NORTHWEST RESIDENTIAL INFILTRATION SURVEY
CYCLE 2

Study Design &
Sample Selection

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Table of Contents

1 Introduction 1

2 Goals and Objectives 1

3 Sample Development 1
3.1 Initial Refinements 2
3.2 Further Refinements 2

4 Telephone Survey and Recruitment 3
4.1 Survey Instrument 4
4.2 Telephone Survey Execution 4

5 Sample Selection 5

6 Disposition of Sample 7

1 Introduction

Battelle Pacific Northwest Laboratories, working under contract with Bonneville Power Administration (BPA) and the State of Idaho's Department of Water Resources, conducted the Northwest Residential Infiltration Survey (NORIS) to shed light on the impacts of air infiltration and ventilation on heat loss in residential buildings. The study was carried out during the 1987/1988 (Cycle 1) and 1988/1989 (Cycle 2) heating seasons. Cycle 1 evaluated homes built since 1979 to establish a baseline for studying infiltration rates. Cycle 2 studied homes with non-heat recovery ventilation (NHRV) systems which met Super Good Cents (SGC) specifications.

2 Goals and Objectives

The primary goal of NORIS Cycle 2 was to measure the infiltration and ventilation characteristics of new SGC electrically heated single-family homes in the Bonneville Power Administration (BPA) service area. We placed special emphasis on the scientific and statistical defensibility of the infiltration estimates. In particular, the sample of homes was to be statistically representative of the populations of interest.

The eligibility criteria defining the target population for NORIS Cycle 2 were:

* Homes built in localities with a SGC program
* No multifamily units
* Built to April 1987 SGC specifications
* No mobile homes
* Electric space heat
* Non-heat recovery mechanical ventilation system

Non-heat recovery ventilation systems were included in SGC specifications to meet ASHRAE standard 62 for residential ventilation. Five types of NHRV systems are defined in the SGC specifications, found in Appendix 1. All five must be controlled automatically either with a dehumidistat or a 24 hour timer to meet the specifications.

We employed two techniques to measure ventilation and infiltration: a blower door leakage test combined with a Sherman-Grimsrud infiltration model and the time-averaged perfluorocarbon tracer method (PFT).

These two tests measure different aspects of ventilation and infiltration. The PFT test is a measure of overall ventilation averaged over a 2-4 week period of time, including ventilation from the NHRV system and other fans, open windows and doors, fireplace use, and other sources. The blower door test is a measure of envelope tightness, and in conjunction with a theoretical infiltration model taking average weather patterns into account, can provide estimates of air infiltration. The secondary goals of the project were to compare results from blower door and PFT tests and determine the impact of the installed ventilation systems on air infiltration and ventilation rates in these homes.

3 Sample Development

Choosing a sample of qualified homes that would match well with Cycle 1 houses was difficult because of the requirement that Cycle 2 houses meet SGC specifications. Only public, municipal and cooperative utilities can implement the SGC program. Many of the counties in which large

numbers of homes were studied for Cycle 1 did not have active SGC utilities or were just beginning such programs. Fortunately, one county, Snohomish County, provided a good basis for our sample.

Snohomish County PUD has been the most active and aggressive SGC utility in the Pacific Northwest. And Snohomish County has had a high rate of new home construction in the last decade. Finally, the number of Snohomish County houses studied during NORIS Cycle 1 was quite large (35 houses or about 25% of the sample) providing a good sample for comparison.

The project budget allowed for field tests on a maximum of 50 homes. Therefore, we developed a random sample of 50 from all the homes built and certified by October 1988 under the current SGC specifications in the Snohomish County PUD service area.

3.1 Initial Refinements

The Snohomish County PUD gave us a list of 246 homes which met the April 1987 Super Good Cents (SGC) specifications. These were houses which had been permitted after June 1987, passed the utility's final inspection and received an SGC incentive by October 1988. These homes were built in the Snohomish County Service territory which covers Snohomish County and parts of Island County. This list contained builder names, addresses of the homes, the dates the homes were certified and additional notes for some of the houses indicating type of sale, modular or mobile home, and existence of heat recovery ventilation (HRV). Twelve homes from this original list were eliminated immediately as they included either heat recovery ventilation systems or they were certified as manufactured homes.

We gathered additional information for our database from the Snohomish County files including zip codes, type of sales, vent system type, heating system type, owner phone number, builder phone number and floor area of the homes.

3.2 Further Refinements

We gave the list of 234 homes to Pacific Northwest Bell along with street addresses and home owner names when they were available. The phone company provided telephone numbers (when these were publicly listed) and verified addresses. Through this process we acquired phone numbers for all but 66 houses. Of these, 19 were privately listed and the others were either not found or no home owner name was available.

We also examined other sources, including building files and utility records, to find phone numbers for these 66 homes. We eventually eliminated 28 homes for which we could find no telephone number in any of these sources. Many of these 28 were probably unoccupied although we could get no independent confirmation of this. Seven owners were listed as living at different addresses, because of the renaming or renumbering of the street or because the house was not yet occupied.

In the process of reviewing the SGC files at Snohomish County PUD, some homes that should have been eliminated in the preliminary search were identified. Seventeen homes were unoccupied, 10 homes were RCDP homes which were being evaluated as part of another research project and nine homes were eliminated for other reasons which are shown in Table 1.

After a review of the SGC program requirements, it was noted that homes with 4-barrel exhaust systems inspected before January 1988 had no requirements for fresh air intake. After 1988, the code for the SGC program changed to require intakes for the 4-barrel systems. Jeff Harris of

BPA recommended that homes with the older 4-barrel exhaust systems be eliminated from further evaluation since they didn't meet the current SGC specification. Thus we eliminated 21 homes from the sample. This reduced the percentage of reported 4-barrel exhaust systems from 16% of the original sample to 4% of the test sample. We later discovered that 5 of the homes actually tested (10% of the sample) had the old 4-barrel ventilation systems although they were reported differently in the SGC file.

Out of the original 234 homes, 149 remained to be contacted during the telephone survey. Telephone calls were made to all of these remaining homes to recruit the home owners for the study. Of these 149 homes, one was used as a summer home, one house had changed hands and the new owner could not be located, and two were never reached after numerous attempts by phone.

Table 1
Reasons for Elimination of Houses
From NORIS Cycle 2 Sample

	DESCRIPTION	NUMBER
(Prior to Phoning)	No Phone Number	28
	Gas Heat	1
	Heat Pump Water Heater	2
	Heat Recovery Ventilation System	4
	Garage/Studio	1
	Mobile Home	1
	Not Occupied	17
	RCDP	10
	4 Barrel Before 1988	21
(During Phoning)	Summer Home	1
	Owner/Occupant Unknown	1
	Never Reached By Phone	2
	Total	89

4 Telephone Survey and Recruitment

We assigned random ID numbers to all 234 homes in the original sample. The sample was reordered by ID number and the 149 eligible homes were called in that order. Phone lists were also assigned randomly to the recruiters. Callbacks for no answers were always made first during the next calling period. Using a quota of ten callbacks per house with no answer, we succeeded in reaching all but two homes.

4.1 Survey Instrument

The telephone survey instrument used was adapted from the one used for NORIS Cycle 1 and is included in Appendix 2. The primary difference between the two surveys is that the Cycle 2 instrument was not used as a screen. Several of the questions in the Cycle 1 telephone survey were designed to screen out older, non-electrically heated houses. The telephone sample for Cycle 2 was already pre-screened, so questions from the Cycle 1 instrument designed to screen the sample were eliminated.

The first question in the Cycle 2 instrument asked if the house was built since 1987. This was true for all the houses called. Most of the other questions were phrased identically to those in the NORIS Cycle 1 questionnaire. We eliminated the question "Would you say your home was drafty?" because it did not provide useful information during Cycle 1. We added the question "Does your home have moisture or odor problems?" which was part of the homeowner survey during Cycle 1 and correlated well with the PFT test results. The remainder of the survey instrument contained the recruitment script which was adapted directly from the Cycle 1 instrument and designed to give occupants enough information so that individual questions could be raised and answered by the recruiters.

4.2 Telephone Survey Execution

Of the 145 homes contacted, 92% completed the telephone surveys. Twelve occupants refused to be interviewed. Twenty-three (17%) completed the interview but declined to participate in the study over the phone. The remaining 110 (83%) who completed the survey either agreed to participate or expressed some interest in participating. Information packets were sent to all these respondents. Appendix 3 contains the information sent in this packet.

Since the sample was pre-screened and relatively small, we used personnel who were knowledgeable about the goals and techniques involved in the study to call and recruit the home owners. This enabled the recruiters to give informed answers about the project during the recruitment process.

We developed a well organized and aggressive approach to the initial and follow-up phone calls. After the literature and access agreements were mailed out, the 110 possible candidates were called back up to three times to remind them to sign and send back their access agreements and to answer any further questions or concerns they might have. These follow-up phone calls were made by the same people doing the initial calling.

Using these procedures we received a very high percentage of participation in the study. 76% of the occupants contacted agreed to receive literature and access agreements in the mail, and 67% of these signed and returned the access agreements. This amounts to over 50% of the entire sample contacted.

A high level of participation was essential for NORIS Cycle 2 because of the smaller number of homes in the initial sample. Of 147 possible houses, a minimum of 50 had to be recruited to yield a statistically relevant sample. This amounts to just over one third of the possible sample. The Cycle 1 success rate was 24% of the possible sample actually recruited for testing. If we had only achieved the same level of participation as Cycle 1, we would have recruited only 35 houses, an inadequate number for this study.

Answers to the questions asked in the telephone survey are shown in Table 2.

Table 2 Results of Telephone Survey				
QUESTION	Response from 133 Respondents		Response from Test Sample of 50	
	Frequency	Percent	Frequency	Percent
House Type				
1 no basement	61	46	18	36
1 w/ basement	12	9	7	14
2+ no basement	49	37	20	40
2+ w/ basement	11	8	5	10
Heat Type				
Furnace	21	16	14	28
Baseboard	7	5	2	4
Wall Units	90	68	29	58
Heat Pump	14	11	4	8
Radiant	1	1	1	2
Wood Fuel?				
yes	49	37	20	40
no	84	63	30	60
Moisture Problem?				
yes	9	7	6	12
no	124	93	43	88

5 Sample Selection

The final sample could have been constructed in a variety of different ways depending on the information desired. To study the overall average effect of the SGC program on houses built in Snohomish County, we could have used a totally random sample drawn from the 74 occupants who agreed to participate. However, if we wanted to know the average effect of the SGC program on building practices in Snohomish County, we needed a sample of houses built by as many different builders as possible.

Since 24% of the eligible sample of 147 homes was made up of houses built by five big builders, the first approach could have yielded a sample dominated by a few big builders. After consulting with Jeff Harris of BPA we limited the number of houses built by any one builder to a maximum of three.

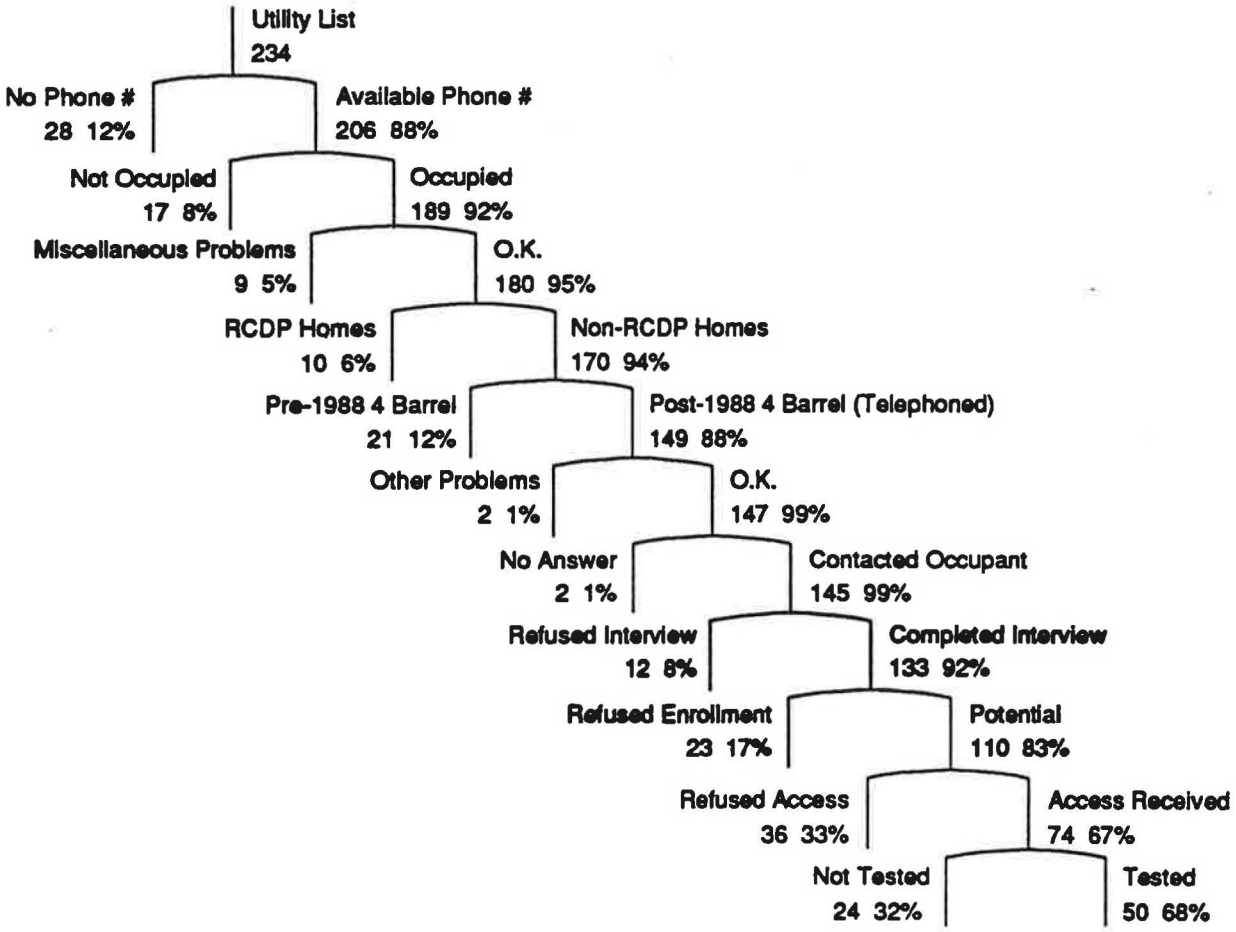
The final sample of 50 test houses were chosen from the 74 homes which sent in access agreements. The 50 chosen were those with the lowest ID numbers, up to a maximum of three for any one builder. Since the ID numbers were originally assigned at random, this method produced a random sample of the original surveyed population.

Houses were assigned 5 at a time in order of ID number to the two blower door contractors. The contractors then contacted the home owners to schedule the testing. This type of random assignment of test houses to contractors is essential to minimize the correlation between contractor bias and other effects. This reduces the probability that all houses in a certain area or all houses built by one builder will be tested by the same contractor.

Figure 1 illustrates the development of the final sample.

Figure 1

Progression of NORIS Cycle 2 Sample



During the testing process one of the houses was dropped from the sample due to scheduling difficulties. This house was inadvertently replaced with a house built by a big builder, raising the number of houses by that builder to 4 out of the final sample of 50. Another house was dropped from the sample when during the walk through audit the contractor determined that there was no installed ventilation system of any type.

Builders that built more than three houses of the 147 houses in the eligible sample are listed in the table below.

Table 3
Effect on Sample of Multiple House Builders in Snohomish County

BUILDER NAME	HOUSES IN ELIGIBLE SAMPLE		HOUSES IN TEST SAMPLE OF 50	
	#	%	#	%
Dujardin	14	9.5	4	8.0
Generation	4	2.7	2	4.0
Hoffman	7	4.8	0	0.0
Posey	4	2.7	2	4.0
Thomas	6	4.1	2	4.0
TOTAL	35	23.8	10	20.0

6 Disposition of Sample

The test sample was compared with the original database to examine for significant biases that could have resulted during sample selection. The results are shown below in Tables 4 and 5.

Table 4
Comparison of Homes by Type of Sale

SALE TYPE	Original Sample of 234		Potential Recruitment Sample		Returned Access Agreements		Final Test Sample	
	#	%	#	%	#	%	#	%
SPEC	105	45	61	42	25	34	16	32
CUSTOM	76	32	53	36	32	43	24	48
PRESALE	27	12	15	10	6	8	4	8
OWNER	26	11	18	12	11	15	6	12
TOTAL	234	100	147	100	74	100	50	100

Table 5 Comparison of Houses by Floor Area								
FLOOR AREA RANGE (ft^2)	Original Sample of 234		Potential Recruitment Sample		Returned Access Agreements		Final Test Sample	
	#	%	#	%	#	%	#	%
0-1500	82	35	51	35	18	24	11	22
1500-2000	84	36	45	31	23	31	13	26
2000-3000	58	25	45	31	29	39	23	46
+3000	10	4	6	4	4	5	3	6
TOTAL	234	100	147	100	74	100	50	100

The test sample seems to be slightly more dominated by middle sized houses and custom built houses than the original sample. Further analysis would be required to determine the significance of this apparent bias.

Appendix 1

Super Good Cents
Energy Efficient Homes

VENTILATION

OPTIONS

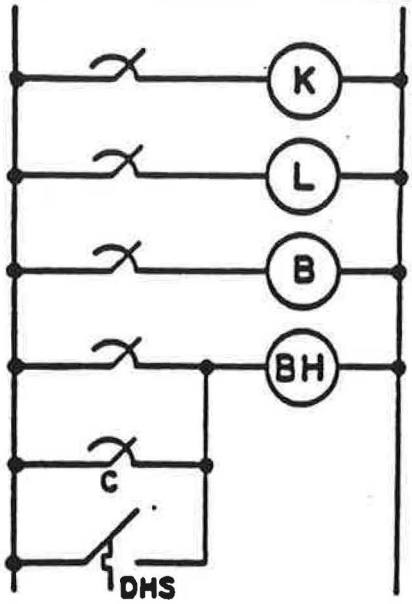
Discuss with your field representative before installation.

FIGURE 12.A

Non-HRV Option 1
Integrated Spot & Whole House System

CONTROL WIRING SCHEMATIC

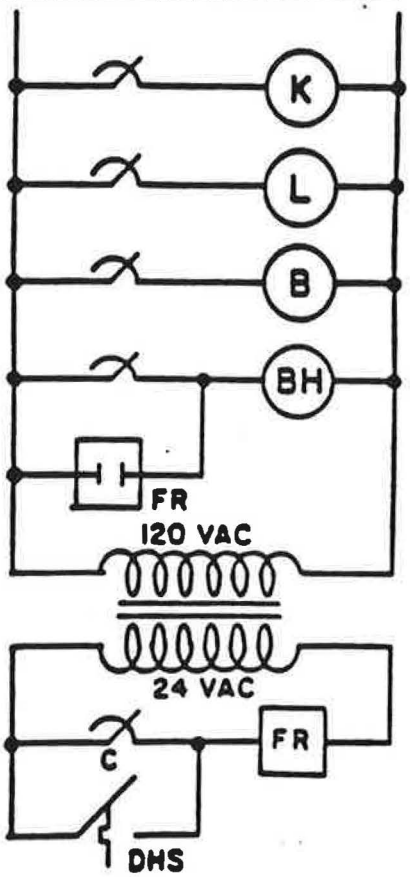
LINE VOLTAGE CONTROL OPTION



LEGEND

	TIME SWITCH
	DEVICE ACTIVATED SWITCH
	FAN MOTOR
	RELAY/CONTACTOR
K	KITCHEN
L	LAUNDRY
B	BATH
BH	BATH/WHOLE HOUSE
FR	FAN RELAY
DHS	DEHUMIDISTAT
C	CENTRAL

24 VOLT CONTROL OPTION

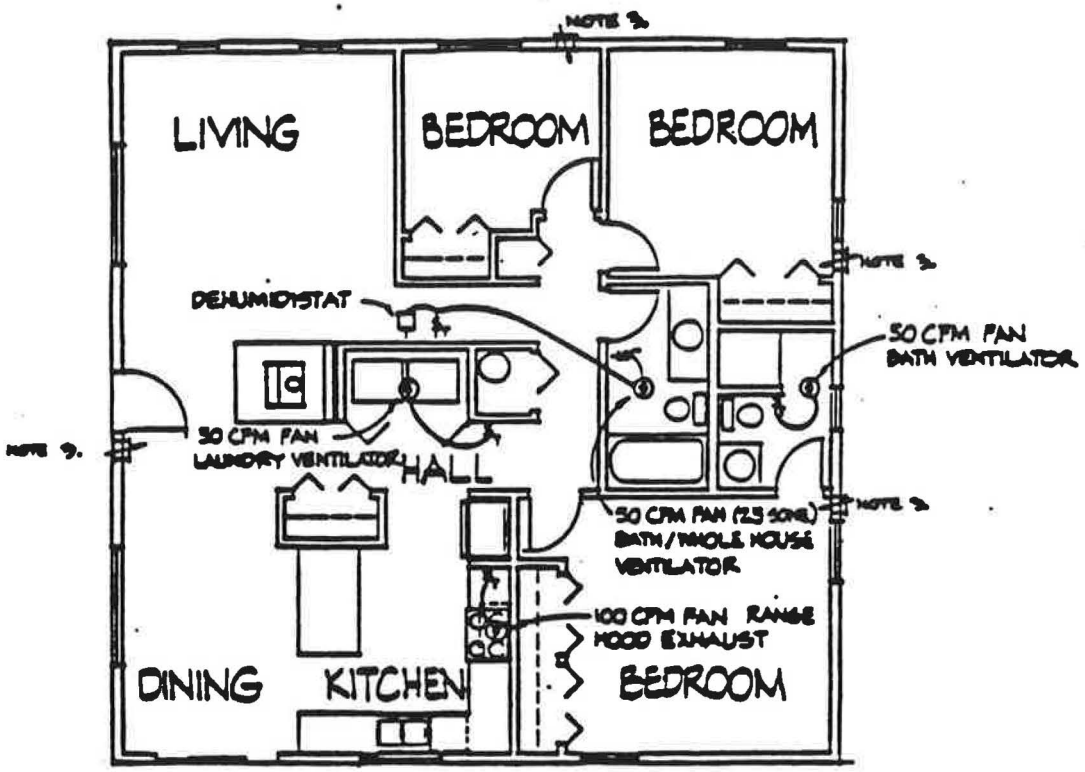


OPTION: SUBSTITUTE ON / OFF SWITCH FOR TIME SWITCH (KITCHEN ONLY)

OPTION: SUSTITUTE CLOCK TIMER FOR DEHUMIDISTAT

FIGURE 12.A

Non-HRV Option 1
Integrated Spot & Whole House System



LEGEND:

- TIMER SWITCH (SPRING WOUND)
- FAN MOTOR
- FRESH AIR INLET
- CONTROLLER

NOTES:

1. WHOLE HOUSE FAN/BATH VENTILATOR (2.5 SONE) CONTROLLED BY SWITCH IN BATH, CENTRAL SWITCH, AND BY DEHUMIDISTAT.
2. UNDERCUT BEDROOM AND BATH DOORS TO ALLOW FRESH AIR CIRCULATION THROUGH HOUSE.
3. PROVIDE FRESH AIR INLETS (10 CFM, MIN.) AS FOLLOWS:

1. @ EACH BEDROOM	3 x 10 = 30 CFM
1 @ LIVING AREA	1 x 10 = 10 CFM
TOTAL (MINIMUM)	4 x 10 = 40 CFM

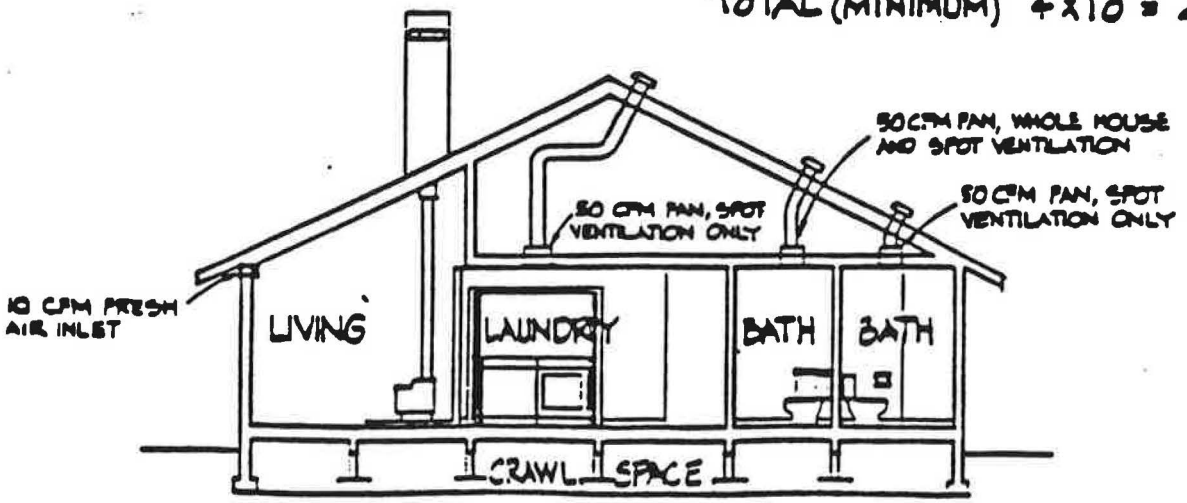
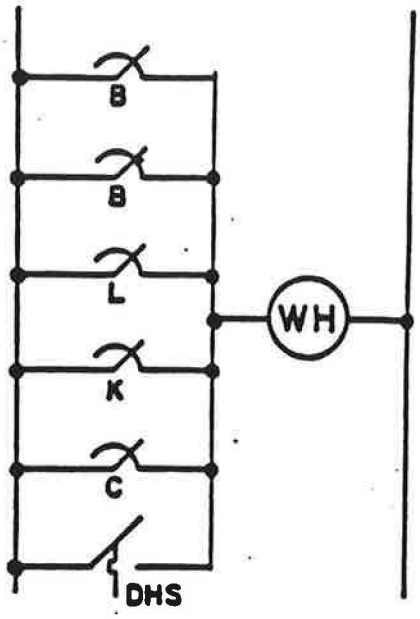


FIGURE 12.B

Non-HRV Option 2
Ducted Central Exhaust System

CONTROL WIRING SCHEMATIC

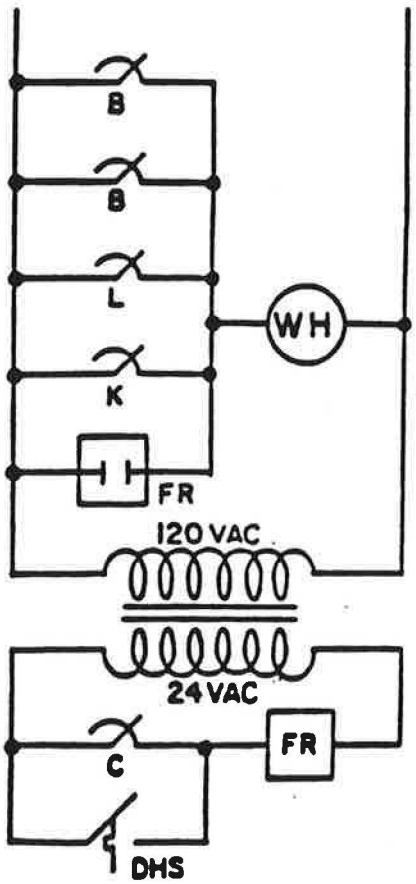
LINE VOLTAGE CONTROL OPTION



LEGEND

	TIME SWITCH
	DEVICE ACTIVED SWITCH
	FAN MOTOR
	RELAY/CONTACTOR
WH	WHOLE HOUSE
B	BATH
L	LAUNDRY
K	KITCHEN
C	CENTRAL
DHS	DEHUMIDISTAT
FR	FAN RELAY

24 VOLT CONTROL OPTION

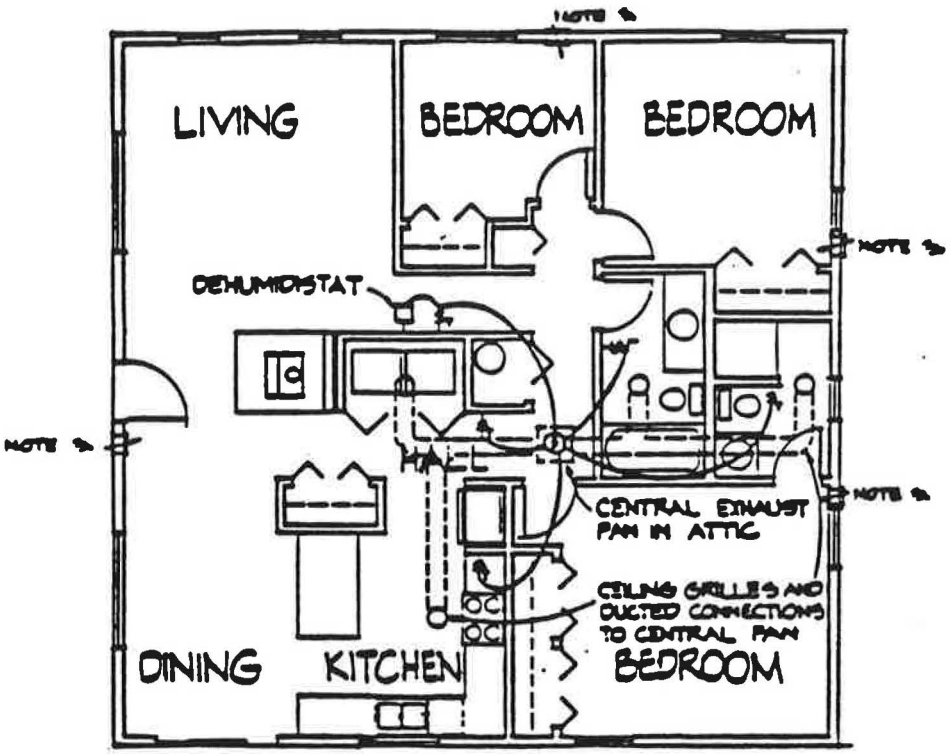


OPTION: SUBSTITUTE ON / OFF SWITCH FOR TIME SWITCH **(KITCHEN ONLY)**

OPTION: SUSTITUTE CLOCK TIMER FOR DEHUMIDISTAT

FIGURE 12.B

Non-HRV Option 2
Ducted Central Exhaust System



LEGEND:

- TIME SWITCH (SPRING WOUND)
- FAN MOTOR
- CEILING GRILLE AND DUCT
- FRESH AIR INLET
- CONTROLLER

NOTES:

1. CENTRAL EXHAUST FAN IN ATTIC CONTROLLED BY CENTRAL SWITCH, SWITCHES IN KITCHEN, LAUNDRY, BATHS, AND BY DEHUMIDISTAT.
2. UNDERCUT BEDROOM AND BATH DOORS TO ALLOW FRESH AIR CIRCULATION THROUGH HOUSE
3. PROVIDE FRESH AIR INLETS (10 CFM, MIN.) AS FOLLOWS:

1 @ EACH BEDROOM	3 x 10 = 30 CFM
1 @ LIVING AREA	1 x 10 = 10 CFM
TOTAL (MINIMUM)	4 x 10 = 40 CFM

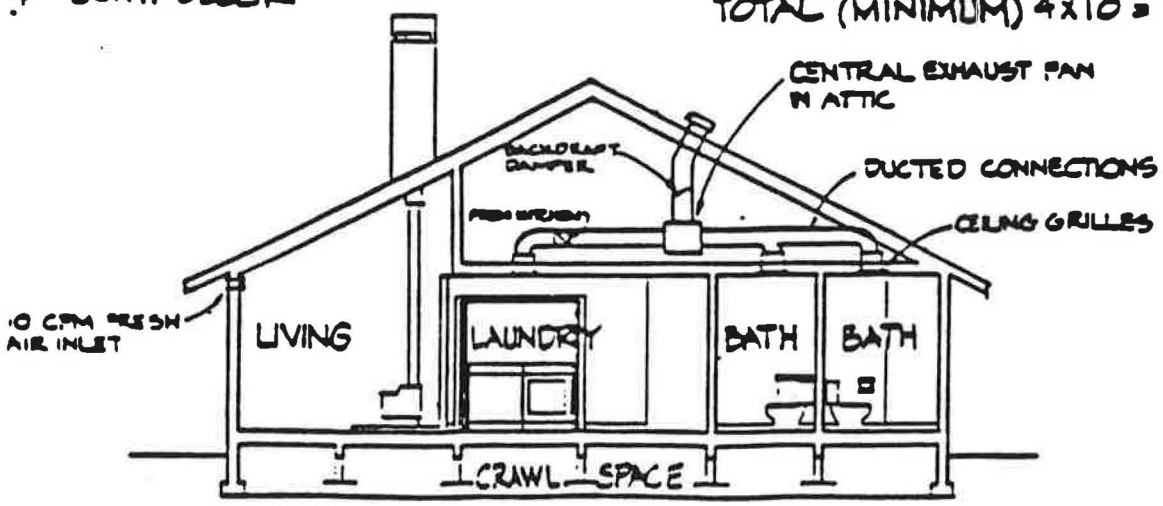


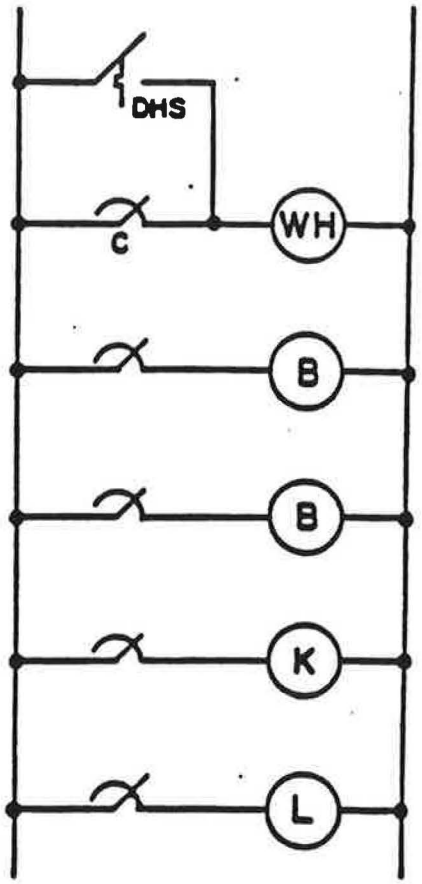
FIGURE 12.C

Non-HRV Option 3
Discrete Spot/Whole House System

CONTROL WIRING SCHEMATIC

LEGEND

	TIME SWITCH
	DEVICE ACTIVATED SWITCH
	FAN MOTOR
WH	WHOLE HOUSE
B	BATH
K	KITCHEN
L	LAUNDRY
C	CENTRAL
DHS	DEHUMIDISTAT

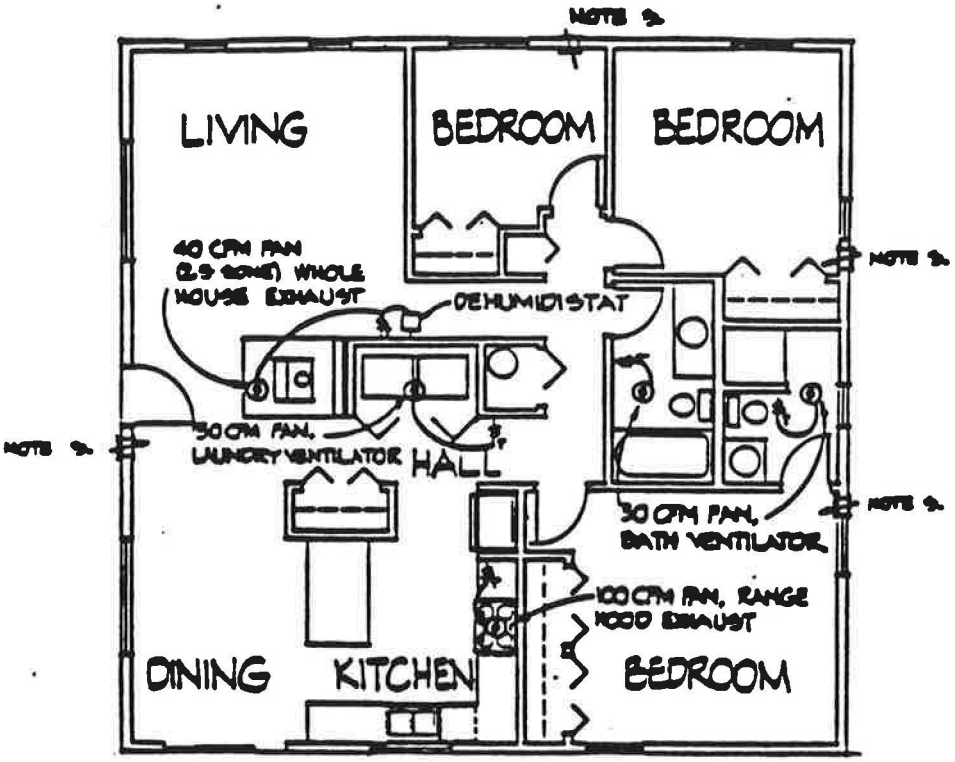


OPTION: SUBSTITUTE ON / OFF SWITCH FOR TIME SWITCH (KITCHEN ONLY)

OPTION: SUSTITUTE CLOCK TIMER FOR DEHUMIDISTAT

FIGURE 12.C

Non-HRV Option 3
Discrete Spot/Whole House System



LEGEND:

- S, TIME SWITCH (SPRING WOUND)
- ⊖ FAN MOTOR
- ⌗ FRESH AIR INLET
- ⊓ CONTROLLER

NOTES:

1. WHOLE HOUSE FAN (2.5 SONE) CONTROLLED BY CENTRAL SWITCH AND BY DEHUMIDISTAT. KITCHEN, LAUNDRY, AND BATH VENTILATORS CONTROLLED BY INDIVIDUAL SWITCHES.
2. UNDERCUT BEDROOM AND BATH DOORS TO ALLOW FRESH AIR CIRCULATION THROUGH HOUSE.
3. PROVIDE FRESH AIR INLETS (10 CFM, MIN.) AS FOLLOWS:

1 @ EACH BEDROOM	3 x 10 = 30 CFM
1 @ LIVING AREA	1 x 10 = 10 CFM
TOTAL (MINIMUM)	4 x 10 = 40 CFM

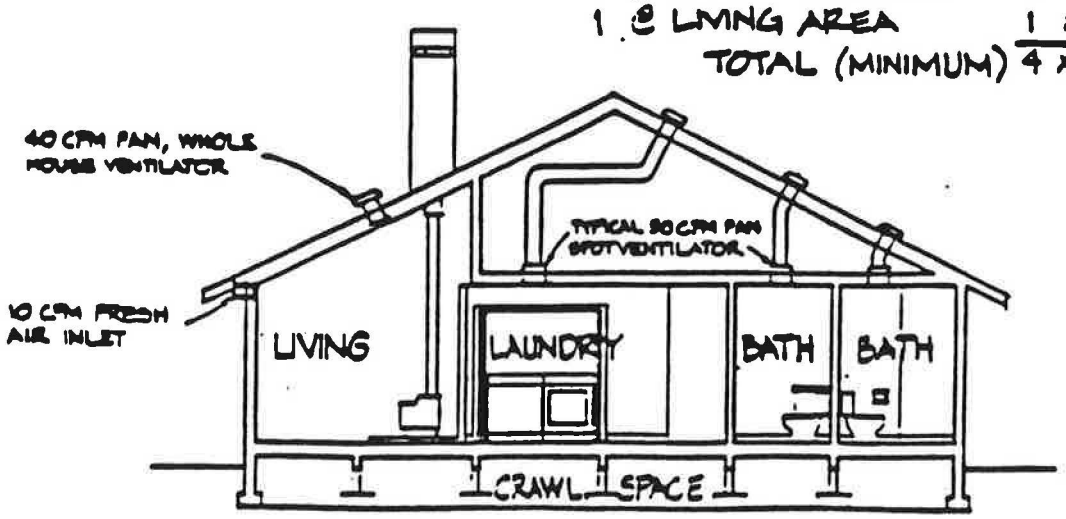


FIGURE 12.D

Non-HRV Option 4
Whole House Ventilation Integrated W/Central Forced Air

CONTROL WIRING SCHEMATIC

LEGEND

	TIME SWITCH
	DEVICE ACTIVATED SWITCH
	FAN MOTOR
	RELAY/CONTACTOR
	⊣⊢ NORMALLY OPEN
	⊣/⊢ NORMALLY CLOSED
B	BATH
L	LAUNDRY
K	KITCHEN
BWH	BATH/WHOLE HOUSE
F	FURNACE
DHS	DEHUMIDISTAT
C	CENTRAL
TSTAT	FURNACE THERMOSTAT
DSR	DEHUMIDISTAT RELAY
HCR	HEATING/COOLING RELAY
D	DUCT DAMPER

OPTION: SUBSTITUTE ON / OFF SWITCH FOR TIME SWITCH **(KITCHEN ONLY)**

OPTION: SUSTITUTE CLOCK TIMER FOR DEHUMIDISTAT

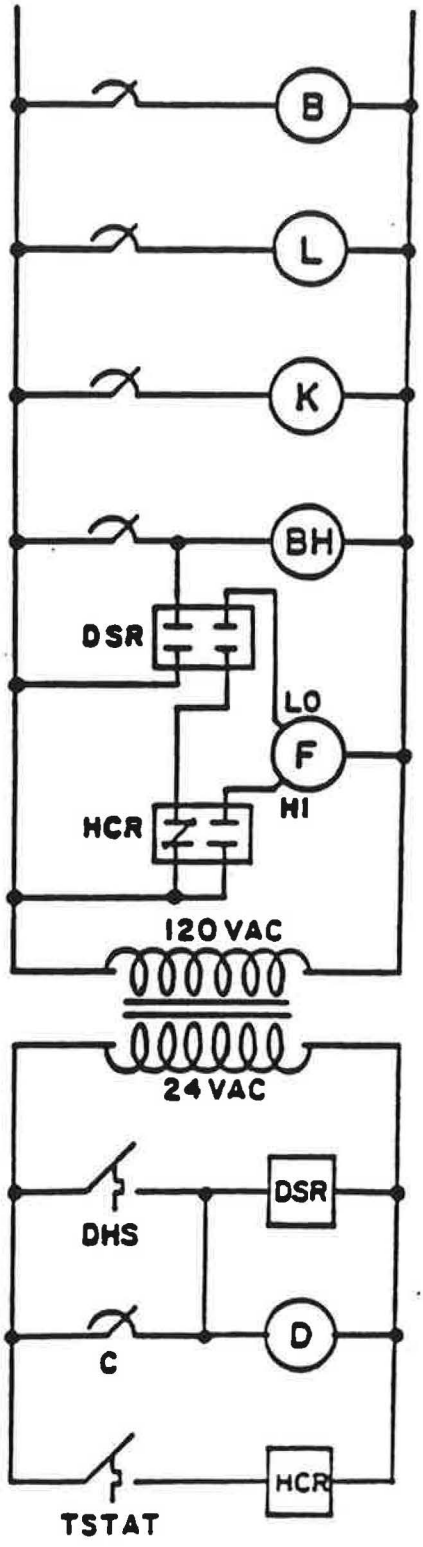
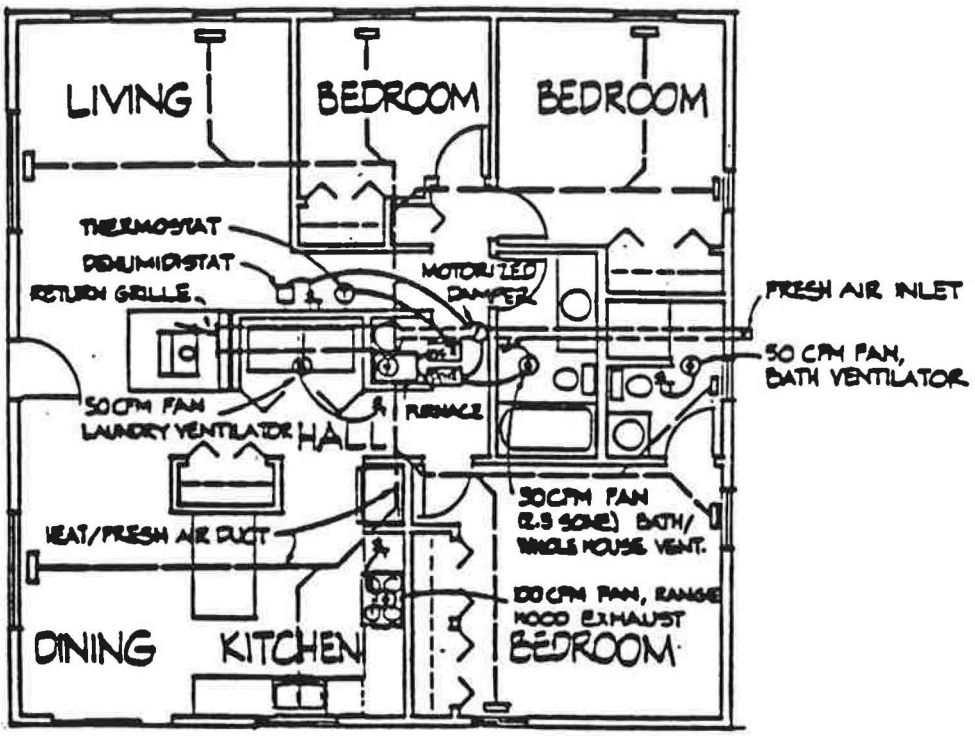


FIGURE 12.D

Non-HRV Option 4
Whole House Ventilation Integrated W/Central Forced Air



LEGEND:

- TIME SWITCH (SPRING WOUND)
- FAN MOTOR
- MOTORIZED DAMPER
- OVERHEAD DUCT
- UNDERFLOOR DUCT AND REGISTER
- CONTROLLER

NOTES:

1. WHOLE HOUSE FAN/BATH VENTILATOR (2.5 SONE) CONTROLLED BY SWITCH IN BATH, BY DEHUMIDISTAT OR BY CENTRAL SWITCH VIA 24VOLT RELAY [DSR]. FRESH AIR SUPPLY DAMPER IS CONTROLLED BY CENTRAL SWITCH OR DEHUMIDISTAT. FURNACE FAN DISTRIBUTES FRESH AIR – CONTROLLED BY 24VOLT RELAY [DSR] OR BY TSTAT VIA 24VOLT RELAY [HCR].
2. UNDERCUT BEDROOM AND BATH DOORS TO ALLOW FRESH AIR CIRCULATION THROUGH HOUSE.

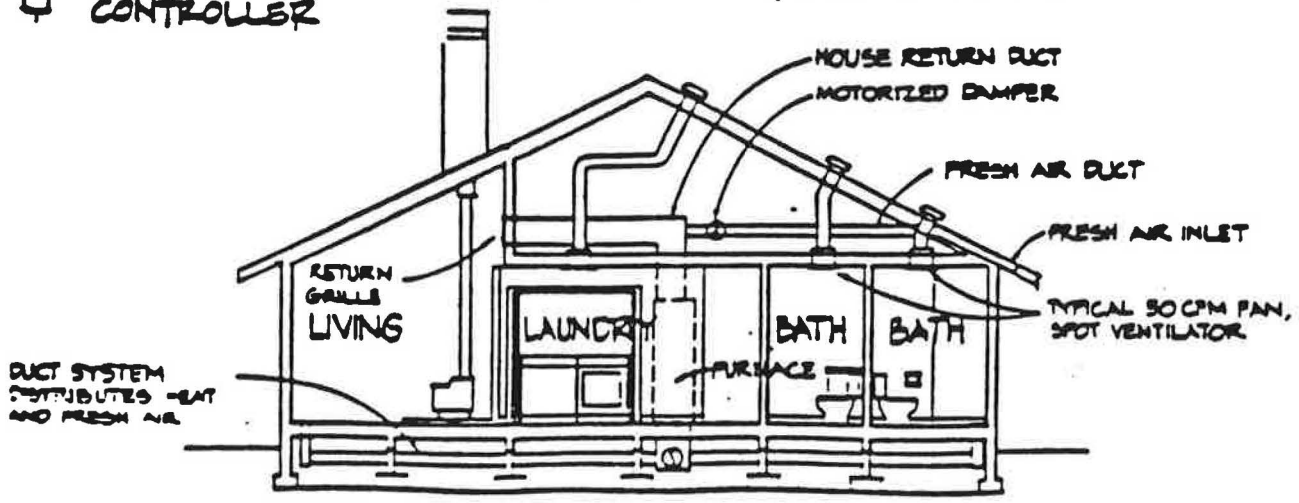


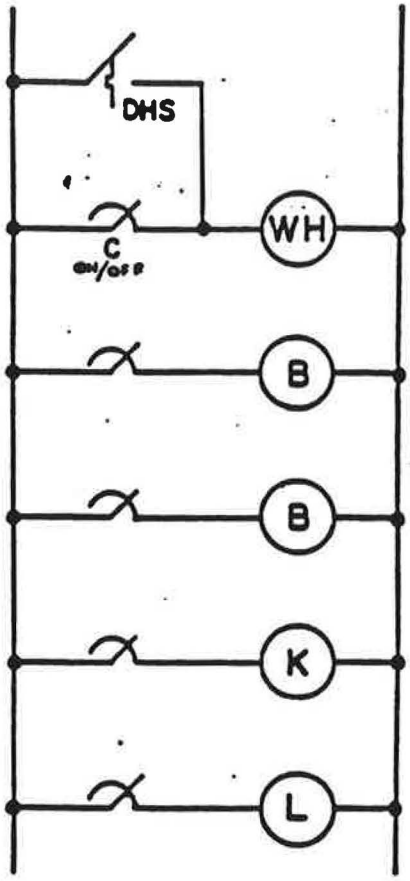
FIGURE 12.E

Non-HRV Option 5
Discrete Spot/Whole House System

CONTROL WIRING SCHEMATIC

LEGEND

	TIME SWITCH
	DEVICE ACTIVATED SWITCH
	FAN MOTOR
WH	WHOLE HOUSE
B	BATH
K	KITCHEN
L	LAUNDRY
C	CENTRAL
DHS	DEHUMIDISTAT



OPTION: SUBSTITUTE ON / OFF SWITCH FOR TIME SWITCH (KITCHEN ONLY)

OPTION: SUSTITUTE CLOCK TIMER FOR DEHUMIDISTAT (TIME OF DAY CLOCK)

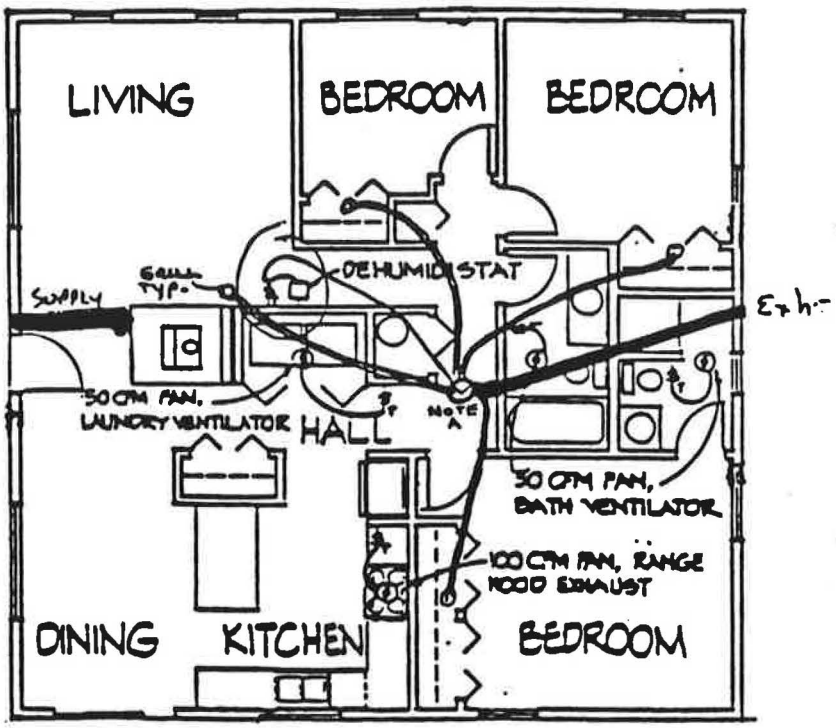
FIGURE 12.E

Non-HRV Option 5
Discrete Spot/Whole House System - DISTRIBUTED EXHAUST/ CENTRAL SUPPLY.

NOTE A: 110+ CFM WHOLE HOUSE EXHAUST FAN.

DUCTED TO BEDROOMS AND LIVING SPACE. ROUTED IN ATTIC.

one make up air supply with backdraft damper

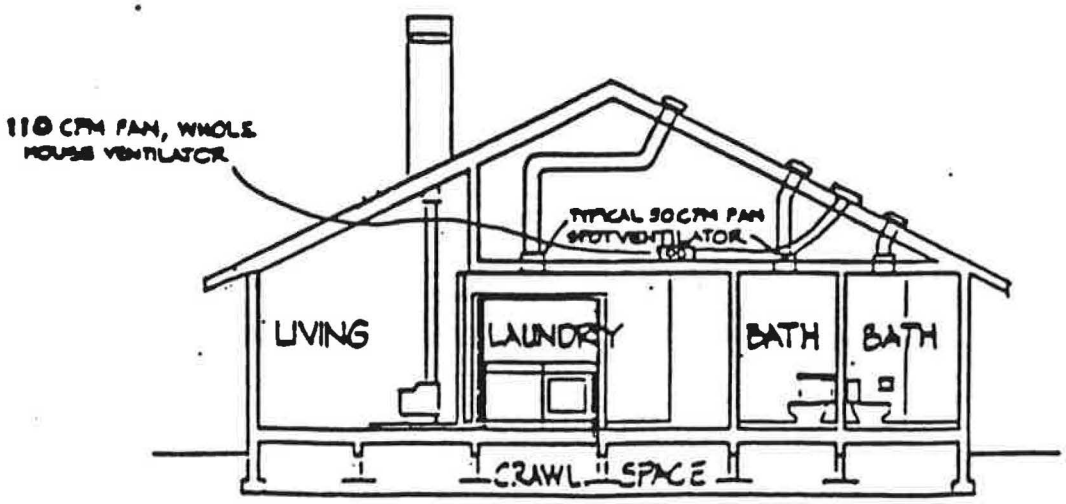


LEGEND:

- S TIME SWITCH (SPRING WOUND)
- ⊖ FAN MOTOR
- O CEILING GRILL
- □ CONTROLLER

NOTES:

1. WHOLE HOUSE FAN (110 CFM) CONTROLLED BY CENTRAL SWITCH AND BY DEHUMIDISTAT. KITCHEN, LAUNDRY, AND BATH VENTILATORS CONTROLLED BY INDIVIDUAL SWITCHES.
2. UNDERCUT BEDROOM AND BATH DOORS TO ALLOW FRESH AIR CIRCULATION THROUGH HOUSE.



Appendix 2

NORIS No. _____ Valid Phone No. _____ Response _____	Call status: Connected No answer Call back Busy time _____	Send: Agreement Brochure only Letter only

TELEPHONE SURVEY
Residential Infiltration Study Sampling Frame

[ASK FOR THE HEAD OF THE HOUSEHOLD]

Hello, my name is _____ and I am representing the Washington State Energy Office. We are conducting research on ventilation rates in new homes. We would like to ask you a few questions for this study. Your answers will, of course, be kept confidential. The purpose of this study is to improve our understanding of how homes built recently provide ventilation and fresh air to their occupants.

1. Was your home built since 1987? _____

   1. Yes
   2. No
   3. Don't Know

   IF NO, [TERMINATE]

2. Which of the following best describes your house? [READ LIST] _____

   1. One story without basement
   2. One story with basement
   3. Two or more stories without basement
   4. Two or more stories with basement
   5. Mobile home

3. What type of heating system do you have? _____

   1. Furnace (forced air)
   2. Baseboard (zonal)
   3. Wall heater
   4. Heat pump
   5. Radiant panel
   6. Boiler (hot water)

4. Do you consider wood to be one of your major heating fuels? _____

   1. Yes
   2. No

5. Does your home have odor or moisture problems? _____

   1. None
   2. Odor
   3. Moisture
   4. Both

Let me explain more about this research: This is an ongoing study sponsored by the Bonneville Power Administration. Last winter, 140 randomly selected new homes were tested throughout the Pacific Northwest. This year, we would like to select your home as one of the 50 houses to be tested in Snohomish County. The purpose of these tests is to assess the ventilation rate and leakiness of the house. During the test, which will be arranged at your convenience within the next two months, technicians will use a special fan designed to pull air through your house so that leakage can be measured. After the test, several passive sensors would be placed in the house. In two to three weeks, you would be asked to mail them to us in the pre-paid mailer provided. In addition, the technicians will conduct a detailed energy analysis, and will interview you regarding the operation of the house. The analysis and tests usually take about 4 hours to complete; your presence is required for about 30 minutes of that time. If you are willing to participate, you will receive a $25.00 payment, as well as a copy of the ventilation test results and energy analysis. (An analysis of this type would normally cost $200.00 or more.)

9. Would you be willing to have this test done in your home?

   1. Yes [SKIP TO Q. 11]
   2. No [RECORD PHONE #, TERMINATE] _____
   3. Undecided

IF NO, May we send you a project brochure and contact you later to see if you have changed your mind?

10. [IF UNDECIDED OR HESITATES]

    The tests would assess the level of air leakage in the building. This information is essential to the development of energy efficiency standards and in assisting builders throughout the region in understanding the effects of current construction practices and changes necessary to ensure that these practices meet the needs of energy efficiency and comfort. If you would like more information, I would be happy to answer any questions. [SEE NEXT PAGE FOR TYPICAL QUESTIONS AND ANSWERS]. If you would like more time to think about it, we can call you back later.

    1. Yes _____
    2. No [TERMINATE]

[IF YES]
When would be a good time to call back? _____

11. [IF YES TO Q. 9]

    Good! We will be sending you a Participation Agreement immediately, and will contact you in about two weeks to schedule an appointment to perform the test in February or March (at your convenience). We will need your name and address:

    Name: _____

    Address: _____

    _____

SOME ANSWERS TO SOME QUESTIONS:

Q. How long will it take?
A. The test will require about four hours to complete. Your presence is not required during most of this time.

Q. What will be done during the test?
A. A large fan will be placed in your doorway and blow air out of your house. The fan is hooked to an instrument that measures the amount of air which flows through the house, and from this measurement, the total area of the holes and cracks in the house can be computed. While the fan is running, a technician will walk around the house with a tracer and try to see where the leakage is. He or she will look at window sills, doors, electrical outlets, and plumbing outlets.

Q. Is it safe?
A. The fan moves as much air as a 15 to 20 MPH wind, which can be felt but is not strong enough to damage the house or its contents. The tracer is a harmless smoke stick, which is used in very small quantities. In short, the test is very safe and the technicians will be instructed to have a minimum impact on your home.

Q. What are the passive sensors?
A. These sensors are in two parts: One part releases a very very small quantity of gas (similar to that used in refrigerators and heat pumps). The other part picks this gas up and measures the amount present in the house. Two or three sources and three to five samplers would be placed in the home under your supervision. They are each the size of an eye dropper and would be placed as inconspicuously as possible. The sensor will be allowed to sit for two to three weeks. Then, you will be asked to place them in a prepaid mailer and return them to the laboratories for analysis. This test is the most modern and effective way we know to measure the amount of ventilation present in a house as it is actually used.

Q. What is the objective of the test?
A. We are attempting to establish the amount of heat required by new homes built to modern standards as accurately as possible. The amount of air leaking in is very important in this calculation, but very difficult to estimate. This set of tests will establish the levels of air leakage and ventilation actually present in today's homes. This information will be used to help builders and utilities address whether these standards are effective and how they might be altered to improve overall comfort and efficiency in new homes.

Appendix 3

ECOTOPE

Dear NORIS Participant:

We appreciate your interest in the Northwest Residential Infiltration Study (NORIS). This work is crucial to our understanding of ventilation and home infiltration, and will be used to evaluate new Building Codes. The goals of this research are both to improve the operating costs of new homes and to insure that the most cost-effective methods are used to promote energy efficiency in this region.

Ecotope's role in this project is to assist the State of Washington to develop a sample frame and to provide technical specifications for the actual test. We will be happy to answer in detail any questions you may have. Do not hesitate to call us collect at (206) 322-3753, and ask for David Baylon or Jonathan Heller. The field technicians who will perform the tests are under contract to the Battelle Pacific Northwest Laboratories. Battelle is responsible for the field work portion of the research.

The testing would be scheduled at a time convenient to you. The field technician will be responsible for making an appointment for the testing.

The enclosed participation agreement is very important. Because of delays in the research effort, the testing must all be done in February and March. It is therefore very important that you sign and return this agreement immediately so we can be sure of your willingness to allow the testing in your home. We have enclosed a stamped addressed envelope for this purpose. We will be calling you within a week to insure you have received this letter and understand it. Once we have received the participation agreement we will be ready to schedule the testing.

We have also enclosed a general project brochure for your review. The project brochure was printed about a year ago, at the beginning of the project, and describes features of the field research that will be conducted on your home. The field work would involve four phases:

1. A home survey (or audit): This will involve a review of the size and volume of the house, and a review of the heating system, fans, and other observable air sources.
2. A homeowner survey: This will be a brief interview with you regarding the house and its operation. This interview will take approximately 15 minutes.
3. A blower door test: To perform this test, a special fan is temporarily installed in a doorway to draw air through the house. Technicians can estimate the amount of air leaking through holes and cracks in the outside shell of your house and estimate the size of these holes from this information. This test takes about half an hour to perform, and the fan will be removed immediately upon completion.

2812 E. Madison,
Seattle, Wa. 98112
(206) 322-3753

4. PFT test: In this test, a harmless tracer gas is emitted by small "sources" placed in various areas throughout the house. The tracer gas is sensed by small "samplers". The sources and samplers are the size of an eyedropper, and will be placed in as inconspicuous a location as possible. The technicians will leave you a prepaid mailer which you would use to return the tests for processing. Battelle will contact you directly about two weeks later and instruct you to remove the tests and mail them.

After the Participation Agreement has been received the field technicians will call you to make an appointment for the testing. After the technician has finished the test a $25.00 check will be mailed to you. This check is a way to say "thank you" for participating, and to compensate you for your time and trouble. When all of the test data has been processed (approximately mid-summer), you will receive by mail a summary of the test results.

Again, we thank you on behalf of the Washington State Energy Office for your cooperation in this test, and hope you will find the results informative.

Sincerely,

David Baylon
Ecotope, Inc.

DB/ss

Northwest Residential Infiltration Survey

A Study of Ventilation in New Homes

A study of housing ventilation—air movement from inside and outside a home—is generating information that will be used to develop energy conservation programs for Northwest homes. This flier provides basic information about the study.

What is the Purpose of the Study?

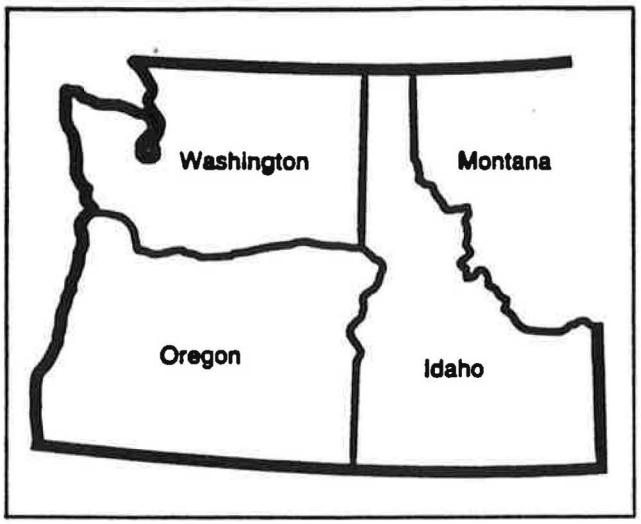
The study is designed to measure—and ultimately to better understand—ventilation rates in new, electrically heated homes. Information from participating residences will be combined and analyzed by researchers. The analysis will compare ventilation rates among the homes and determine possible reasons for variations.

Why Is this Study Needed?

The Northwest Power Planning Council has proposed construction standards—called Model Conservation Standards—for making new homes more energy-efficient. In 1983, the Bonneville Power Administration initiated a program to encourage builders to use these standards in constructing homes in four Northwest states: Washington, Oregon, Idaho, and western Montana. Bonneville and the four state energy agencies that operated the program supervised the construction and evaluated the energy performance of 450 houses built to Model Conservation Standards as well as a control group of 450 houses built before 1984.

The objective of the study is to identify the average ventilation rate for homes constructed in the Northwest region since 1980.

Instruments were placed in both groups of houses—those built to Model Conservation Standards and the control houses—to record energy consumption as well as indoor and outdoor temperatures. Other types of measurements were taken to assess specific performance characteristics of various construction components in the houses. Two different types of equipment were used to measure the air tightness of the houses' shells. Fan pressurization (blower door) equipment was used in every new house; in 200 of both the new and older homes, perfluorocarbon tracer (PFT) equipment was also used to measure air tightness.



Over 200 homeowners in four states are participating in the ventilation study.

The study results revealed significant differences in estimates of ventilation rates as measured by the two types of equipment. Because government agencies rely on ventilation data to help establish policy and program directions for energy conservation, it was important to further investigate ventilation rates in new homes; in particular, to identify the factors that cause different measurement techniques to yield different results. To address these issues, a regionwide study has been carefully designed to expand our knowledge of residential ventilation.

Who Is Conducting the Study?

The study is being carried out under a three-way partnership. With support from the region's State Energy Offices, two agencies sponsor and review the study: the State of Idaho's Department of Water Resources and the Bonneville Power Administration. Under contract with these agencies, Battelle Pacific Northwest Laboratories conducts the ventilation study.

How Will the Information Be Used?

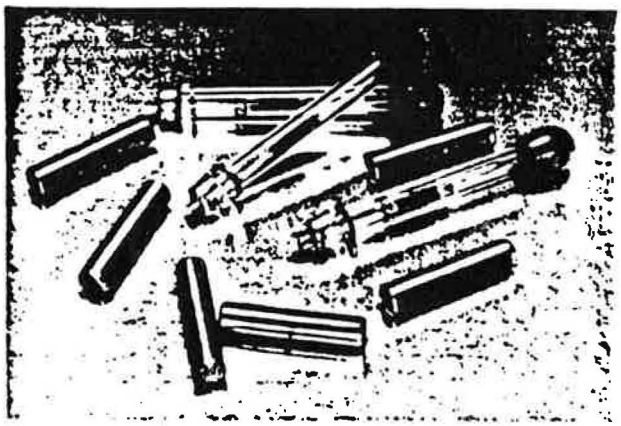
Bonneville Power Administration will use information from the study to plan and design energy conservation programs for new homes built in the Northwest. Data from the tests will help Bonneville evaluate the cost effectiveness of various conservation measures. Ultimately, the study will help Bonneville and regional power planners in making decisions about the management of the Northwest's electrical resources.

How Long Will the Study Last?

The study will be conducted during the 1987/1988 and 1988/1989 heating seasons. Ventilation-measuring equipment will be placed in homes for a 2- to 4-week period. Additional equipment will be placed in some of the homes for the entire heating season to measure ventilation changes over the winter.

How Many Homes Are Participating?

More than 200 homes are participating in this study. The houses are distributed within the Bonneville service area, which includes Washington, Oregon, Idaho, and western Montana. The wide distribution of homes ensures that various construction methods and climates throughout the region are represented in the study results.



PFT capsules and sample tubes are placed in homes to measure all contributions of fresh air flow over a period of time.

How Were Homes Chosen for the Study?

A random phone survey of homeowners in the study region was used to identify houses with the characteristics needed for the ventilation study. Important factors included year of construction, building techniques, architectural style, type of heating system, and the presence or absence of a whole-house ventilation system. Homeowners whose residences met the study criteria were asked to participate. From the volunteers, more than 200 homes were selected for the study.

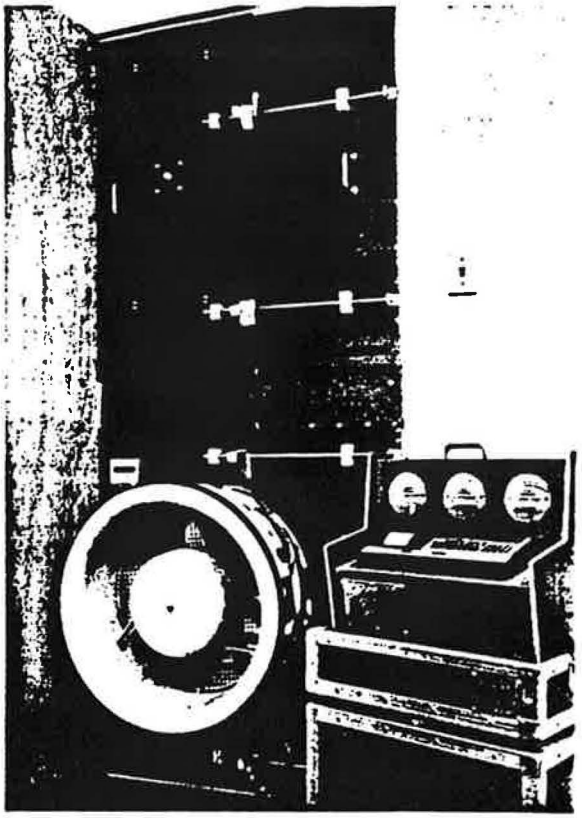
What Equipment Will Be Installed?

In each home, technicians install two devices commonly used to measure ventilation. The first is a blower door, which is a fan temporarily mounted in an outside door. The other is PFT equipment, which consists of several small containers that are placed in carefully selected locations in the home.

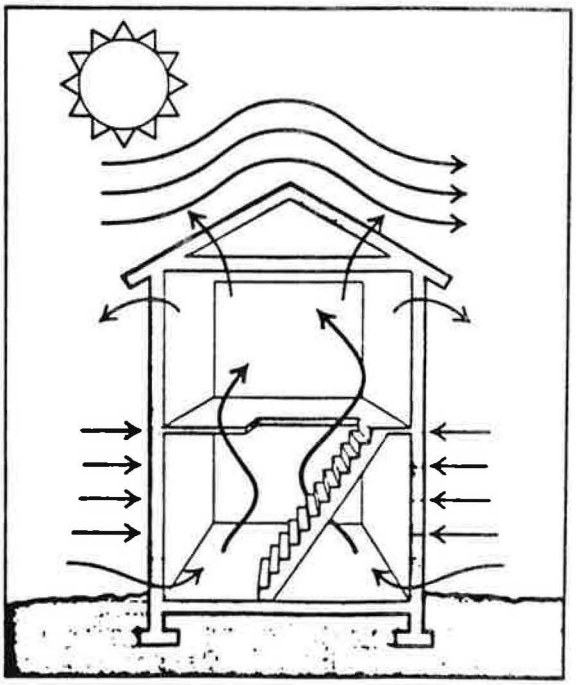
How Does This Equipment Measure Ventilation?

The blower door blows air into or out of a house to pressurize or depressurize it. While the blower door is operating, instruments on the blower door indicate the amount of air that is entering or escaping through tiny openings in the house's shell. The blower door measurement is like a snapshot because it provides a one-time measurement of ever-changing conditions.

The PFT measurement gives an estimate of the average ventilation rate of the entire house over a period of time. The PFT measurement includes all contributions to ventilation, such as kitchen and bath exhaust fans, open windows, opening and closing doors, and air leaks through the building shell.



The blower door is used to measure the amount of air that leaks, at one point in time, through tiny cracks or holes in the building's shell. (Photo courtesy of Retrotec Energy Innovations, Ltd.)



Information provided by homeowners will be used in conjunction with ventilation measurements to develop energy conservation programs for Northwest residences.

The PFT equipment is in place for at least 2 weeks. Small capsules (sources), about the size of a cap for a ball-point pen, slowly release a tiny quantity of harmless tracer into the home. Sample tubes, about the same size as the tracer capsules, measure the tracer concentration in the home. The tracer concentration gradually changes as outside air flows into the house over a period of time. Knowing the tracer concentration, researchers can calculate the amount of outside air that has entered the home.

About Battelle

Battelle Memorial Institute is an independent, multinational organization devoted to improving the quality of life through the advancement and use of science. Through sponsored programs, Battelle serves the research and development needs of industries and governments worldwide. Each year, the laboratories undertake thousands of studies extending from fundamental research for new knowledge to applied programs directed toward developing new materials, products and processes.

The Pacific Northwest Division includes the Battelle laboratories at Richland; the Marine Research Laboratory at Sequim Bay on the Olympic Peninsula; and the Human Affairs Research Centers on the campus of the Battelle Seattle Research Center, an advanced study and conference site.

Where Can I Get More Information?

If you have questions or comments, we would like to hear from you. For more information about the ventilation study, please call one of the following numbers:

Washington State Energy Office: *(206) 586-5000*

Oregon Department of Energy: *1-800-221-8035*

Idaho Department of Water Resources: *1-800-334-7283*

Montana Department of Natural Resources and Conservation: *(406) 444-6697*

Or write to:

Graham Parker, Project Manager
Battelle/Pacific Northwest Laboratories
P.O. Box 999
Richland, Washington 99352

The patented PFT technique is licensed by AIM, Inc.

BN2-87-11-10-1130

RICHARD H WATSON
Director

STATE OF WASHINGTON
WASHINGTON STATE ENERGY OFFICE
809 Legion Way S.E., FA-11 • Olympia, Washington 98504-1211

Northwest Residential Infiltration Study

Agreement to Participate in Research

I understand that the Washington State Energy Office, in cooperation with the Idaho Department of Water Resources and Battelle Pacific Northwest Laboratories, is conducting research on the air infiltration characteristics of new homes in the Pacific Northwest.

I agree to participate in this research by permitting scientific tests of air leakage areas and infiltration rates to be performed on my home. I have read and understand the description of these tests and agree to permit them to be performed at my home by a representative of Battelle Pacific Northwest Laboratories. The time and date of the tests will be scheduled at my convenience.

In consideration of my participation in this research project, I understand that I will receive a payment of twenty-five (25) dollars, as well as an analysis of the results of all tests performed on my home.

_____ _____
Signature Date

Address (please print) Phone

_____ _____Home
_____ _____Business
_____
_____

(206) 586-5000 or SCAN 321-5000 Telefax (206) 753-2397