactured Home (NEEM) program is a consortium of state agencies, utilities and manufacturers that has evolved from this relationship. Over 55 utilities offer rebates on NEEM homes. Approximately 60% of all manufactured homes built currently in the Northwest meet NEEM program standards and are among the most energy efficient manufactured homes in the United States. Quality control processes were developed and became an integral part of the program, to ensure that the homes meet NEEM, Building America Industrialized Housing Partnership (BAIHP) and EnergyStar guidelines. The U.S. Department of Energy BAIHP program also provides technical support to the NEEM consortium and, along with a DOE State Energy Program (SEP) Special Projects Building America grant, provided funding support for this study.

As part of the quality control process, field studies of a random sample of homes were conducted on homes manufactured in 1992-93, 1997-98 and 2001-02. Observations during these field tests led the NEEM program to suspect that a significant amount of reported duct leakage was due to failure of various duct sealing tapes.

HOMES BUILT AFTER JANUARY 1, 2004

Starting January 1, 2004, NEEM specifications were revised to require all central forced air duct systems to use UL181 AM or BM rated duct mastic for all sealing (the only exception is tape on duct board assemblies). To evaluate the efficacy of mastic used to seal ducts combined with in-plant duct leakage testing in the program, field data on 71 homes built after January 1, 2004, with duct systems sealed with mastic was collected and compared to data from previous studies in the region.

STUDY DESIGN/ RECRUIT SELECT HOME

The sample selection was one of convenience because we choose to test home before they were occupied and/or focused on occupied homes built by manufacturers who were also known to be duct testing at least some of their homes at the factory. NEEM inspectors also tests ducts in the 19 participating plants on a quarterly basis. Ten of the regions 19 factories (including all of the major builders) were represented in the sample. 41 homes sited in Oregon were tested from September 2004 through March 2006. Homes tested were all sited, set up and either occupied or ready for occupancy. 30 homes sited in Washington was tested between March 2005 and August 2005. Homes were visually inspected to confirm the use of mastic and identify obvious deficiencies.

ADOPT TESTING PROTOCOLS

Tests were performed with the same protocol to determine total duct leakage, duct leakage to the exterior, envelope leakage, and airflow through the systems. Air flows were determined with either a TrueFlow^{TM} air handler flow meter or duct tester pressure matching, depending on system configuration. Prior to summarizing the results of the duck leakage tests and the blower door tests cases that were suspect as a result of exponent values out of range were removed. A total of 3 blower door tests and 5 duct leakage tests were removed as a result of this screening.

PUBLISH REPORT ON THE ENERGY PERFORMANCE OF HOMES WITH MASTIC SEALED DUCTS AND NEW DUCT DESIGNS

Field Data

Duct Leakage Results

All homes tested used mastic to seal the duct work. Table 1a shows previously reported exterior duct leakage in Super Good Cents (SGC) and Manufactured Acquisition Program (MAP) homes in the Northwest. As reported (Davis and Baylon 2004) only about 12% of the tested SGC homes built in 2001-02 used mastic to seal ducts. Results are presented with both medians and means to preserve the previous reports' approach; in 1997-98 homes, outliers greatly skewed the mean.

Table 1b contains exterior duct leakage values for the homes in the current study. In general there appears to be about a 60% reduction in exterior duct leakage for the overall group compared to the 2001-02 study, and an overall 43% reduction compared to the previously best reported values from the 1992-93 MAP study.

Air handler flows in the current study averaged 1145 cfm . Duct leakage to the exterior at 25 Pascals was normalized to system flow.. The average leakage to the exterior at 25 Pascals/ft^3-minute was 5.0 %.

Duct leakage to the exterior at 25 Pascals was normalized to the home's conditioned floor area. In this measure the leakage was equal to about 3.4% of the floor area over the entire sample. The result in Table 2 is compared to previous studies and shows an improvement of more than 50% in the mean percentage.

TABLE 1a
Exterior Duct Leakage (Previously Reported)

Group	SGC Mfd homes built 2001-02 Medians (avgs)		SGC Mfd homes built 1997-98 Medians (avgs)		MAP 1992-93 (avgs except for triples)	
	Leakage @ 25 Pa (ft^3/min)	Leakage@ 50 Pa (ft^3/min)	Leakage @ 25 Pa (ft^3/min)	Leakage @ 50 Pa (ft^3/min)	Leakage @ 25 Pa (ft^3/min)	Leakage @ 50 Pa (ft^3/min)
All cases	131 (139) n=94	192 (209)	103 (151) n=47	159 (231)	(104)	(157)
Double section home	119 (132) n=69	180 (199)	97 (157) n=34	157 (240)	(101) n=124	(155)
Triple section home	176 (174) n=22	259 (265)	144 (134) n=13	223 (210)	122 n=11	169
Idaho	127 (151) n=20	187 (229)	106 (165) n=24	168 (254)	-	-
Oregon	135 (134) n=37	200 (198)	NA	NA	-	-
Washington	115 (132) n=39	179 (202)	103 (135) n=25	159 (208)	-	-

TABLE 1b
Exterior Duct Leakage (Current Study)

Group	SGC Mfd homes built after January 1, 2004 Medians (avgs)	
	Leakage @ 25 Pa (ft^3/min)	Leakage@ 50 Pa (ft^3/min)
All cases (Washington & Oregon)	51 (56) n=66	73 (80)
Single section home	53.0 (53.0) n=2	85.0 (85.0)
Double section home	49 (42) n=41	64 (71)

Triple section home	62 (65) n=21	88 (82)

TABLE 2
Leakage to Exterior Normalized to Conditioned Floor Area

Study	Mean %	Median %
Exterior duct leak @25 Pa/ft^2 of house area (Built after 1/1/2004, 66 homes)	3.4	3.0
Exterior duct leak @25 Pa/ft^2 of house area (2001-02 homes, 89 cases)	7.9	7.5
Exterior duct leak @25 Pa/ft^2 of house area (1997-98 homes, 49 cases)		5.9
Exterior duct leak @25 Pa/ft^2 of house area (1992-93 homes, 150 cases)	7.2	

Table 3 shows the total duct leakage as tested at the factory compared to the leakage to exterior as tested after set up in the field for the subset of sites where data for both were available. As can be seen in Table 3 the impact of in-plant testing is to improve the field observed exterior duct leakage by about 30%. Even with this small sample size this difference is statistically significant.

According to the U.S. Environmental Protection Agency it should be assumed "that 50 percent of the total measured duct leakage will leak to the outside after the home is set."[1] For the sample 55% of the total duct leakage at the factory was observed as leakage to exterior after set up on site. When the adjustments for indoor air handler were made this ratio rose to 114%.

TABLE 3
Total Leakage at Factory Compared to Leakage to Exterior on Site

	Total Leakage at Factory @ 50 Pa (ft^3/min)*	Leakage to Exterior on Site @ 50 Pa (ft^3/min)
In Plant Test (n=37)	126.0	70.0
No In-Plant Test (n=29)	n/a	92.8

***unadjusted gross leakage**

House Tightness

Northwest manufactured homes have gotten tighter over the past 14 years as can be seen in the blower door results summarized for previous studies in Table 4a. As seen in Table 4b, this trend has continued with the current study. In the current study, the minimum ACH_{50} is 1.31, and maximum ACH_{50} is 8.94. Only 11 cases out of 68 have ACH_{50} over 5.0. The nominal program standard was reduced from 7.0 ACH_{50} to 5.0 ACH_{50} effective January 1, 2004. The standard deviations in most categories are very similar to the 2000 and 2004 studies. These studies show less scatter than the original MAP results, which should be viewed as an indicator of successful quality control. The two single wide units tested have high leakage rates for both their duct systems and envelopes.

TABLE 4a
Blower Door Results (ACH_{50})

	SGC Mfd Homes 2001-02			SGC Mfd Homes 1997-98			MAP 1992-93		
Group	**# of cases**	**ACH_{50} average**	**Std. Dev.**	**# of cases**	**ACH_{50} average**	**Std. Dev.**	**# of cases**	**ACH_{50} average**	**Std. Dev.**
All	93*	4.16	1.02	49	4.76	0.95	157	5.50	1.87
Double Wide	66	4.30	1.03	36	4.90	0.99	127	5.50	1.90
Triple Wide	24	3.84	0.94	13	4.40	0.72	12	4.92	1.22
Idaho	19	4.59	0.96	25	4.63	0.81	32	6.12	1.55
Oregon	33	4.36	1.13	N/A	N/A	N/A	48	5.43	2.10

Washington	41	3.89	0.89	24	4.90	1.08	62	5.36	1.77

*Four cases thrown out for having unacceptable flow exponents, case weights applied

TABLE 4b
Blower Door Results (ACH50) Current Study

	SGC Mfd Homes built after January 1, 2004		
Group	**# of cases**	**ACH_{50} average**	**Std. Dev.**
All	68	3.82	1.42
Single Wide	2	6.14	1.35
Double Wide	44	3.88	1.46
Triple Wide	20	3.42	1.18

SHARE RESULTS AT SEMI-ANNUAL MEETINGS OF NEEM PARTNERS

The selection of homes in this study was not random but it did include 10 of the regions 17 manufacturers and all of the major manufacturers in the NEEM program. Based on this limited sample, indications are that the revision to the specifications starting in January 2004 requiring the use of mastic to seal duct systems has produced a significant improvement in duct tightness over all previous samples in the region. Duct leakage to the exterior after set up was reduced by 43% over the next best reported value in the region.

The comparison between the homes that received in-plant duct testing and those that did not showed a distinct improvement in overall performance with an in-plant quality control step. Indeed, about half of the benefit from the change in specifications and the use of duct mastic seem to be attributable to the in-plant testing. This study suggests that in-plant testing is essential to achieving the benefits of the improved duct tightness and installation specifications.

The ACH_{50} of the homes averaged 4 and was well below the revised NEEM program standard of 5 ACH_{50}. The significant reduction in duct leakage to exterior contributed to the reduced ACH_{50}.

Both duct tightness and overall house tightness for this group of manufactured homes was significantly better than values reported for site built homes in Washington State. As reported (Hales, Gordon and Lubliner 2003) 29 site built homes constructed after 1995 with ducts outside conditioned space averaged 7.1 ACH_{50} and with average duct leakage to the exterior of 406 ft^3/min @ 50 Pascals.

Leakage to exterior tested after set up averaged 74% of total duct leakage as tested in the factory. This represents a significant variance in the region to the suggested 50% found in the referenced EPA manual. The 50% EPA assumption may be overly optimistic and result in field tests indicating leakier ducts than would be expected from in-plant tests using the EPA assumptions.

The results were presented at meeting of the Industry was held on September 6, 2006. A power point was developed and individula plants were able to see their test numbers.

TRAININGS AND WORKSHOPS FOR NEEM PRODUCERS

A technical training program was developed and taught at each of the 19 plants. Copies of the power point were given to each plant to train new employees and refresh techniques of existing employees.

TRACKING AND DOCUMENTATION OF NEW SPECIFICATION AND NEW DESIGNS

The quarterly inspection randomly test homes in all 19 plants. Each manufacturer is required to respond in writing to all inspection finding. The new specification are being meet in all 19 plants.

ACKNOWLEDGEMENTS

This work is sponsored, in large part, by the US Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy, Building Technologies Program under cooperative agreement DOE SEP Special Projects Building America grant number R00058. We appreciate the support and encouragement of our program managers, Mr. George James, Mr. Ed Pollock and Mr. William Haslebacher. This support does not constitute DOE endorsement of the views expressed in this paper. The authors would also like to thank David Hales of Washingotn State University Energy Programs, David Baylon and Bob Davis of Ecotope for their contributions and comments on this work.

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[1]Energy Star Labeled Manufactured Homes: Design, Manufacturing, Installation, and Certification Procedures, EPA 430-B-04-005, p. C.3.

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