Summary of SGC Manufactured Home Field Data (2001-02)

Bob Davis
David Baylon

February 2004

Prepared for:

Northwest Energy Efficient Manufactured Homes
Northwest Energy Efficiency Alliance
Idaho Department of Water Resources, Energy Division

Table of Contents

1. Introduction

Over the last fifteen 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. The USDOE Building America Industrialized Housing Partnership program also provides technical support to the NEEM consortium. Quality control processes were developed and became an integral part of the program, to ensure that the homes meet NEEM, BAIHP and EnergyStar guidelines.

Quality control standards were primarily aimed at in-plant practices and inspections. Nevertheless the efficiency of the homes manufactured under this program depends on the quality of the set-up of the home conducted on-site rather than in the factory. Over the last fifteen years, a series of field samples were drawn and reviewed both for compliance to the set-up specifications and to assess overall performance of ducts, ventilation and infiltration—all items that must be evaluated after the home is sited to obtain a meaningful understanding of the home's performance. These reviews assist in the quality control of the homes and assess the progress and impacts of changes in specification and manufacturing techniques on the performance of the homes sited in the region.

The basis for this review has been a simple random sample of homes in each state. The size of these samples is based on statistical significance criteria (to represent the set-up practice in each state) as well as the available resources to execute a region-wide field study.

This study is conducted periodically to establish performance levels of manufactured housing in the region built to the NEEM standard. Three previous studies were conducted, in 1989, 1994-95 and 1998-99. The focus of the studies was to establish the performance of components of the building that are not easily regulated as part of manufacturing standards, such as duct tightness, ventilation system operation and set up. From the spring through the fall of 2003, a random sample of homes was drawn, recruited, and reviewed. These homes were constructed over the period of one year from June 2001 through June 2002. The sample is meant to be representative of the homes built under the program as well as of the standards that are engendered by the program. Since the efficiency standards are regional and the setup standards are controlled by individual states, the sample was designed to be representative of both the region as a whole and of each state.

2. Sample Design

A simple random sample is drawn in each individual state. The sampling standard is designed around a sample size at a 10% significance level and 90% confidence interval for each state. A representative sample of duct and building shell tightness is taken to represent the remainder of the set-up and installation practices and is not as easily quantified.

A second criterion was designed to provide a regional review with a 5% significance rate and a 95% confidence interval. This sample is much larger. A minimum sample is assembled for each state and the remaining sample size is allocated roughly by percentages of the total homes in the NEEM set sample. As a result of this, the sample is stratified by state so that case weights can be assigned to each individual state and a regional summary can be prepared.

The overall sample goal for this study was approximately 100 cases. Given the past experience, a random sample of approximately 260 homes would be required. This sample would be drawn at random from the Super Good Cents (SGC) database that includes all homes constructed to the standards over the last three years. The database was screened to include all SGC homes constructed between June 2001 and June 2002. A total of 4286 were in the final sample frame. This criteria resulted in homes built to the current standard that when surveyed would be old enough to collect at least a year of performance data. Furthermore the impact of aging on seals, especially duct sealing, would be apparent when the fieldwork was conducted.

Unfortunately for this study, the SGC database did not contain owner's names and addresses; there was only information from the dealers and manufacturers. The sample was drawn by state using only dealer locations. Since the name and address of the owner was not known, many stock homes were also included. These homes typically occupy dealer lots and are not representative of either set-up standards or final infiltration and duct sealing control. As a result of these factors, a sample of about 350 homes was needed that were more or less allocated by individual states.

Once the sample was drawn, serial numbers and SGC numbers were assigned and a list was compiled and submitted to individual states. In turn, the states used their own database and warranty information, and, in some cases, visits to manufacturer plants to review files. We were then able to assemble a list of names, addresses and phone numbers as the basis for recruiting the final sample.

Of the original list submitted to the states for review, approximately 11% of the homes could not be identified in any of the database sources available. An additional 12% of the homes were outside of the region and/or were stock homes that had not actually been sold by the time the review was conducted. This sampling and review was conducted between April and May 2003.

2.1. Sample Frame

Table 1 shows the distribution of homes believed to be built and sited in 2001 and 2002, as well as the distribution of homes in the sample frame (June, 2001-2002). For this summary, the state assigned is the state in which the home was sold (dealer location). Table 2 shows the distribution of SGC homes based on the state of manufacture. Oregon dominates the regional manufacturing with 75% of the overall production.

Table 1: SGC Manufactured Home Production by Dealer State

State	Year		
	2001	2002	Sample Frame*
Idaho	560	605	644
Montana	181	163	191
Oregon	1200	1493	1490
Washington	1662	2062	1961
Total Region	3615	4341	4286
Other States	276	579	-
Total Production	3891	4920	4286

*Dealers located out of region not included in sample

Table 2: SGC Manufactured Home Production by State

State	Year		
	2001	2002	Sample Frame*
Idaho	728	840	697
Oregon	2844	3592	3181
Washington	314	419	387
Canada†	5	69	21
Total Production	3891	4920	4286

*Homes shipped to dealers out of region not included in sample
†SGC Production in a Canadian plant but administered as part of Washington

Table 3 shows the distribution of homes sited and the distribution of the states in which the home was sold. Since this summary is based on the random sample of 300 homes for which data are available, the summary is in percentages. For Oregon, Washington, and Idaho, about 88% of sales are sited in the dealer's state. Of the remaining homes, about 12% originated at a dealer in an adjacent state. In Montana, however, only about 50% of the homes sited are actually sold by dealers located in that state. About 11% of the homes shipped in this year were stock homes located on the dealer lots at the time of this study. This also illustrates the potential biases associated with summaries based on dealer location rather than actual location. The remaining homes were sited in adjacent states including Alaska, Utah, Wyoming and California. It is important to realize that the summaries are based on homes originally shipped to a dealer in one of the four states. SGC homes shipped to other states are not included in this summary.

Table 3: Distribution of Homes by Dealer Location (percentages)

State Sited	Dealer State				
	ID	MT	OR	WA	Total
Idaho	76.6	0.0	0.0	4.2	15.9
Montana	6.4	100.0	0.0	0.8	2.7
Oregon	0.0	0.0	72.7	6.7	27.9
Washington	0.0	0.0	15.9	75.8	40.7
Stock	10.6	0.0	10.2	11.7	10.8
Other States	6.4	0.0	1.2	0.8	2.0
Total	100.0	100.0	100.0	100.0	100.0

2.2. Sample Design and Recruitment

Table 4 shows the distribution of the final recruiting sample delivered by the state energy offices. The original 349 homes drawn as the random sample were reduced to 309 homes eligible for recruiting as phone numbers and contact information became available and the homes were verified to be sited in one of the four states of the region. This sample can be compared to the distribution shown in Table 3. Most of the apparent discrepancy is the result of the relatively large number of homes sold in Washington but sited in Oregon, and the homes sold in Idaho but sited in Montana. The rest of the discrepancy is the need to over sample Montana and Idaho to develop a representative sample for those states. Thus the distribution of the homes that are not stock homes is somewhat biased toward the smaller states. This bias was corrected by case weights in the final data analysis and summaries.

Table 4: Final Distribution of the Recruiting Sample

State Sited	Number	Percent
Idaho	53	15.2
Montana	26	7.5
Oregon	99	28.4
Washington	131	37.5
Stock	34	9.7
Other State	6	1.7
Total	349	100.0

The final recruitment sample was sent to the field technicians in order for them to recruit homes into the sample. In general, they were given targets that were approximately based on the original random sample. In Washington and Oregon, the targets were closely followed. There were some difficulties with recruitment in Idaho. The nonresponse biases caused the number of cases to be noticeably lower than the original Idaho target.

The overall targets for each state were based on the assumption that the distribution of relevant variables such as envelope and duct tightness would have a coefficient of variation of approximately 25%. This assumption was made as a result of distributions observed in the previous studies. Using these criteria, a sample size was set at approximately 90 homes in the region distributed throughout the states. In individual states, the studies were done using much lower significance criteria: 90% confidence interval and a 10% significance rate. This suggests sample sizes between twenty-two and thirty five for each state.

A difficulty in Idaho arose from certain confusion about what should be included in the random sample. This resulted in four homes recruited and tested that were not included in the original sample frame. These homes have been included in the analysis database but were screened for purposes of any regional summaries. The sampling criteria were met for Oregon and Washington in the recruited sample. However, the sample recruited for Idaho was smaller than the requirements. Thus the four extra homes in Idaho were included in the state summary so that the minimum sample requirements were met. Table 5 summarizes the final sample.

Table 5: Regional Field Sample Distribution

State	Freq.	Percent
Idaho	17*	16.8
Montana	5	5.0
Oregon	38	37.6
Washington	41	40.6
Total	101	100.0

*4 cases not included in regional sample

Case weights were used in summarizing the regional samples. They were based on the relative sampling of each of the states. In general, the case weights have a small impact. The sample sizes in each state were largely proportional to the states share of the SGC market.

3. Field Sample Overview

This report includes several summary tables and related text that present the field data gathered by Delta T and WSU Energy Extension between June and September 2003 for a random set of 105 NEEM homes. The data collection protocol is included in the appendix. All told, auditors made it to 21 sites in Idaho, 5 sites in Montana, 38 sites in Oregon, and 41 sites in Washington. At a few sites, the full protocol was not completed because of time or other constraints.

The summaries presented in the following tables correspond (in most cases) with the tables found in the previous report published in November 2000 (Davis, et al, 2000). That report looked at 25 homes in Idaho and 24 in Washington that were built in 1997-98. Note the original MAP study was completed in 1995 and looked at about 170 homes built to the original MAP specifications in 1992-1993 (Baylon et al. 1995).

The field data collected for this study was of very high quality, but there are some cases where the summaries will not include all possible cases. Furthermore, because four of the Idaho cases were not taken from the original sampling frame, they will not be included in the overall data summaries (but will be left in the Idaho summaries). Table 6 outlines the basic sample characteristics of the types of homes and the basic house size. House size has climbed steadily since the original MAP study, tracking along with the increased number of triple section homes and just plain bigger double section homes.

Table 6: Basic Sample Characteristics

	Idaho (n=21) %*	Montana (n=5) %	Oregon (n=38) %	Wash. (n=41) %	All (n=105) %	1997-98 Homes (n=49) %**	MAP Homes 1992-93 (n=178) %
Double section home	100	80	63	71	74	73	81.5
Triple section home	0	20	37	24	24	27	6.7
Quad section home	0	0	0	5	2	0	0
Home size (sq. ft)	1,719	1,761	1,750	1,835	1,769	1,750	1,433

*n shown is possible number of cases that could have been used. Actual numbers used in subsequent summaries are usually smaller because of various reasons (not all tests apply, very occasional bad data, etc). The average house size is weighted by state case weights.
**This study included homes sites in WA and ID only

The sample includes all Northwest manufacturers; some (Marlette, Redman, Golden West/Oakwood, Fuqua) are much better represented than others (Liberty, Fleetwood of Idaho). Production of NEEM homes has fluctuated considerably by manufacturer since the end of the MAP in the mid-90s; some plants have continued to produce a majority of SGC level homes and others have focused on other market segments. Table 7 lists the number of homes used in a sample corresponding with the manufacturer of the homes.

Table 7: Manufacturer Information

Manufacturer	# of homes in sample	Manufacturer	# of homes in sample
Fleetwood*	9	Marlette	19
Fleetwood-Wash.	7	Moduline (Idaho)	1
Fleetwood-Idaho	1	Nashua	2
Fuqua	9	Redman	11
Golden West/Oakwood	10	Redman-Idaho	3
Guerdon-Idaho	5	Palm Harbor	7
Homebuilders NW	2	Silvercrest	3
Karsten	4	Skyline	2
Kit	6	Valley	3
Liberty	1		
		Total	105

3.1. Set Up Summaries

An important part of the field review takes place mostly under the house, where the auditor looks at the structural and the related physical set up of the house as noted in Table 8.

Table 8: Structural & Operational Set-up Compliance

Compliance Issue	% complying in Idaho	% complying in Oregon	% complying in Washington	% complying in all states
Skirting installed	100	90	100	95
Ground vapor barrier present	95	98	90	92
Pier supports in place under I-beam	100	100	100	95
Pier supports in place under ext. doors	100	100	100	100
Pier supports capped and shimmed	95	88	97	90
Footings sized and installed correctly	100	100	100	100
Belly penetrations sealed	55	46	81	59
Marriage line sealed	95	92	95	93
No visual problems with roofline	85	92	95	92
All liquid drains exit perimeter of home	90	82	98	89
Exterior doors operate smoothly	65	93	81	83
Windows operate smoothly	90	90	93	91

Generally set up compliance is very good; the problem areas are doors (especially in Idaho) and belly penetrations. Belly penetrations have been a problem in every field study, at least in terms of the visual inspection. Houses have gotten more airtight despite the persistence of this problem. There are some notable exceptions to the general success. Homes with serious problems will be referred to the state offices for review.

Table 9: Crossover Duct Set-up Compliance

Compliance Issue	% complying in Idaho	% complying in Oregon	% complying in Washington	% complying in all states
Crossover cut to length	100	100	83	94
Crossover connections secure	79	83	83	84
Crossover connected with sheet metal elbows	86	51	57	60
Crossover connections insulated	100	94	86	94

It is unclear to the authors why such a high number of systems are installed without sheet metal elbows. A number of homes used a splitter box for one of the main crossover connections, but this alone cannot explain why almost half of the Oregon homes apparently did not use elbows. The purpose of this detail is to improve the connection and the seal between the crossover duct and the trunk ducts. Interestingly, though, the 45 cases which were identified as using elbows had a median supply leakage fraction (which normalizes duct leakage by air handler flow) of about 10% more than the median supply leakage fraction of cases that didn't use elbows (n=32). Homes with interior crossovers (n=17) are not included in this comparison. Apparently, there is still work to be done to improve the air tightness of the duct and crossover system. (See Section 3.3 for a full discussion of duct leakage.)

3.2. House Tightness and Ventilation

There is no doubt Northwest manufactured homes have gotten tighter over the past 10 years as can be seen in the blower door results summarized in Table 10. Production techniques have standardized and intentional air inlet vents are no longer required for NEEM. This has made the performance of the whole house ventilation system even more important.

Table 10: Blower Door Results (ACH_{50})

	This study			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

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

In the current study, the minimum ACH_{50} is 2.33, and maximum ACH_{50} is 7.45. Only 19 cases have ACH_{50} over 5.0 and only 2 are over 7.0 ACH_{50}, the nominal program standard. The standard deviations in most categories are very similar to the 2000 study; both of these studies show less scatter than the original MAP results, which should be viewed as an indicator of successful quality control. Note Idaho results are essentially the same between the 2000 and current study. There were 4 Montana cases with acceptable blower door results; the average ACH_{50} for these cases is 4.35.

Results are also expressed in equivalent leakage area (ELA) in Table 11. As one would expect, the numbers scale along with the ACH results. Even though houses are much larger than in the original MAP study, the ELA has decreased in most comparisons. (That is, ACH results are normalized by house size, while ELA is not.) Note singlewide units and bad blower door tests are excluded in the summaries. (Only the MAP 1992-93 study included singlewide units.) Results from the 1997-98 study are based on a relatively small sample; the most meaningful comparison with the other samples is the median ELA for double-section homes. Note the ELA has decreased by about 13% for double-section homes since the original MAP.

Table 11: Blower Door Results (ELA in in^2)

	This study			SGC Mfd Homes 1997-98			MAP 1992-93		
Group	# of cases	Mean ELA	Median ELA	# of cases	Mean ELA	Median ELA	# of cases	Mean ELA	Median ELA
All*	92	62.1	64.4	49	73.2	73.0	130	67.4	61.9
Double Wide	71	59.0	52.7	36	68.0	65.2	118	65.7	60.5
Triple Wide	24	73.4	74.6	13	87.5	92.4	12	83.4	87.6
Idaho	20	66.1	66.7	25	67.6	64.8	26	74.9	71.3
Oregon	32	64.8	61.0	N/A	N/A	N/A	43	69.3	60.1
Washington	41	58.7	62.2	24	79.0	79.3	52	62.7	59.1

*Case weights applied to overall summary figures in current and MAP 1992-93 studies, very few cases also thrown out because of bad test exponents.

Whole House Ventilation System Performance

A dedicated whole house fan is now almost a standard item in NEEM homes. Over 2/3 of the homes in this study used a fan installed in the hallway as the whole house ventilation system. Almost all whole house fans (84%) use a manual switch for control; about half of these systems (final tally pending) use a high wall switch or closet switch to differentiate the fan control from a light switch. Only 5 cases used a timer; 1 case used the MAP furnace timer kit and 3 used a humidistat control.

The median flow rate measured (out of 93 possible cases) for the whole house fan is 60 CFM, which is slightly less than that found in the 2000 study. There were 12 cases with measured flow rate of less than 30 CFM, and there were 2 cases with a zero reading. One of these cases had no terminus outside the building; the other had an unspecified problem.

The median fan flow rate is more than adequate to ventilate the average size of home in this study (about 1750 ft^2) using the HUD requirement of 0.035 CFM/ft^2 of floor area. However, in several cases, the delivered flow was clearly inadequate, either due to the fan being undersized based on the formula or due to poor fan performance. Assuming the fan is sized close to correctly, it must be run enough hours in the day to provide long-term effective ventilation.

Whole house fan run time has improved greatly, on average: 42% of the homeowners say they run their fan continuously. (In the 2000 study, none of the homes ran the fan continuously.) However, there is still room for improvement: 30% of homeowners say they never use their whole house fan (63% of homeowners in 2000 said they never used the whole house fan). In several cases, this was apparently because they were confused about the need for the fan or how to turn it on; after the auditor explained the system, the homeowner usually decided to turn on the fan. It should be noted that 66% of homeowners said they had been told about the whole ventilation system by their dealer and given at least some information on its use. This may be due to the improved occupant instructions, distribution of those instructions to manufacturers and encouragement to include the instructions in the homeowner's "important papers" folder.

The summary of current whole house fan use: flow rates, on average, are adequate. Many more people than before are running their fan all the time. Still, there are many homes that are almost certainly under ventilated, and continuing education is needed to assist homeowners in taking full advantage of their mechanical ventilation system. It should be mentioned that field auditors noticed very, very few instances of air quality problems. The testing was mostly completed in summer months, which could mask problems that could arise at other times of the year.

Intentional Envelope Holes and Attic Ventilation

It is very important to note that the intentional provision of outside air has also changed greatly since the last field study, where 85% of the homes contained some type of intentional leak meant to supply fresh air. NEEM home envelopes are getting tighter, but there is still enough unintentional envelope leakage (on the order of 45 in^2 in the average house) to supply the whole house fan.

Manufacturers are no longer required by NEEM to provide intentional holes in the building envelope, whether these holes are window slot vents or air ducted into the furnace cabinet. Still, about 25% of the homes in this study had an intentional leak ducted into the furnace cabinet (a POS or Blend-air ventilation system); 65% of these ducts were not dampered. Of the remaining 9 cases, 8 had dampers that were wired to open when the whole house fan turned on.

It is also significant that the number of homes with mechanically vented attics has dropped from more than 75% in the MAP study to 35% in the 2000 study to nearly none in the current study. In part this must have to do with the preponderance of vaulted ceilings, but manufacturers are also apparently seeing very few attic moisture complaints. This is a consequence of widespread use of tape and texture finishes and much better success in preventing either bulk moisture transport or diffusion of moisture into the lid. The preferred method of attic venting appears to be continuous soffit vents paired with near-ridge vents.

Combustion Appliances (Non-Furnace or Domestic Hot Water)

The field study identified 55 homes that contained combustion appliances other than central furnaces or water heaters. Combustion appliances used in manufactured homes are supposed to be supplied with dedicated combustion air and with an exhaust system that is sealed from the home's interior.

These appliances are mostly wood stoves and gas fireplaces. Some homes had multiple combustion appliances. The auditor was asked to confirm whether the appliance was direct-vented; in 85% of the cases, the answer was affirmative. This is concerning, since these homes are getting much tighter and the potential for back drafting is significant. In fact, in 6 sites, homeowners said they had experienced back drafting in their home. Half of these cases had the problem whenever the furnace came on. It is apparent that homeowners are not uniformly aware of the back drafting problem that is likely when they install after-market combustion appliances that are either not directly vented or are installed improperly. More education is a very good idea. Washington building code requires a permit and inspection for all after market installs; this is not generally enforced.

A worst-case depressurization test was performed in a majority of these homes. The objective of this test is to establish the amount of draft pressure that is required to overcome the operation of the various fans and the heating system. The worst-case test was performed by closing interior doors and turning on exhaust fans; this combination reduces the amount of "free" air available for burning fuel, since the combustion zone is smaller with the doors closed and the house is being depressurized by fan operation. If there are duct leaks, the house is further depressurized when the air handler operates. The average and median values for these homes in worst case conditions are close to 20 Pa, which approaches the CHMC action level of concern for closed combustion appliances. It should be noted that the home is ventilated at 5 ACH per hour when all these devises are on, and that the likelihood that they are all on at once is very small.

An indoor CO concentration measurement was conducted in most cases where combustion appliances were found. The results are shown in Table 12. Only very small (less than 4 ppm) of CO were measured in four cases; it is plausible these readings could be due to a zeroing problem on the meter. This suggests that, at least at the time of the audit, there was little or no cause for concern. The results of the worst-case depressurization test, however, suggest that homebuyers should be informed as to the need to correctly install after market combustion appliances.

Table 12: Combustion Safety Measurements

	Worst Case Depressurization (WCD) (Pa)	WCD with only air handler running (Pa)	CO measured in living space (ppm)
Average value (n=39)	-19.4	-7.4	N/A
Median value	-17.9	-5.8	N/A
Range	-4 → -47	-0.5 → -28	0-4; 35/39 cases were 0

No case weights applied

3.3. HVAC and Ducts

A major focus of the work is evaluating the efficiency of the HVAC system. Auditors inventoried the central heating/cooling system and measured duct leakage, air handler flow, and operating static pressure. Table 13 shows the results of the audit.

Table 13: Central Heating & Cooling System Survey

	% of cases that have
An electric furnace (elements + fan only)	54
A heat pump (HP)	24
A furnace fired by natural gas or LPG	22
Central air conditioning (other than HP; includes evaporative cooler (2 cases))	19
Overall cases with central air conditioning	43
Gas/propane furnace with central AC	7*

* 2 these cases have separate evaporative coolers
**Other than central natural gas or LPG furnace

The percentage of homes with central electric forced air is very similar to the 2000 study, but the number with heat pumps has doubled and the number with gas or propane has halved. The percentage of homes with central air conditioning (including heat pumps) is about the same as in 2000 as well, but there are more heat pumps providing the cooling.

Duct Leakage Results

A number of important summaries are included in this section, including raw duct leakage, air handler flow, and supply leakage fraction. The most important comparisons and explanations occur in the supply leakage fraction table, where the duct leakage is normalized both by air handler flow and by house size as can be seen in the following Table 14.

Results are presented with both medians and means to preserve the last report's approach; in that case, outliers greatly skewed the mean. In general, there looks to be about a 30% increase in exterior duct leakage for the overall group; the increase is smaller for double section homes but still is around 20%. Note home size on average is very similar for the two study groups.

Table 14: Exterior Duct Leakage

Group	This study 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)	-	-

Case weights applied for regional results

The manufacturer who used the interior crossover duct had a higher leakage rate (on average about 30% more), than the overall fleet average. This set of homes was built during the earlier stages of that new technique, however.

These summaries also do not reflect the widespread use of duct mastic. Only a few manufacturers employed mastic as a standard option in 2000, with foil tape (with butyl or acrylic adhesive) still the primary choice. Auditors were asked to list the type of duct sealant noted at both register and furnace boots and also note if it was failing. Table 15 shows the type and location of the sealant as noted by the auditors.

Table 15: Duct Sealant Types

	Butyl tape	Acrylic tape	Mastic	Combination*
Percent using at furnace boot (n=57)	74	5	9	14
Percent using at register (n=92)	72	17	8	3

*Usually combination of butyl & acrylic tapes

Auditors were also asked to assess failure rates at furnace and register boots. It was not always possible to evaluate the furnace boot, depending on the line of sight, but out of 73 cases where the evaluation could be performed, 22 (30%) had some amount of sealant failure. Register failure was much higher, with 53 out of 101 sites (52%) having some amount of sealant failure at the registers.

In general, the use of tape as the primary sealant, even when the tape is thought to have a better sealant, has meant that duct leakage has not decreased. This means heating system performance will be degraded and represents one of the significant remaining areas where NEEM homes can be improved.

Airflow and Supply Leakage Fraction

Furnace airflow was measured both with the TrueFlow® plate and by using a Duct Blaster® to match system static pressure. This comparison was done in order to provide insight into the accuracy of the TrueFlow® in systems that do not contain a ducted return. Corrections were made to the raw TrueFlow® numbers to account for test conditions. Static pressure was measured with a long Pitot tube in several registers at each site and averaged. The results of the airflow measurements are shown in Table 16.

Table 16: Furnace Airflow and System Static Pressure

	Mean	Median
Air handler flow (TrueFlow®); n=81	1,075 CFM	1,047 CFM
Air handler flow (Duct Blaster®); n=97	1,087 CFM	1,070 CFM
System static pressure; n=99	24.7 Pa	22.4

Case weights applied

Supply leakage fraction (SLF) is found by determining the flow equation for exterior duct leakage and then applying it using the average system static pressure at normal operating conditions at each site. The supply leakage fraction is the percentage of conditioned air that is not delivered to the home's interior during normal heating or cooling operation. It is difficult to scale the SLF directly from the air handler flow and duct leakage measured with the Duct Blaster® test since the operating pressure can vary quite a bit from home to home and therefore the leakage at operating conditions also varies quite a bit for homes that might have very similar air handler flows and Duct Blaster® results.

The SLF was calculated somewhat differently in the 2000 study; a weighting procedure between plenum and register pressure was used (rather than taking an average of all register static pressures. These results are summarized in Table 17.

Typically, static pressure was measured in more than half of the registers. Therefore, the SLF (in row 1) looks as though it has decreased (compared with row 3) even though the Duct Blaster® results show increased leakage, expressed in terms of the exterior duct leak at 25 Pa divided by the house's heated floor area (last 3 rows of table).

Table 17: Supply Leakage Fraction

	Mean%	Median%
Based on TrueFlow® AH flow (n=76)*	13.4	11.4
Based on Duct Blaster® (DB) AH flow (n=89)	12.2	11.1
Results from '97-98 study	15.4	13.8
Idaho (DB)* (n=20)	14.0	13.2
Oregon (DB) (n=36)	12.8	11.1
Washington (DB) (n=37)	10.7	8.3
Exterior duct leak at 25 Pa per ft^2 of house area (This study)**	7.9%	7.5%
Exterior duct leak at 25 Pa per ft^2 of house area ('97-98 homes; 49 cases))	--	5.9%
Exterior duct leak at 25 Pa per ft^2 of house area ('92-93 MAP homes, ca. 150 cases)	7.2%	Not calc

* The lowest SLF was calculated at 1.6%; the highest was 46.4%.
** The median comparison is most robust for the most recent data sets since there were only 49 cases in the last study. These ratios are of overall medians; they are not the median of the calculation for each case.

Some of the heating or cooling energy may be recovered indirectly ("regained"); this effect is not accounted for in the SLF but is estimated as part of the overall system efficiency impact. The most recent version of Ecotope's duct model (specially adapted to manufactured homes), estimates the impacts of the measured duct losses. Results are expressed for Portland and Boise for both electric furnaces and heat pumps. Homes with heat pumps have a lower delivery at a given level of supply leakage than homes with electric furnaces because they do not make very warm air and therefore more back up (electric resistance) heat must be used to meet heating loads over the course of a heating season (see Francisco, et al, 2004 for a full discussion of this effect). The overall effect on a gas heating systems can be found by taking electric furnace results and dividing them by the combustion efficiency of the gas furnace.

Table 18: System Efficiency Effects**

	10% SLF -- EF	10% SLF – HP*	15% SLF -- EF	15% SLF -- HP
Portland	0.892	0.872	0.810	0.822
Boise	0.883	0.837	0.792	0.766

*Heat pump control strategy is "best case"; compressor is not locked out regardless of ambient temperature and heat pump is sized large enough to meet the peak load.
**System efficiency of 1 means no duct losses.

The table shows that even for the smaller leakage case (10% SLF), there is a similar increase in the heating energy; that is, if we needed 100 units of heating energy without duct losses, we now need 110. For heat pumps, the effect is greater for a given amount of leakage. It should be pointed out that a significant number of homes are being built with a SLF of 5% or less. At this leakage level, the duct system efficiency is over 90%, and very little of the conditioned air is lost into the crawlspace. A home with the NEEM label should be attaining system efficiencies closer to 1 than to 0.9 (or certainly 0.8).

Duct systems have not improved appreciably over the last decade despite huge improvements in other home components and installation practices. Recent changes in duct material and NEEM sealing requirements (requiring mastic) should improve this situation.

3.4. Customer Satisfaction Survey

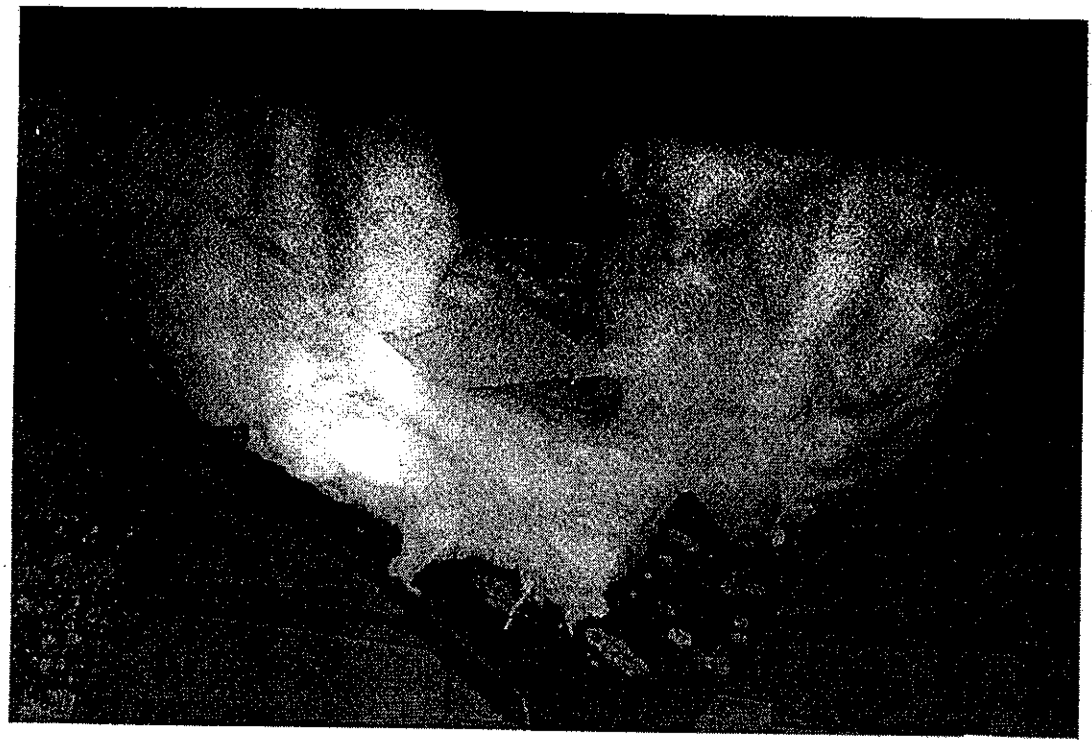
Customers were asked several questions about how they felt about the performance and value of their NEEM home. Results are encouraging, as Table 19 shows. An overwhelming majority (94%) were at least "somewhat satisfied" with the efficiency and comfort of their home, and 80% would recommend to others that they buy a NEEM home.

Table 19: Customer Satisfaction

Customer response	% answering affirmatively
Very satisfied with home	69
Somewhat satisfied with home	25
Would recommend to another buyer	80
Would recommend with reservations	18

The most important elements influencing the purchase of a NEEM home were comfort, followed by low energy bills, cost of homes, quietness of homes, and investment value of the home. In general, homeowners thought they were getting a good value, but some still complained their utility bills were higher than expected. In some cases, this had to do with moving into a larger home and keeping the thermostat set higher than before, but in other cases, there were some isolated installation and set up problems that were contributing to the higher bills. Some of these problems have been brought to the attention of state agencies concerned; detailed comments are available for all homes.

In general, complaints from homeowners were typically related to perceived deficits in customer service and scheduling from the manufacturer rather than problems with the energy efficiency characteristics of the home. In those few cases where the quality of the home was cited as less than satisfactory, the primary complaints centered on poor set up or higher-than-expected heating bills. For example, one homeowner's comment typifies that of several others, indicating, "we don't feel we got what we paid for".
Another complained that the home "does not hold heat". Where poor set-up was cited, complaints concern poor ductwork and water leakage during storms.



Example of failing belly insulation. Photo courtesy of Paul Tschida, Montana Department of Environmental Quality.

Only about 25% of the homeowners reported receiving a NEEM utility incentive, and only about 50% of homeowners were encouraged by their retailer to purchase a NEEM home. Given the high level of homeowner satisfaction with their purchase, and given the benefit to the dealer to sell a higher priced home, it would seem a good idea to encourage retailers to promote NEEM more actively.

4. Results

This study presents some unique opportunities to track the development of energy efficient manufactured homes over the last decade. There are several key trends that arise from this review:

- Average house size is 1769 ft^2; double section homes are also getting bigger, on average. The house size is very comparable to the homes built in 1997-1998 but 20% larger than the homes in the early MAP program (1992-1993)
- Houses are getting tighter, according to the blower door results. The average air leakage rate at 50 Pa is 4.2, which represents a tightening of almost 25% over the original MAP home average. The median equivalent leakage area (ELA) for double-section homes has decreased by about 12% despite a substantial increase in house size.
- Only about 20% of NEEM homes in this study contain intentional outside air inlets. This is indicative of the program change to not require the inlets. This compares with MAP homes, where virtually all sites used integral window slot vents as air intakes, and the 1998 SGC homes where 18% used slot vents after a specification change made these vents optional.
- 2/3 of homes in the study have dedicated whole house fans and a substantial fraction of homeowners are using their whole house fans. However, a significant minority (30%) does not turn them on.
- About half of homes in the study use central cooling, with more than half of these homes using a heat pump.
- Duct systems are about 20% leakier than in the 2000 study and about 10% leakier than in the original MAP study (when the comparison is normalized by house size).
- The median supply leakage fraction is 11-13% for the homes in this sample (depending on the measurement technique used); that is, about 11-13% of heated or cooled air is not delivered through the registers.
- The duct loss translates into a heating system efficiency loss of between 10-20% overall, depending on the location of the home (west side or east side of the mountains) and type of heating equipment (heat pumps perform worse). (This efficiency loss does not include combustion efficiency or losses associated with various heat pump control strategies.)

Compared to homes built to MAP specifications (and sited in 1992-93), the total duct leakage has increased about 30% but at the same time the house size has increased over 20%. The comparison with 1997-98 homes suggests virtually no change since that period in either house size or overall duct leakage. Overall this seems to indicate that little or no progress has been made to deliver more efficient ducts. The NEEM program has recently implemented new duct sealing procedures. These procedures were not in place when the homes in this study were built.

On the other hand, overall shell tightness has increased considerably. The results of this study show that current homes are about twice as tight as homes built in 1989 and 12% tighter than the homes built in the 1997-98. It is likely that homes of this tightness should have some level of central fan-forced ventilation. While all these homes have ventilation systems as required by the SGC specifications, many of the occupants do not use their system. While the progress made in occupant understanding is significant, more progress is needed as the homes become tighter.

Homeowners report overall high levels of satisfaction with their homes, in terms of value, utility costs, and other factors. The sample did include some notable "problem" homes, however. As in the previous studies, these added energy efficiency features are well received by the homeowners.

5. References

Baylon, D., B. Davis, L. Palmiter. 1995. *Manufactured Home Acquisition Program: Analysis of Program Impacts.* Prepared for Bonneville Power Administration under Contract No. DE-AM79-91BP13330, Task Order #71945.

Davis, B, A. Roberts, D. Baylon, 2000, *Summary of SGC Manufactured Home Field Data (1997-98 Sitings in Idaho and Washington).* Prepared for Idaho Department of Water Resources- Energy Division

Francisco, P., D. Baylon, B. Davis, L. Palmiter, 2004, Heat Pump Performance in Northern Climates, *ASHRAE Transactions*, Vol. 110, Part 1

HUD. 1994. *Manufactured Home Construction and Safety Standards.* Revised Part 3280 of Title 24. United States Department of Housing and Urban Development.

Palmiter, L., T. Bond, I. Brown, and D. Baylon. 1992. *Measured Infiltration and Ventilation in Manufactured Homes.* Prepared for Bonneville Power Administration under Contract No. DE-AM79-91BP13330.

6. Acknowledgements

This study was the result of a substantial cooperation between the state agencies responsible for the NEEM program and funding from other cooperating agencies. It was only through this cooperation that the field and analysis effort could be accomplished.

The authors would like to thank the NEEM program administered by Tom Hewes of the Oregon Department of Energy and Doug Plourde of the Idaho Department of Water Resources, Energy Division for the initial funding. Additional funding came from the Northwest Energy Efficiency Alliance, a consortium of utilities and states in the Pacific Northwest, and from the Building America program of the U.S. Department of Energy through the Washington State University Energy Extension Program (WSU). The efforts of Jeff Harris and Mike Lubliner, respectively, were crucial to securing this funding and the scope and quality of this effort is directly affected.

David Hales of WSU, Regan Eberhart of Delta-T and Paul Tschida of the Montana Department of Environmental Quality conducted the fieldwork. Their commitment to quality and careful measurement was very important to the study. This is the third study of this kind that Ecotope has managed and this field effort was the highest quality of any thus far.

Finally, we would like to acknowledge Erin Kruse and Mike Kennedy who assembled and managed the database for the collection of the field data.

Appendix

Field Protocol

NEEM FIELD SURVEY 2003

Site ID#________ Date____________

Occupant Name:______________________Address:______________________

City, State________________________Zip________

Phone____________________________

Utility__________________________

Dealer/location______________________

Set-up crew/number (if known; check metal plate next to HUD sticker)________________________

Person filling out this report______________________________

Basic Information

Manufacturer ________________ Model ____________________
HUD #:___________________ NEEM#___________________

____Single Wide
____Double Wide
____Triple Wide

____Other (two stor , four-section, etc)
Describe: ______________________________

Attach a sketch of the floor plan with accurate exterior dimensions. Use back page of protocol if desired. Put a north arrow on the sketch. Sketch in interior rooms and number heating registers. Calculate house volume and write on the sketch.

Perform a quick visual inspection of the home interior and ducts. Use a mirror. Note problems on sketch and in grid on page 5.

Does homeowner report problems germane to testing (moisture, high bills, air flow, roof/siding, plumbing failures):____

Central Heating Source

Is there an electric furnace? ______yes ______no Size (kW) @ 208/240V ________
Is there central AC/heat pump*? ______yes ______no
(*confirm HP by turning on heat and seeing if compressor comes on. This doesn't rule out either a 5 minute lockout of
controls problem. Can also look for reversing valve in outdoor unit.)

Make and model of: outdoor unit________________indoor unit________________

Is there a gas furnace? ______yes ______no
Make and Model # ______________________________
Confirm unit is sealed combustion: ______yes ______no (check house dataplate first)

Additional Combustion Appliances

(Units fueled by fossil fuels or biomass: natural gas, kerosene, wood, etc.)

Type (water heater, gas FP, woodstove, portable heater,	Fuel	Outside combustion air (hard ducted)?	Notes (evidence of venting problems, et

Perform worst-case CAZ test (page 6 of protocol) and record highest negative pressure measured _____ Pa

Conditions producing this result:

Measure ambient CO and record _______________ ppm

I __________________________ (homeowner name) have reviewed this information and have been informed by the contractor that the reading listed above could change at any time, depending on condition of equipment, changes in sources of combustion air, or other factors. I have been advised that operating exhaust fans and/or closing interior doors may cause combustion appliances to back draft. In addition, I have been notified that all non-venting combustion appliances should be operated using the manufacturer's specifications for venting.

I acknowledge receipt of information by signature below.

____
Signature

____
Date

Air Quality/Ventilation

Technician's observations of odors or moisture

____None ____Odors ____Moisture _____Mold/Mildew

Location and Description:____

____

____

Note any conditions which may significantly affect air quality or ventilation (e.g. smokers, solvents, aquarium):____

____

Number of full-time _______ adult occupants ______children (under 12)

Ventilation systems (assumes central exhaust; note if balanced flow system)

Make and Model	Type: whole house, spot, combined	Location (bath, hall, etc.)	Flow (cfm)	Daily r time (hr	Noisy	Control type*

*manual switch, timer

Classify the **make-up air** system installed in the home.

None	
Passive duct (POS or VentilAire™ I)	
Dampered duct	
Dampered duct with interlock (NW Timer Kit)	

Make-up duct diameter _______inches. Note if the make-up damper is jammed or otherwise inoperable: ____.

Do all bedrooms have pass-through vents or door undercuts? Note deficiencies:____.

Air Handler Flow Measurement Using TrueFlow Plate

Set-up: Turn on air handler (by using fan-only switch or by turning on heat/AC). It is best to call for the flow that will be used during most of the year (probably heating) so that the leakage fraction will be applied to the predominant use.

Measure normal system operating pressure (NSOP). Position static pressure probe as close to furnace as possible for all measurements and make sure it doesn't move.

Place appropriate plate and spacers into filter slot. Turn on air handler and record register static with TrueFlow in place (TFSOP) and pressure drop across plate.

Plate used (14 or 20) _______________

Normal System Operating Pressure (NSOP) _____Pa
True Flow System Operating Pressure (TFSOP) _____Pa
Correction Factor √(NSOP/TFSOP) __________

Plate pressure drop ________Pa
Raw Flow (CFM)________
Corrected Flow ________CFM

Air Handler Flow Measurement Using Duct Blaster

Record normal system operating pressure (NSOP) as described in flow plate test. Install Duct Blaster on furnace. Turn on air handler. Turn Duct Blaster on and slowly increase flow until the supply plenum pressure is the same as NSOP. Record Duct Blaster flow pressure, ring#, and CFM.

NSOP: ______Pa
Ring # ______
Flow pressure:______Pa
Air Handler flow:______CFM

As-Found Blower Door Test

Set-up: Close all windows and doors to the outside (except door which will receive blower door). Open all interior doors, close all dampers and doors on wood stoves and fireplaces. Make sure blower door is set to depressurize the house. Ensure that furnace and (gas-fired) water heater can not come on during test. Make sure all fans are off (including make-up air fan). Close window inlet vents.

Record outdoor temperature__________ Record indoor temperature __________

Record beginning baseline pressure WRT outside__________

Use most restrictive flow ring possible to improve accuracy of tests.

House P near 50 Pa	BD fan pressure	BD Ring	BD flow near 50 Pa	House P near 25 Pa (P_{25})	BD fan Pressure	BD Ring	BD flow near 25 Pa (Q_{25})

Record ending baseline pressure WRT outside __________

To check test, calculate the flow exponent, n. Use the following formula, $n = \ln(Q_{50}/Q_{25})/\ln(P_{50}/P_{25})$. *Note* Q_{50} *and* Q_{25} *are the flows through the blower door at the testing pressures (which are denoted* P_{50} *and* P_{25}. *Depending on the test, you may not get the house to exactly –50 or –25 Pa WRT outside. Use the exact ΔP you measure when checking the flow exponent. For example, if the house gets to –48 Pa for the high ΔP, use this as the* P_{50} *in the equation. If the flow exponent is not between 0.50 and 0.75, repeat the test.*

Total and Exterior Duct Leakage Test

Tape registers. Place system static pressure tap in register near mid point of home on side opposite the furnace ("B side".) For total test, open door to outside or leave BD open. Pressurize ducts to 50 Pa with respect to outside; repeat at 25 Pa. For exterior leak test, pressurize house and ducts to the same pressure (near 50 or 25 Pa) WRT outside. Adjust Duct Blaster until the duct pressure (WRT house) is 0 ± 0.2 Pa. Reread the duct pressure WRT outside at this point and record, along with DB fan pressure, ring, and DB flow. **Make sure to use the correct calibration for the DB you are using (Series A (white DB) or B (black DB)**. Note register # where duct pressure measured: __________

	Duct P near 50 Pa (P_{50})	DB fan Pressure	DB Ring	DB flow near 50 Pa (Q_{50})	Duct P near 25 Pa (P_{25})	DB fan pressur	DB Ring	DB flow near 25 Pa (Q_{25})
Total								
Exterior								

Check flow exponent as above for both tests:

CHECKLIST:

________ Untape all registers
________ Furnace filter in place
________ Furnace buttoned up and operable
________ Check thermostat setting
________ Check for tools and equipment
________ Complete set-up review (next page)

Set-Up Review

Crawlspace/Exterior:

Yes	No		Comments
		Is skirting in place?	
		Is there a ground vapor barrier? Is it properly lapped? Is it damaged? Is there water or wet soil under the VB?	
		Are pier supports in place under I-beam with at most 8' O. C spacing?	
		Are pier supports in place under exterior doors, windows ov recessed entries or bay windows?	
		Are pier supports properly shimmed (not overdriven)?	
		Are footings proper size and smooth (min 256 in^2 or 18" wid runner)?	
		Is crossover duct cut to length?	
		Are crossover duct connections secure?	
		Are crossover ducts connected with sheet metal elbows?	
		Are crossover connections insulated to R-8?	
		Are belly penetrations sealed?	
		Is marriage line sealed? (indicate where inspected)	
		Evidence of problems from looking at exterior marriage line roofline?	
		Do water heater, AC/HP, and clothes dryer drains/vents exit home properly?	

Crossover duct size__________ Describe any unusual T's, Y's, or junction boxes. Are these features insulated to at least R-8?:

Other comments:

Operations:

Yes	No	
		Do exterior doors operate smoothly and seal against weather-stripping?
		Do windows operate smoothly?

Comments:

Ventilation/Interior Ducts:

Yes	No	
		Does the attic have a mechanical ventilation system?
		Does the attic have passive vents?
		Continuous soffit vents?
		High vents in each section?
		Gable end vents?
		Is the tape/mastic failing at the furnace boot? Note adhesive type: butyl acrylic mastic
		Is tape/mastic failing at register boots? Note adhesive type: butyl acrylic mastic

Comments:

WORST CASE DEPRESSURIZATION TEST

The purpose of this test is to assure that backdrafting problems associated with unbalanced pressures in the house are recognized and addressed. This test can also be used to assure that contaminants from an attached garage do not enter the house due to unbalanced flows. In some cases homeowner education is the only corrective action that is feasible.

1. Identify the zone with the combustion appliance. This is referred to as the combustion air zone (CAZ).

2. Identify exhaust fans. These may include, but are not limited to:
   bath fans *kitchen fans* *clothes dryers* *attic fans*
3. Close all exterior doors and windows.

4. Place one end of the measuring tube outside, and attach the other end to the reference tap on either channel of the digital pressure gauge. Switch the mode selection knob to pressure. An extra long hose is very handy for this test.

5. Close the interior doors to zones that do not contain return grilles.

6. Turn on the air handler (either with fan switch or by turning on the heat).
   Read pressure gauge and record_____. If gauge is reading negative, the house is being depressurized.
7. Turn on exhaust fans that are in the CAZ.
8. Turn on fans located behind interior doors that were shut for step # 5.

9. While watching the pressure gauge, open these doors one at a time. If the CAZ goes more negative (for example -5 Pa to -6 Pa), keep the door open. If the CAZ becomes less negative (for example -5 Pa to -4 Pa), shut the door. Repeat this procedure for each room containing a fan.

10. Record the greatest negative number measured during this process and transfer to Page 2 of protocol:_______

If worst case reading is > -5 Pa or .02" WC, the homeowner should be notified of the conditions that produce this depressurization.

Supply Register Pressures and Flows (you need reliable flowhood and thermometer for this test)

Set up: Open all registers. Look for toekicks. If it is helpful to make sure you haven't forgotten a register, name registers as you go or number starting at the front door and going clockwise.

Pressures: Measure pressure in register boot with the air handler running, using a long Pitot tube pointed into the flow.

Flows: Measure supply flows and temperatures with the air handler running. It is necessary to measure temperatures because air temperature affects the volumetric flow reading. Use a good thermometer and fast-acting thermocouple. The Fast-1 flowhood temperature is generally unreliable. Make sure flowhood has known calibration.

The flow hood should be centered on the register wherever possible and it should be noted where centering is not possible. Use plastic bags or cardboard boxes if necessary.

Flow hood used: _______________ Temperature Measurement Device: _____________

Reg. loc or #	Static P (Pa)	Temp (°F)	Raw flow	Corrected Flow

Measuring Air Handler Flow With the Temperature Rise Method (Electric Heat)

1. Turn up the thermostat and let equipment run for at least 5 minutes on resistance heat only.
2. Record return plenum temp ______ (specify °F or °C)
3. Record supply temp in nearest register ==========> ______________
4. Remeasure return plenum temp _______ (°F or °C) avg return T_______
5. Record element amps and volts to get input Watts delta T ___________

Element	amps	volts	watts
1			
2			
3			
4			
		total	

6. Alternately, use utility meter to get input Watts. You must turn off all appliances but furnace for this test, or make sure you can accurately determine the baseload during the test.

$$W = (3600 \times k_h \times revs)/t$$

Where:

k_h	= meter constant on face of meter in watt-hrs per revolution (often 7.2)
revs	= number of revolutions of meter wheel counted
t	= time required for the revolutions you count

7. Record base load (as needed) = (3.6 x ___ x ___)/ _____ = _______ W
8. Record total watts = (3.6 x ____x _____)/_____ = _______ W
9. Subtract base load from total to get furnace Watts in: _______ W

10. SCFM = (Watts in · **constant**)/(delta T)
Where the **constant** is either 3.16 (if using °F) or 1.75 (if using °C)

Show work:

Measuring Air Handler Flow With Temperature Rise (Gas Furnace, °F)

1. Select position(s) to measure supply temperature. Measure in main trunk near plenum.
2. Turn off all gas appliances but furnace. Note or draw water heater temperature setting:
3. Turn up thermostat and let furnace run at least 5 minutes.
4. Record combustion efficiency for each port in natural draft equipment or use single reading for induced draft equipment:_____/_____/_____/_____/_____

   Average efficiency: _______%

   *Note: if not measuring this directly, record assumed efficiency from dataplate*___________

5. Measure return temperature ________
6. Measure supply temperature(s):

Record average:________________

7. Remeasure return temperature:__________
8. Subtract average of Steps 5______ & 7 _________:____________

   from average of Step 6__________

   temperature rise _________

9. **Clock the meter** by timing several revolutions of the ½ CCF dial (assume 1040 BTU/CCF if not otherwise known. Use table on next page to speed up process if desired):

   CCFs:_________ BTU/CCF:_______ Time:_________ seconds

   Total input consumption = (CCF * BTU/CCF) /(seconds for revs) * 3600 sec/h

   =___________BTUh at meter (or use table)

10. Multiply result from Step 9 by the combustion efficiency (Step 4):

    ______Btu/hr at meter * _____avg effic = _______ Btu/hr into supply airstream

11. Find system airflow in standard CFM (SCFM):

    (Step 10 result_______* 1.08)/temp rise (Step 8 result) = __________SCFM

12. Turn on any gas appliances turned off earlier; set to as-found levels.

Notes:

- Should also record CO readings on separate form and give to homeowner. Note any problems with furnace (deteriorated or incorrect venting, cycling on high limit, electrical wiring problems, etc.)
- Must derate for altitude if house at over 2000 ft. Consult Sun Power procedure for this correction.

Gas Input to Burner in Cubic Feet per Hour

Seconds for 1 revolution	One-half Cu Ft dial	One Cu Ft dial	Seconds for 1 revolution	One-half Cu Ft dial	One Cu Ft dial	Seconds for 1 revolution	One-half Cu Ft dial	One Cu Ft dial
10	180	360	32	56	113	54	33	67
11	164	327	33	55	109	55	33	65
12	150	300	34	53	106	56	32	64
13	138	277	35	51	103	57	32	63
14	129	257	36	50	100	58	31	62
15	120	240	37	49	97	59	30	61
16	112	225	38	47	95	60	30	60
17	106	212	39	46	92	62	29	58
18	100	200	40	45	90	64	29	56
19	95	189	41	44	88	66	29	54
20	90	180	42	43	86	68	28	53
21	86	171	43	42	84	70	26	51
22	82	164	44	41	82	72	25	50
23	78	157	45	40	80	74	24	48
24	75	150	46	39	78	76	24	47
25	72	144	47	38	77	78	23	46
26	69	138	48	37	75	80	22	45
27	67	133	49	37	73	82	22	44
28	64	129	50	36	72	84	21	43
29	62	124	51	35	71	86	21	42
30	60	120	52	35	69	88	20	41
31	58	116	53	34	68	90	20	40