Summary of SGC Manufactured Home Field Data (1997-98 Sitings in Idaho and Washington)

Bob Davis
Alison Roberts
David Baylon

November, 2000

Prepared for the Idaho Department of Water Resources – Energy Division
Ken Eklund, Project Manager

ECOTOPE
Consulting
Research
Design

4056 9th Avenue NE Seattle, WA 98105
(206) 322-3753 FAX: (206) 325-7270

Introduction

In April and May, 2000, a random sample of manufactured homes built to energy efficient standards and sited in Idaho and Washington during 1997-98 were visited and evaluated. Field technicians from Delta T, Inc. (Alan Van Zuuk and Bruce Manclark), WSU Cooperative Extension Energy Program (David Hales), and the Idaho Energy Division (Ingo Stroup) assessed the quality of home set-up (structural and operational issues), and tested house and duct tightness, system airflow, and performance of the whole-house ventilation system. The study employed most of the protocol used for the 1993 evaluation of the Manufactured Housing Acquisition Program (MAP). That study was much larger (162 sites) and included homes from all four states in Bonneville Power Administration's (BPA) service territory. The homeowner survey was omitted and additional tests for HVAC system airflow and operating static pressure were added.

BASIC SAMPLE CHARACTERISTICS

	Idaho %	Washington %	Both States %	MAP Homes (1994 study)
Double section home	80	67	73	81.5
Triple section home	20	33	27	6.7
Home size (sq. ft)	1,648	1,856	1,750	1,433

This study includes 25 homes from Idaho and 24 from Washington. This size of random sample should be viewed as an absolute minimum from which to generalize. Some general sample characteristics are worth noting. There were more triple section homes in this study than in the MAP study and average home size was thus considerably greater. No single section homes were surveyed in this study. (About 13% of the MAP sample was single section homes). All manufacturers were not represented in the sample, but given the size of the sample, inclusion of 15 manufacturers was encouraging. In the 1995 MAP evaluation, 19 manufacturers (including one California manufacturer and one Nebraska manufacturer) were represented. More than half of the homes in the sample (34, to be exact) were built in Oregon facilities, 12 were built in Idaho, and 3 were built in Washington.

MANUFACTURER INFORMATION

Manufacturer	# of homes in sample	% of sample
Fleetwood-Idaho	3	6.12
Fleetwood-Oregon	1	2.04
Fleetwood-Wash.	2	4.08
Fuqua	6	12.24
Golden West	4	8.16
Guerdon-Idaho	3	6.12
Guerdon-Oregon	2	4.08
KIT	3	6.12
Liberty	1	2.04
Marlette	5	10.20
Nashua	3	6.12
Redman	7	14.29
Silvercrest	4	8.16
Skyline	4	8.16
Valley	1	2.04
TOTAL	49	100

Set-up Compliance

The set-up compliance data table is based on a simple yes/no answer for a checklist of items. The survey was mostly unchanged from the MAP set-up survey. Individual states have developed their own set-up standards since MAP, so in some cases the data are not as detailed as would be required by the states. But in general, structural compliance is near 100%, with the exception of a low score in Idaho for pier support spacing under I-beams (56%). The "Pier supports installed per manufacturer's markings" field is somewhat obsolete, as most manufacturers do not mark piers as they did in MAP.

Not surprisingly, the lowest overall compliance rate is for belly penetrations, with 54% of all homes in compliance. This is worse than the MAP rate of 66%. Idaho's compliance rate of 29% is especially low. This is probably a combination of problems occurring at or before time of set-up and subsequent problems (plumbing fixes, etc.). The MAP and SGC specifications do not offer specific guidance on how to repair these penetrations. Most crews use some sort of pressure-sensitive tape, and given moisture and dirty surfaces, these tapes tend to fail rather quickly. The most secure means of ensuring patch success is to use building wrap (such as Tyvek), construction adhesive, and an outstitch stapler. Weatherization crews often use this technique when blowing insulation into a belly, but set-up crews and servicemen (such as plumbers) are unlikely to go to this much trouble.

Vapor barrier and skirting compliance were effectively 100%. Windows and doors were found to operate smoothly in most part, but about half of the Washington homes had doors which did not seal against the weatherstripping. This may account in part for the relative leakiness of Washington homes (see House Tightness section, below).

STRUCTURAL & OPERATIONAL SET-UP COMPLIANCE

Compliance Issue	% complying in Idaho	% complying in Washington	% complying in both states
Skirting installed	100	96	98
Ground vapor barrier present	100	92	96
Pier supports in place under I-beam	56	92	73
Pier supports in place under exterior doors	88	100	94
Pier supports installed per manufacturer's markings	90	95	94
Pier supports capped and shimmed	87	100	94
Footings present under pier supports	100	100	100
Belly penetrations sealed	29	79	54
Marriage line sealed	70	100	86
Exterior doors operate smoothly	92	92	92
Exterior doors seal against weather-stripping	83	54	69
Windows operate smoothly	88	96	92

Special attention was paid to crossover duct set-up, as problems with the crossover can result in huge energy penalties. Very low compliance of secure crossover ducts was noted in Idaho. In most cases, this was because only tape was used to make the connection, the crossover was poorly supported, or there was some combination of these factors. In a few cases (triple section homes), splitter boxes or tees were poorly connected or even disconnected. Catastrophic exterior duct leakage (over 500 CFM at 50 Pa) was found in these cases.

The compliance of the crossover duct being connected with sheet metal elbows has risen substantially over the 1995 data (54.5%), certainly affected by the 1994 MAP specification change requiring sheet metal elbows. Insulated connections have also risen substantially over the 1995 data (67%).

CROSSOVER DUCT SET-UP COMPLIANCE

Compliance issue	**% complying in Idaho**	**% complying in Washington**	**% complying in both states**
Crossover duct cut to length	88	88	88
Crossover duct connections secure	24	92	57
Crossover ducts connected w/ sheet metal elbows	72	92	82
Crossover duct connections insulated	92	88	90

House Tightness

A two point depressurization blower door test (with ducts unsealed) was conducted on all homes. Duct pressurization tests (with registers sealed and house pressurized to the same level as the ducts with respect to outside) were also conducted and are reported in a later section.

BLOWER DOOR RESULTS

	SGC Mfd Homes 1997-98 (this study)				**MAP 1992-93**		
Group	**# of cases**	**ACH_{50} average***	**Std. Dev.**	**CFM_{50} average**	**# of cases**	**ACH_{50} average**	**Std. Dev.**
All	49	4.76	0.95	1187	157	5.50	1.87
Double Wide	36	4.90	0.99	1102	127	5.50	1.90
Triple Wide	13	4.40	0.72	1424	12	4.92	1.22
Idaho	25	4.63	0.81	1101	32	6.12	1.55
Washington	24	4.90	1.08	1277	62	5.36	1.77

*minimum ACH_{50} is 2.33; maximum is 8.52

The average ACH_{50} for homes in this study is much lower than the MAP sample. Idaho's average ACH_{50} has improved substantially and is now lower than Washington's ACH_{50}. Because of high standard deviations and the small sample size, a review of the air changes per hour at 50 Pa separated by home manufacturers is not noted in the report.

The following table is presented in order to place the newest results amidst other house tightness results from recent studies. Although these manufactured homes still exhibit a moderate amount of shell leakiness, the trend toward a tighter building envelope continues.

BLOWER DOOR RESULTS FOR NORTHWEST HOMES

Group (Study Reference)	n	House Type, Year Built	ACH_{50} (averages)
WWP, Spokane [Kennedy et al 1994]	33	Site-built, "historic"	14.3
WWP, Spokane [Kennedy et al 1994]	21	Mobile home, "historic"	13.3
NORIS I [Palmiter & Brown 1989]	134	Site-built, 1980-86	9.28
NORIS II [Palmiter et al 1990]	49	Site-built, 1987-88	7.18
"Current Practice" Mfd homes [Palmiter et al. 1992]	29	Manufactured in late 1980's	8.75
Super Good Cents Mfd homes [Palmiter et al. 1992]	131	Manufactured in late 1980's	6.10
MAP [Baylon, Davis, Palmiter 1995]	157	Manufactured, 1992-93	5.50
Super Good Cents Mfd homes (this study)	49	Manufactured, 1997-98	4.76

What are the implications of the level of SGC tightness for average natural ventilation rates (from stack-induced infiltration/exfiltration)? If we divide the average ACH_{50} by 25, the estimated average ventilation rate for this set of homes is 0.19 ACH. (The tightest home has an estimated ACH_{nat} of 0.09; the leakiest, an estimated ACH_{nat} of 0.34.) This compares with 0.22 ACH for the MAP homes using the same methodology. This methodology is an artificial construct, since it says nothing about ventilation rates on a particular day or in specific parts of a home. Still, it gives a good rough idea of how much infiltration/exfiltration stack will provide on average. At levels of natural infiltration around 0.20 ACH, an assist is certainly needed from mechanical ventilation to reach levels recommended by ASHRAE.

The average equivalent leakage area (ELA) for this set of homes, as determined by the LBL Stack Method, is still on the order of 60 in^2. That is, there is plenty of shell leakage left to feed exhaust systems (leaving aside the issue of where the leaks are). The problem is not finding the make-up air for the exhaust systems. The problem is making sure the systems are properly designed and installed by the manufacturers and are turned on and maintained by the occupants.

Whole House Ventilation System Performance

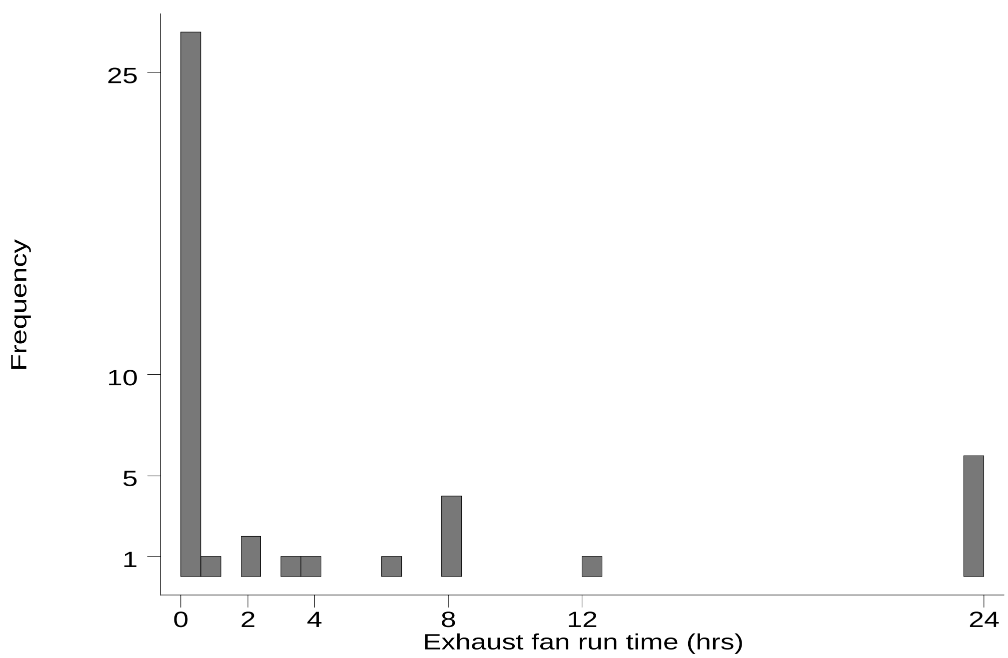
The ventilation systems reviewed in this study are all based on a central exhaust fan. HUD’s 1994 ruling on mechanical ventilation barred use of spot ventilators (bathroom fans) for whole house ventilation (HUD 1994). HUD later explained that fans located in the bathroom were not necessarily disallowed; their intent was to require manufacturers to install a high quality fan than commonly used for the whole house ventilator. Since the 1994 ruling, some manufacturers have received approval to use a bath fan for whole house ventilation. As the table shows, the most common location of the whole house fan is the hallway (43% of all cases), with the utility room (22%) the next most common. A bath fan is used in 20% of the cases.

WHOLE HOUSE FAN DATA

Location of fan	% in Idaho (n=25)	% in Washington (n=24)	% in both states (n=49)
Hall	28	58	43
Utility room	28	17	22.5
Bathroom	24	17	20
LR/Fam Rm/DR	16	8	12
Kitchen	4	0	2
Fans with timers	24	21	22.5
Fans with disabled timers	12	0	6
Fans w/dedicated breaker on panel	8	0	4
Fans controlled by manual switch only	56	79	67.5

Median measured fan flow is 73 CFM. No measurable flow was reported in only 4 homes; 2 others had flow of less than 30 CFM, indicating a very dirty fan, obstructed ductwork, or some other problem. About 75% of the fans had measured flow of 40 CFM or more.

Limited run time is really the issue here. Even a 40 CFM fan can provide effective ventilation if it is run continuously. As the chart below shows, 63% of the fans not controlled by an automatic timer (26/41 cases) were turned off at the time of the audit. In most of these cases, this was the normal operating condition of the fan as ascertained by the auditor. Only 27% of the homes had whole house fans controlled by an operating timer or dedicated circuit breaker.



A fan moving 70 CFM has to run about 20 hours/day to augment natural ventilation of 0.20 ACH sufficiently to reach the ASHRAE-recommended level of 0.35 ACH. There are only 3 cases in our set of homes where the fan was run at this level and only 8 homes where the fan was controlled to operate for 8 hours/day or more. In three of these cases, whole house fan operation was controlled by the Northwest Timer Kit.

About 20 % of the whole house fans were reported as noisy (next table); several were reported as extremely quiet (while still delivering rated flows). Several fans were also reported as very dirty (even though they had been installed and operating for a relatively short time). Fan maintenance is important, but few homeowners think about it or take the time to perform this task.

Lessons are clear: (#1) Homeowners need to be educated (once again) about the importance of ventilation (especially as homes get tighter), controls need to be labeled (and placed so that the homeowner notices them), and fans need to be operated. Homes are still leaky enough to provide plenty of air to these fans, but if they are never turned on, the average ventilation rate of many of the homes is quite likely to fall well below ASHRAE-recommended levels. (#2) Manufacturers must install fans properly and in-plant inspection and quality assurance need to ensure this.

WHOLE HOUSE FAN MANUFACTURER

Maker	n	# reported as noisy
Broan	26	5
Nutone	6	3
Panasonic	13	0
Unknown/not reported	4	

Two homes reported strong odor problems, specifically, sewage odors. In one of these cases, the utility room (containing the gas furnace and gas water heater) had no pass-through grille to the body of the home and the furnace was getting all of its return air from shell leakage (including the plumbing soil stack). In this home, the utility room was depressurized to 42 Pa with respect to outside. Even though the water heater was a closed combustion unit, depressurization was so severe that the water heater had difficulty operating. Carbon monoxide was also re-entrained in the utility room through leaks in the building shell.

Make-up air systems and attic ventilation systems were tallied. Make-up air systems are intended to provide extra dilution/removal air for indoor pollutants. Manufactured homes are getting more air-tight, but most have sufficient unintentional shell leaks which provide adequate make-up air for whole house ventilation systems. Leaks, whether intentional or otherwise, need to be combined with an adequate driving force for an adequate amount of time each day to meet air quality standards such as ASHRAE Standard 62.

ATTIC VENTILATION & MAKE-UP AIR SYSTEMS

Characteristic	# of units		
	Idaho	**Washington**	**both states**
Attic has mechanical venting systems	11 (44%)	6 (25%)	17 (35%)
Blend Air (Coleman)	9	5	14
VentilAire II (Intertherm)	2	1	3
Make up air system type (includes in-operable systems)			
Blend Air (Coleman)	4	1	5
Blend Air w/NW Timer Kit*	5	4	9
VentilAire II (Intertherm)	1	5	6
Passive Duct (POS or VentilAire I)	9	12	21
Make up air system inoperable**	4 (16%)	3 (12.5%)	7 (14%)
No make-up air system	6 (30%)	2	8*** (16%)
	% of homes reviewed which had		
Window fresh-air vents	24	13	18
Attic passive vents	100	96	98
Continuous soffit vents	54	30	43
High vents in each section	67	100	83
Gable end vents	36	21	29

*Median run time of whole house exhaust fan for this system was 8 hours. Two NW Timer Kit systems were disabled so that the whole house fan did not operate.
**Includes two Blend-Airs with Northwest Timer Kits, three Blend-Airs without the Timer Kit, and two with passive inlet ducts with dampers that are screwed shut.
***Out of the 8 cases without make-up air systems, only two, which were in Idaho, did not have window vents. One out of 49 sampled had window vents that were stuck and did not operate.

The Idaho homes had higher measured average indoor relative humidity than Washington (46% vs. 36%). The average readings are not noteworthy, but it should be noted that a majority of homes in the study were sited east of the Cascades.

Several factors could be contributing to higher relative humidity in some of these homes. None of the whole-house fans in the eight homes that had above 50% relative humidity were controlled by a timer or a dedicated circuit. One of these homes had a wet crawlspace and another has five occupants. Another home has a dryer that vents to the crawlspace and 8 occupants. One home has no comments or data that would suggest an obvious reason for the high humidity other than the previously mentioned lack of a whole house fan on a timer.

Heating/Air Conditioning System Data

Distribution of heating system type is much wider in this group of homes than in the MAP impact evaluation. Only half the homes have a central electric furnace versus about 85% in the MAP sample. The percentage of heat pumps is about the same in the two samples. Heating system size is not dictated by the size of the homes or the type of heating system.

Originally, it was thought that only electric heating systems would be included in this study. But natural gas and LPG furnaces are becoming more common in manufactured homes in the Pacific Northwest because of price advantages and consumer choice. A significant portion of the sample had other combustion appliances in the home other than a gas or LPG furnace. Natural gas water heaters were the most common of these appliances (found in 24% of the sample). Only four homes had a wood stove or wood fireplace; only one had a wood pellet stove. Combustion appliance flue gases were checked for CO emissions, as was home ambient air.

HEATING/COOLING SYSTEM SURVEY

	% in Idaho	% in Washington	% in both states
Has electric furnace	56	42	49
Has heat pump (HP)	4*	25	14
Furnace fired by natural gas or LPG	40	33	36
Has central air conditioning (other than HP)	28	46	37
% of gas/LPG furnaces with central air conditioning	40	75	56
Combustion appliances present**	40	46	43
	kBtu/hr	**kBtu/hr**	**kBtu/hr**
Average electric furnace size	50	60	54
Average heat pump size	36	41	40
Average nat. gas or LPG furnace size	56	51	54

*only one heat pump in Idaho, located in Juliaetta (SE of Moscow)
**other than central natural gas or LPG furnace

Duct work type was noted, mostly to show the percentage of duct board used in these homes. Only three homes in this sample used duct board trunk ducts: two Redman homes and one Guerdon-Idaho home. Another manufacturer, Palm Harbor Homes, uses a duct board system and mastic for sealing joints (unlike Redman or Guerdon) and has achieved good duct tightness results. Palm Harbor is not represented in this sample.

The table also breaks down duct tape type. Every plant uses some type of tape to seal joints. The tape most commonly used before the latter stages of MAP is aluminum tape with a thin (2 mil) acrylic adhesive backing. A push was made to encourage manufacturers to use aluminum tape with thicker (10 mil) butyl rubber based adhesive. Each tape can be defeated by a dirty application surface (common) or sharp metal edges (also common); neither tape has much tensile strength and will usually fail if used for a mechanical connection or if applied to a piece of metal which is under spring tension (an incompletely bent finger joint is a common example). The table shows butyl tape was the primary sealant used in half of the homes; another 11% of homes used a combination of butyl and acrylic tape.

Auditors were asked to evaluate tape for failure. Failure at supply registers was defined as lack of adhesion at one or more registers; lack of adhesion meant open gaps were visible or a finger could be inserted behind the tape. Failure at the furnace connection was sometimes hard to observe, but smaller failures here can result in larger energy penalties than at the registers.

Failure rates are substantial for both tapes, and suggest the need to come up with a more reliable means of supporting duct connections and limiting air leakage. Duct leakage results (below) confirm that a shift to the thicker adhesive tape has had no effect on reducing leakage rates.

DUCT TYPE AND CONNECTIONS

	% of homes reviewed		
Characteristic	**Idaho**	**Washington**	**both states**
Duct Board	8	4	6
Sheet Metal	92	96	94
Type of tape used at furnace & registers			
Acrylic	36	46	39
Butyl	55	42	50
Butyl and Acrylic	9	13	11
Tape falling off at furnace	33	17	24
Acrylic (% falling off)	80	33	24
Butyl (% falling off)	0	33	16
Butyl and Acrylic (% falling off)	20	33	14
No tape present	13	0	6
Tape falling off at registers	42	48	45
Acrylic (% falling off)	33	18	25
Butyl (% falling off)	44	73	60
Butyl and Acrylic(% falling off)	22	9	15
No tape present	5	0	2

Duct leakage data are of particular importance in determining duct losses. Average duct leakage is considerably higher than the MAP study showed; however, a small number of very leaky cases skew the average. These are the catastrophic failures where splitter boxes or tees of triple section homes were disconnected, as mentioned on page 4.For this reason, median values are a better measure of performance. Medians for SGC homes are quite close to the MAP figures. While this means leakage not caused by poor on-site installation has probably not increased, it also means leakage rates for ducts installed in the plants have not decreased. Work remains to be done in the area of duct connections—both in the plants and on-site.

DUCT LEAKAGE TO EXTERIOR*

	SGC Mfd Homes 1997-98 Median (Average)		MAP 1992-93 (Averages except for triples)	
Group	**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 (n=47)	103 (151)	159 (231)	(104)	(157)
Double section home (n=34)	97 (157)	157 (240)	(101);n=124	(155)
Triple section home (n=13)	144 (134)	223 (210)	122; n=11	169
Idaho (n=24)	106 (165)	168 (254)	-	-
Washington (n=25)	103 (135)	159 (208)	-	-

*Leakage back into the home's interior neutralized by blower door operation

Some additional points are worth noting. If we compare median leakage rates for homes with ducts sealed with the butyl tape and acrylic tape, the butyl tape group is much leakier: 156 CFM_{25} (for 21 cases) vs. 93 CFM_{25} (19 cases). Ducts attached to electric forced air furnaces (median 113 CFM25 for 24 cases) were leakier than natural gas cases (median 97 CFM25 for 11 cases). The three leakiest duct systems (437 CFM_{25}, 555

CFM_{25} and 628 CFM_{25}) were attached to electric furnaces. The leakiest system was found in a Washington double-section home. The next six leakiest homes were sited in Idaho; five of these homes were double-section units.

Air handler flow and system static pressure data were collected to enable estimates of duct distribution efficiency. Idaho used the temperature rise method (nearest register minus return air temperature) and Washington used the Energy Conservatory flow grid (currently under development) to find furnace data.

FURNACE AIR FLOW AND SYSTEM STATIC PRESSURE

	Mean	Median
Air handler flow (standard CFM); n=49	1,082 SCFM	1,087 SCFM
Static pressure at registers (average of 4 readings); n=39	20.3 Pa	15.6 Pa
Static pressure at furnace supply plenum; n=36	57.6 Pa	47 Pa

Static pressure data varied somewhat by furnace size (or, more accurately, by home size). The smallest furnaces (40,000 Btu/hr bin) correspond to smallest houses, but these homes have fewer registers so the median register and supply plenum static are relatively high: 25 Pa and 59 Pa respectively. The largest furnaces (60,000 Btu/hr bin) have a median supply plenum static of 64 Pa and median register static of 14 Pa. Ten cases were eliminated from the register static mean/median results because the static pressure was measured incorrectly. In 13 cases, it was not possible to measure the supply plenum static pressure because of access problems.

The supply leakage fraction is the ratio of exterior duct leakage at average system static pressure divided by furnace air handler flow. The average system static pressure is a weighted average of supply plenum and register static pressures. For this type of home, the supply plenum static pressure and the average of register statics each receive equal weight. For example, if the supply plenum static pressure is 50 Pa, and the average register static is 20 Pa, the overall average system static pressure is 0.5*50 Pa + 0.5*20 Pa = 35 Pa. Several cases for which register statics were measured incorrectly (mostly in Idaho) were taken out of this analysis.

SUPPLY LEAKAGE FRACTION*

	Mean %	Median %
All (n=33)	15.4	13.8
Double section (n=24)	14.6	12.8
Triple section (n=9)	17.6	14.5
Idaho (n=11)	12.8	8.9
Washington (n=22)	16.7	14.4

*Exterior duct leakage as % of air handler flow.

Detailed analysis has not been performed as yet on the system efficiency implications of the supply leakage fraction. However, first order approximation suggests an average distribution efficiency of around 80% for an SLF of 15% combined with an R-33 cut-in floor. Overall system efficiency, on average, should then be expected to range from about 80% for an electric furnace system to about 65% for a system heated with an 80% AFUE gas furnace.

Obviously, there is room for improvement, and the most obvious place is the furnace and register boot connections. Tape alone will not do the job, so SGC must look to permanent mechanical solutions (augmented by better sealants) to bring duct leakage levels down to a level truly befitting SGC designation. At least one manufacturer already uses an improved register and boot design which promotes a much better connection and facilitates application of mastic (but on a duct board trunk). This design is not at all experimental, but is now everyday practice at this plant.

Summary of Findings

- Set-up compliance was generally acceptable, but certain problem areas (especially unsealed belly penetrations and crossover connections) remain.

- SGC manufactured homes are getting tighter; averaging 4.76 ACH_{50} vs. 5.50 ACH_{50} for the MAP random sample.

- Small sample size makes drawing a definite conclusion difficult, but it appears duct leakage was not appreciably greater than measured for the MAP homes. Leakage is still substantial, and duct distribution efficiency suffers as a result. The study results indicate that use of butyl tape has not solved the problem. Better duct connection techniques and materials are needed.

- More than half the whole house ventilation systems (not controlled by timers) were not customarily operated by homeowners.) Only 29% of the systems had an operating timer or dedicated electrical breaker, and only three systems out of 49 were operated continuously. Central ventilation systems require intentional controls and labeling and homeowners need better information if these systems are to deliver effective ventilation.

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.

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

Kennedy, M., P. Francisco, J. Heller, B. Manclark, and L. Palmiter. 1994. *Energy Exchanger Installation Quality Assurance Study*. Prepared for Washington Water Power Company under Contract No. R-0166-93.

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.

Palmiter, L., I. Brown, and T. Bond. 1990. *Northwest Residential Infiltration Study, Cycle II: Infiltration and Ventilation in New Electrically Heated Homes in the Pacific Northwest*. Ecotope, Inc., Seattle.

Palmiter, L. and I. Brown. 1989. *Northwest Residential Infiltration Study, Volume 1: Analysis and Results*. Prepared for the Bonneville Power Administration under Washington State Energy Office Subcontract No. 88-24-01.

Appendix – Field Protocol

NEEM FIELD SURVEY

Site ID#_________ Date_______________

Occupant

Name:__________________________Address:_________________________________

City, State______________________________Zip__________

Phone_________________________________

Electric Utility____________________________

Dealer/location___________________________

Set-up crew (if known)________________________________

Person filling out this report_____________________________________

Basic Information

1. Manufacturer _____________________ Model ________________________
HUD #:__________________________NEEM#_______________________

____Single Wide ____Other
____Double Wide Describe: _______________________________________
____Triple Wide ____

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

2. Perform a quick visual inspection of the ducts. Use a mirror. Note problems on sketch.

Heat Source

Is there an electric furnace? ______yes ______no Size (kW) @ 208/240V
____

Is there a heat pump? ______yes ______no
Make and Model # Outdoor unit________________Indoor unit______________

Is there air conditioning? ______yes ______no
Make and Model # ____

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):____

____

Measure relative humidity with sling psychrometer or digital meter. Record: _____________

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

List whole house fan make/model. Measure flow and note timer setting (if applicable).

Make and Model	Location (bath, hall, etc.	Flow (cfm)	Daily run time (hrs)	Noisy?	Timer disabled by occupant?

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

None	
Blend Air™ (Coleman)	
Blend Air™ (Coleman) w/NW Timer Kit	
VentilAire™ II (Intertherm)	
Passive duct (POS or VentilAire™ I)	

Make-up duct diameter _______inches

Note if the make-up damper is jammed or otherwise inoperable: ________________________.

Combustion Appliances

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

Type (stove, portable heater, etc.)	Fuel	Outside combustion air (hard ducted)?	Notes (evidence of venting problems, etc.)

Set-Up Review

Conduct a review of set-up quality and operational features of the home:

Crawlspace:

Yes	No		Comments
		Is skirting in place?	
		Is there a ground vapor barrier?	
		Are pier supports in place under I-beam with at most 6' O. C. spacing?	
		Are pier supports in place under exterior doors?	
		Are pier supports installed per manufacturer's markings?	
		Are pier supports properly capped and shimmed?	
		Are footings present under pier supports?	
		Is crossover duct cut to length?	
		Are crossover duct connections secure?	
		Are crossover ducts connected with sheet metal elbows?	
		Are crossover connections insulated (no exposed metal)?	
		Are belly penetrations sealed?	
		Is marriage line sealed?	

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

Operations:

Yes	No	
		Do exterior doors operate smoothly?
		Do exterior doors seal against the weather-stripping?
		Do windows operate smoothly?
		Do window fresh-air vents operate properly?

Comments:

Ventilation/Ducts:

Yes	No	
		Does the attic have a mechanical ventilation system?
		VentilAire II (Intertherm)
		Blend Air (Coleman)
		Does the attic have passive vents?
		Continuous soffit vents?
		High vents in each section?
		Gable end vents?
		Is the tape failing at the furnace boot? Note adhesive type: butyl acrylic
		Is tape failing at register boots? Note adhesive type: butyl acrylic

Comments:

Measuring Air Handler Flow With the Temperature Rise Method

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* *delta T ___________*

Element	amps	volts	watts
1			
2			
3			
4			
		total	

SCFM = (Watts in · **constant)**/(delta T)

Where the **constant** is either 3.16 (if using °F) or 1.75 (if using °C)

Show work:

Record furnace blower make and model number and speed tap setting (check which speed is operating with ammeter):

Measure static pressure in supply plenum (if possible) and at least 4 registers to enable an estimate of system operating pressure:

Register#	Static P (Pa)
Supply plenum	

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.

Make and model of blower door used ______________________________________

Record outdoor temperature__________ Record indoor temperature ____________

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	Ring	BD flow near 25 Pa (Q_{25})

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.

Exterior Duct Leakage Test

Tape registers. Pressurize the house to 50 Pa with respect to outside. Turn on the Duct Blaster™; increase speed until the duct pressure (with respect to the house) is 0 ± 0.2 Pa. Reread the house pressure and adjust the blower door (if necessary) to approach 50 Pa pressure difference between house and outside. Again read the duct pressure with respect to house and adjust the DB until this pressure difference is 0 ± 0.2 Pa. Note where duct pressure(s) measured: ________________________________

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

Duct P near 50 P	DB fan pressure	DB Ring	DB flow near 50 Pa (Q_{50})	Duct P near 25 Pa (P_{25})	DB fan pressure	DB Ring	DB flow near 25 Pa (Q_{25})

Check flow exponent as above:

DEPARTURE CHECKLIST:

________ All registers untaped
________ Furnace filter in place
________ Furnace buttoned up and operable
________ Check thermostat setting
________ Check for tools and equipment, especially under house