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Northwest Residential Infiltration Survey (NORIS) Project Protocol

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Battelle
Pacific Northwest Laboratories

NORTHWEST RESIDENTIAL INFILTRATION SURVEY (NORIS)

PROJECT PROTOCOL

INTRODUCTION

This document describes the personnel, procedures, and schedule for the Northwest Residential Infiltration Survey (NORIS) being conducted for the State of Idaho Department of Water Resources (IDWR) by Battelle, Pacific Northwest Laboratories. Described below are the research goals for the study, the background and previous relevant studies in the Northwest region, the Battelle project management organization for this study, the field data collection procedures, the data recording and reporting procedures, the quality assurance plan summary, and the schedule for major milestones.

This document, along with the Recruitment Plan and Sample Design documents, gives a detailed description of how the entire project will be conducted.

PURPOSE OF THE PROJECT

The purpose of this project is to determine the infiltration rate in single family detached electrically-heated homes in the Pacific Northwest region, and to investigate the relationship between fan pressurization (blower door) and perfluorocarbon tracer (PFT) measurements in these homes. These homes will represent two categories of homes: 1) those constructed to current building practice since 1980 and, 2) those constructed to the Model Conservation Standards (MCS) with whole-house exhaust ventilation or built under the 1986 Super Good Cents (SGC) monitor/mitigation option.

The project is intended to provide answers to the following three questions:

1. What is the ventilation rate (air exchange rate) for a typical home of each of the two categories of homes measured by the PFT technique?
2. What are the leakage parameters (e.g., effective leakage area, air exchange rate at 50 pascals pressure, flow rates, and air exchange rate) for a typical home for each of the two categories of homes using the fan

pressurization measurement and the Lawrence Berkeley Laboratory algorithm for calculating these parameters from the fan pressurization results?

3. Can a method or procedure be developed to estimate the heating season average total fresh air ventilation rate for the heating season from the fan pressurization test, and if so, what is the method or procedure?

The study will focus on the first category of homes during the first year of the study (1987/1988 heating season).

During the 1988/1989 heating season, the study will focus on the second category of homes. The protocol and recruitment plan for this category of home will be developed prior to the start of the recruiting effort using data acquired in the first year of the study.

STUDY BACKGROUND AND CRITICAL ISSUES

A similar study was conducted by the Bonneville Power Administration (BPA) during the 1984/1985 heating season in over 200 new homes in the Pacific Northwest region. These homes were constructed as part of the Residential Standards Demonstration Program (RSDP). Approximately one-half of the homes were constructed to the MCS and one-half constructed to current building practice (these were the "control homes").

Both a fan pressurization test to quantify the air tightness of the home's exterior envelope and a one time PFT test over several consecutive weeks to measure the air exchange rate were performed in each home. Results of these measurements were analyzed in 1986.

The data showed that the PFT air exchange rates differed significantly from the air exchange rate estimates obtained using the fan pressurization test for both the MCS and control homes. This data raised concerns about the state of knowledge on fresh air ventilation rates in homes and on the techniques for estimating those rates.

This region relies on this type of data for establishing policy and program directions. A critical environmental issue confronting new energy-efficient homes is the effect that reduced levels of ventilation may have on indoor air quality and the subsequent health of occupants. The primary analysis of the New Homes Environmental Impact Statement being prepared by BPA hinges on the

This region relies on this type of data for establishing policy and program directions. A critical environmental issue confronting new energy-efficient homes is the effect that reduced levels of ventilation may have on indoor air quality and the subsequent health of occupants. The primary analysis of the New Homes Environmental Impact Statement being prepared by BPA hinges on the measured ventilation rates in the sample of RSDP homes and the interpretation of the data (BPA 1987).

In addition, the measurement and evaluation of fresh air ventilation in homes is necessary to decide the level of heat loss associated with the incidental infiltration of cool outside air into a dwelling (during the heating season) and the necessary fuel requirements to bring that air to an appropriate temperature.

For these reasons, it is important to further investigate natural infiltration and air exchange rates in different categories of new homes and to investigate the two primary measurement techniques. The protocol and results of this study are intended to expand our knowledge of these issues.

PROJECT MANAGEMENT ORGANIZATION

Figure 1 shows the project management organization for this study. All of the key tasks in the study are managed by experienced staff at Battelle. In addition, a backup staff member has been identified for each task manager. For most tasks, the backup is from the project team. The backup will have an understanding of the entire study and tasks and has experience to step in and assume responsibilities in case the task manager is unavailable for an extended time period. This is to insure both project continuity and that important milestones are met.

Battelle does not anticipate hiring new staff to work on the project. As shown in the organization chart, we will employ qualified subcontractors for the sample design task and most of the field work. The experience and responsibilities of key staff members appearing on Figure 1 are given here.

PROJECT MANAGER AND RESEARCH PROTOCOL TASK MANAGER

Graham Parker, Senior Research Engineer - Mr. Parker will have overall responsibility for the success of the study and is the prime interface between Battelle and the State of Idaho. He will be responsible for assuring that the project milestones are met and that Idaho is kept informed of the work progress. He is also responsible for technical input into the field measurements and into the planning portion of the project where decisions are made that will have a major impact on the success of the project.

ASSISTANT PROJECT MANAGER, SAMPLE DESIGN TASK MANAGER, RECRUITMENT TASK MANAGER AND METEOROLOGY

Don Hadley, Senior Research Scientist - Mr. Hadley will manage the sample design and recruitment tasks in the study, as well as, supply all meteorology data for the field work. He has over 17 years experience managing large and complex field monitoring programs throughout the western United States.

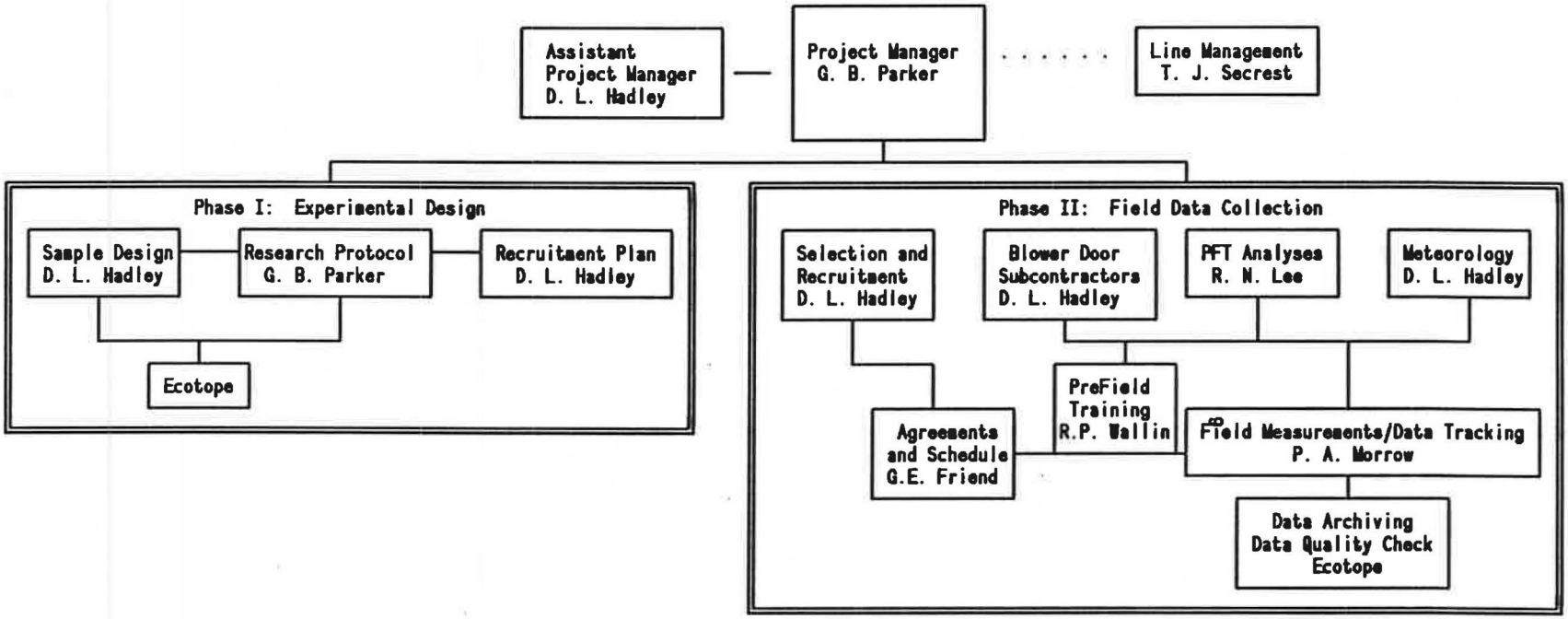


FIGURE 1. Project Organization

Specific activities have routinely included preparation of procedures manuals, scheduling and coordination of equipment installation and routine maintenance activities, supervision of field personnel, and quality control review of incoming data. Mr. Hadley participated in the field recruitment effort in the End-Use Load and Conservation Assessment Program (ELCAP) during the initial phases of the study. Mr. Hadley is a meteorologist and leads the meteorology analysis for ELCAP.

The sample design, review of the blower door and field data will be performed by Ecotope under the direction of Mr. Hadley.

PREFIELD TRAINING MANAGER

Randall Wallin, Engineer - Mr. Wallin is responsible for initial development of all protocol and forms for use in the field and will lead the training of blower door subcontractor field specialists during the prefield testing.

Mr. Wallin has considerable experience in the calibration and use of blower doors in the field which is relevant to this study. He has performed blower door tests in over 100 homes and understands the relationship between the various leakage measurement ratings and the air exchange rates predicted by models commonly used in blower door tests. He has constructed and operated a calibration chamber and performed parametric sensitivity analysis to demonstrate the sensitivity of measurement errors in critical structure and environmental parameters incorporated in the blower door tests including building volume, height, and indoor/outdoor temperature difference.

FIELD MEASUREMENT AND DATA MANAGEMENT TASK MANAGER

Patty Morrow, Technical Specialist - Ms. Morrow will be responsible for all field data management including data quality assurance. Ms. Morrow is a computer specialist with a knowledge of dBase III®, Lotus 1-2-3®, and other programs used to produce data for entry into the main engineering database. She will perform periodic quality checks and manage the flow of data from the field.

SITE RELATIONS, AGREEMENTS AND SCHEDULING COORDINATOR

Grace Friend, Clerk - This subtask includes interfacing with the residents sending letters and agreements, keeping track of the recruiting on the database, informing the blower door subcontractors and residents of the schedule for measurements, sending field measurement instructions, and general interfacing blower door subcontractors to answer routine questions during the field measurements.

PFT ANALYSES TASK MANAGER

Richard N. Lee, Senior Scientist - Dr. Lee is the leading analyst at Battelle for all atmospheric tracer studies including PFT studies indoors. He has conducted tracer studies for over eight years at Battelle, working closely with other national laboratories in tracer experiments. Dr. Lee is nationally known for this work. He was instrumental in the design and development of the tracer sources, sample tubes, and analytical equipment currently used for all indoor PFT experiments at Battelle. He was also responsible for writing the specifications for a unique automatic PFT sampler.

He will be primarily responsible for directing the analytical work for the PFT samples and for PFT analysis data reduction. He will supply all materials for the field work task. He will also prepare and carry out the quality assurance plan for all PFT chemical and data analysis efforts.

PLANNING AND PROJECT OVERSIGHT

During the planning stage of the project, input has been received from the Project Oversight Committee (POC). The POC is made up of representatives from the state energy offices, BPA, the Northwest Power Planning Council, and other organizations as designated by the State of Idaho.

The POC has discussed the background to the study, the goals and objectives of the study, the design and selection of the sample of homes to be studied, the protocol to be used in the field measurements, data analysis, and special studies. The results of the POC meeting are reflected in this document. The POC will continue to offer guidance and review to Battelle throughout the study period.

APPROACH TO THE SAMPLE DESIGN AND SELECTION

Ecotope, Incorporated, subcontractor to Battelle, will assume the responsibility for the sample design. Throughout the design phase, emphasis will be placed on assuring that final results are scientifically defensible with respect to both random and systematic error. The sample design is a sequential process in which experimental designs are proposed to IDWR and the POC. These designs will include estimates of sample size (and therefore cost) for several levels of precision and confidence. The POC will play an important role in guiding the stages of the design, refining the research goals, and deciding the tradeoffs between representativeness, precision, and cost.

The current approach to the sample design will be as described here:

1. An analysis of the previously completed RSDP ventilation data will be performed to gain an understanding of the factors that influence ventilation in these residences. Prior analysis has indicated that ventilation rates in these homes were strongly influenced by heating system type, architecture type, and climate zone.

2. A random telephone survey in the region will be conducted to determine the age, geographical distribution, heating system type, and house architecture of post-1980 current practice homes (Category 1) in the Northwest region. This survey will be conducted in four stages: 1) a simple random sample from the 136 counties; 2) a random sample stratified by county with allocation proportional to the estimated household growth in 43 counties; 3) a random sample stratified as stratified above for Missoula, Gallatin and Ravalli counties in Montana; 4) a random sample drawn to meet weights in Kalispell and Lewis and Clark counties in Montana.

3. This survey will involve contacting over 60,000 homes, with a target of approximately 290 qualified homes with occupants indicating a willingness to participate in the study. The results of the telephone survey will be used to characterize the target population and serve as the sampling frame used in the recruiting of participants (see next section for

recruiting details). It will also provide the basis for developing separate strata such heating system type.

4. The recruiting of homes will return a list of project participants who have signed an agreement to participate in the study. From this list the actual homes to be monitored will be selected. A target of 160 homes has been set based on preliminary estimates of precision and accuracy requirements.

5. The population and characteristics of the 1987 Super Good Cents (SGS) homes (Category 2) will be available from the BPA in early 1988. This list will be used for designing the sample from this home category.

A comprehensive document will be published describing the sample design and selection for both Category 1 and 2 homes.

RECRUITMENT OF RESIDENCES

Recruitment of the Category 1 homes will begin as soon as the list of potential participants is received from the State of Idaho. This list will consist of approximately 290 households developed as a sampling frame for the NORIS project from the random telephone contact and survey conducted for the Washington State Energy Office. At the time of the contact these households indicated a willingness to participate in the study. Battelle will be responsible for obtaining from these individuals a signed cooperative agreement allowing project personnel access to the residence to conduct the tests. The final sample design and selection of homes for testing will be based on the set of homes that have returned the signed cooperative agreement.

Considerable effort has been spent in the development of the sample frame to ensure that it is a representative and clearly interpretable sample of the region. The recruitment activity will be designed to make sure that the final sample drawn is defensible and as unbiased as possible. All cooperative agreements will be mailed to the potential participants on the same day. This is to ensure that, if it becomes necessary to set a cut-off date for the return of the agreements, all potential participants have an equal opportunity to respond. No participant will be considered a part of the project and specifically no assignment of the residence for field testing will be done until the cooperative agreement is received.

In order to estimate the nonresponse bias and to account for it in the final sample design, Battelle will provide Ecotope with the dates the residences return the signed cooperative agreement.

Recruitment of Category 2 homes for testing for the 1988/1989 heating season will be completed during the late summer of 1988.

The complete recruitment plan, including procedures for tracking the recruitment data, is described in a separate document (PNWD-1197-2).

FIELD DATA COLLECTION PROCEDURES

The field data collection phase of the project involves performing a blower door test on each home, collecting structural and occupant characteristics data, and recording occupant activity during a 2 to 4 week measurement of air exchange rate using PFT.

The field data will be collected by qualified field specialists. They will be trained in field and data collection procedures during a prefield training session conducted by Battelle in October, 1987, in Richland, Washington. Battelle will train the field specialists to conform with the set of guidelines for PFT deployment given in Appendix B, and for the blower door test procedures given in Appendix C. A document will be prepared describing the prefield training session and results.

A field specialist will be assigned groups of homes (5 to 10 each) by Battelle for the field measurements. The subcontractor firm will receive a colored booklet for each home that contains resident information and the forms to be filled out for that home. Each subcontractor firm will be assigned a unique booklet color. The booklets will contain the following information and forms (see Appendix A):

- name, address, and telephone number(s), and three-digit Battelle-assigned house ID on the address label (on cover)
- copy of signed cooperative agreement
- Suggested PFT Zones
- Homeowner Survey
- Walkthrough Survey
- Structural Measurements and Sketches
- Meteorological Data and Exterior Building Parameters
- Blower Door Test
- PFT Data Sheet
- Checklist
- PFT Short Form (with address label affixed)

- Occupant Activity Record (with address label affixed)
- Instructions For The Resident.

For each group of assigned homes, the field specialist will receive a listing of the homes with names, addresses and phone number(s). Based on the telephone survey information, we will attempt to ascertain the number of zones in the home, identify those zones, and suggest PFT source and sample tube placement scheme. The source placement and sample tube deployment locations will ultimately be chosen by the blower door subcontractor in consultation with the homeowner.

The field specialist will receive, in advance, a supply of PFT sources, sample tubes, tube holders, temperature recorders, additional forms, and mailers. a Field Manual will also be supplied to each specialist describing all procedures. The specialist will have received instruction from the Field Manual during the prefield training.

The field specialist will be responsible for setting up an appointment for the field measurements. We will assist in this step only if there is some type of difficulty or misunderstanding on the part of the resident. It is necessary that the field measurements always be completed in the presence of an adult resident so that accurate information can be acquired and PFT recovery instructions explained to the person most likely to recover the samplers.

Once the field specialist has received the home assignments and materials (booklets) from Battelle, he/she will do the following:

1. Review the material in the Booklet for each home assigned. Read carefully the Suggested PFT Zones form. Call Battelle with any immediate questions.
2. Schedule the blower door test with the homeowner. Remind the resident not to burn wood on the day of the test.
3. Bring the PFT sources, temperature recorder and "demonstration" sample tube and holder in the home. Leave the fresh glass sample tubes in the vehicle under the hood or in the pickup truck bed.
4. Show the homeowner the Letter of Introduction (see Appendix A). Tell the resident what is going to transpire and how long it will take.

5. Complete the Homeowner Survey. Perform the Walkthrough Survey. Note the PFT zones and discuss placement of PFT sources with resident during Walkthrough Survey. Take the temperature in each zone. Carefully complete the Structure Measurement And Sketches and at the same time securely place the PFT sources with putty and (optional) place temperature recorder. Note these placements on the Structure Measurement And Sketches.

6. Return unused PFT sources to cab of vehicle.

7. Record the onsite Meteorological Data And Exterior Building Parameters.

8. Take two photographs of the outside of the home. Note House ID number on back of photos and place in Booklet.

9. Take out blower door equipment. Perform the blower door test. Record data on Blower Door Test form. Place blower door calculations tape in Booklet.

10. Return blower door equipment to the vehicle. Take out correct number of PFT glass sample tubes for this home from hood or bed of vehicle.

11. Hang the tubes, uncap the tubes, note four-digit ID number of each tube on PFT Data Sheet. Complete the PFT Data Sheet. Complete the PFT Short Form.

12. Demonstrate recovery and mailing instructions with resident for sample tubes and temperature sensor. Discuss completing the PFT Short Form and the Occupant Activities Record. Leave the Instructions For The Resident along with mailers containing spare red caps. Emphasize that the PFT sources will be collected later.

13. Clean up any debris and thank resident.

14. Complete and include all information in Booklet. Remove duplicate copies (the back) of the forms and mail Booklet to Battelle immediately.

The field specialist will not perform the measurements in any home that is not detached (e.g., duplex, apartment), a manufactured home, a home built prior to 1980, or a home that has other than electricity as permanently installed space heat. A home with a mechanical ventilation system (e.g., air-to-air heat exchanger) is acceptable for testing.

An undetermined number of homes (up to 15%) may be tested a second time with the blower door depending upon the meteorological conditions during the first test and availability of the field specialist. In addition, some homes may be tested a second time by the energy offices of the states. These homes will be chosen in consultation with IDWR and with the cooperation of the homeowner. In those homes tested a second time, the field specialist will recover the PFT sample tubes, sources, temperature recorders, Occupant Activities Records, and PFT Short Form. Also, approximately 25 homes will be tested the second heating season (1988/1989) in a special study. Appendix D describes this special study and protocols in detail.

FIELD PROTOCOL

Proper field protocol is an important element in conducting measurements in homes of volunteer residents. Therefore, the field specialists will be instructed during the prefield training session to follow certain guidelines while conducting work in a home. These guidelines are:

- The resident should be contacted by the specialist if the specialist is unable to meet the scheduled appointment.
- The specialist should not smoke, eat, or drink inside the home. The specialists' appearance should be clean and neat.
- The specialist should avoid using resident's telephone or bathroom.
- No PFT sources or samplers will be left in locations or rooms unacceptable to the homeowner, or in rooms where children are sleeping at the time of the test. Dimensions of rooms a technician cannot enter during the measurements should be estimated.
- The specialist should not solicit the homeowner for services or provide information beyond the scope of this study. For example, the specialist should not discuss infiltration sealing or radon mitigation.
- The specialist will carry a hand vacuum to clean up any debris caused by the measurements.
- The specialist should not make statements to the resident concerning the observed leakiness or tightness of the home. If a resident is very curious about infiltration, the specialist should tell them blower door test results, but stress that these are preliminary results. We want to avoid a resident changing occupant behavior during the PFT results based on blower tests.

Approximately 5% to 10% of the residents participating in the study will be queried by Battelle shortly after the completion of the field measurements to ascertain their impressions of the measurements completed in their home. Residents will be chosen representing each field specialist. Any significant problems with the measurements or field specialists noted by the residents will be corrected immediately.

DATA MANAGEMENT

Management of the data for the study is a critical element to the success of the study. Therefore, careful attention will be paid to data collection, entry procedures and checking. A diagram of the process for tracking and entering the data is given in Figure 2. All permanent primary data for the project will be kept on a Spreadsheet database. See Appendix E for a description of the database.

The field specialist will return a completed resident Booklet immediately after making the field measurements as shown in Figure 2, Step 1. Battelle will return the booklet to the field specialist if a second blower door measurement is to be conducted in the home. The data recorded in the Booklet will then be checked by Battelle for completeness. Any uncertain or missing data will be discussed with the field specialist if necessary.

A "tickle file" tracking system will be established for each home to alert Battelle of the week that the PFT sample tubes and (optional) temperature recorder should be recovered by the resident. During the appropriate week, the Battelle site relations coordinator will contact the residents and ask them to cap and return sample tubes. If possible, we will remain on the phone with the resident until the samples are recovered, and the forms are completed and ready for mailing.

Once the PFT sample tubes (and temperature recorder) are received by Battelle (Step 2), the date and time of capping the tubes from the short form are entered on the PFT Data Sheet and into the database (Step 9).

The database contains fixed field lengths. Missing data will be noted in the database by a -99. The first column in the database is the house ID number. The first five digits in the ID number will be generated from specific information taken during the field measurement that is entered into the database. The last three digits of the ID number are assigned by Battelle. See Appendix E for description of the house ID number code.

The temperature data recorder is recovered, average temperature determined (Step 3) and the data is entered into the database and on the PFT Data Sheet. The temperature data is saved in a separate file.

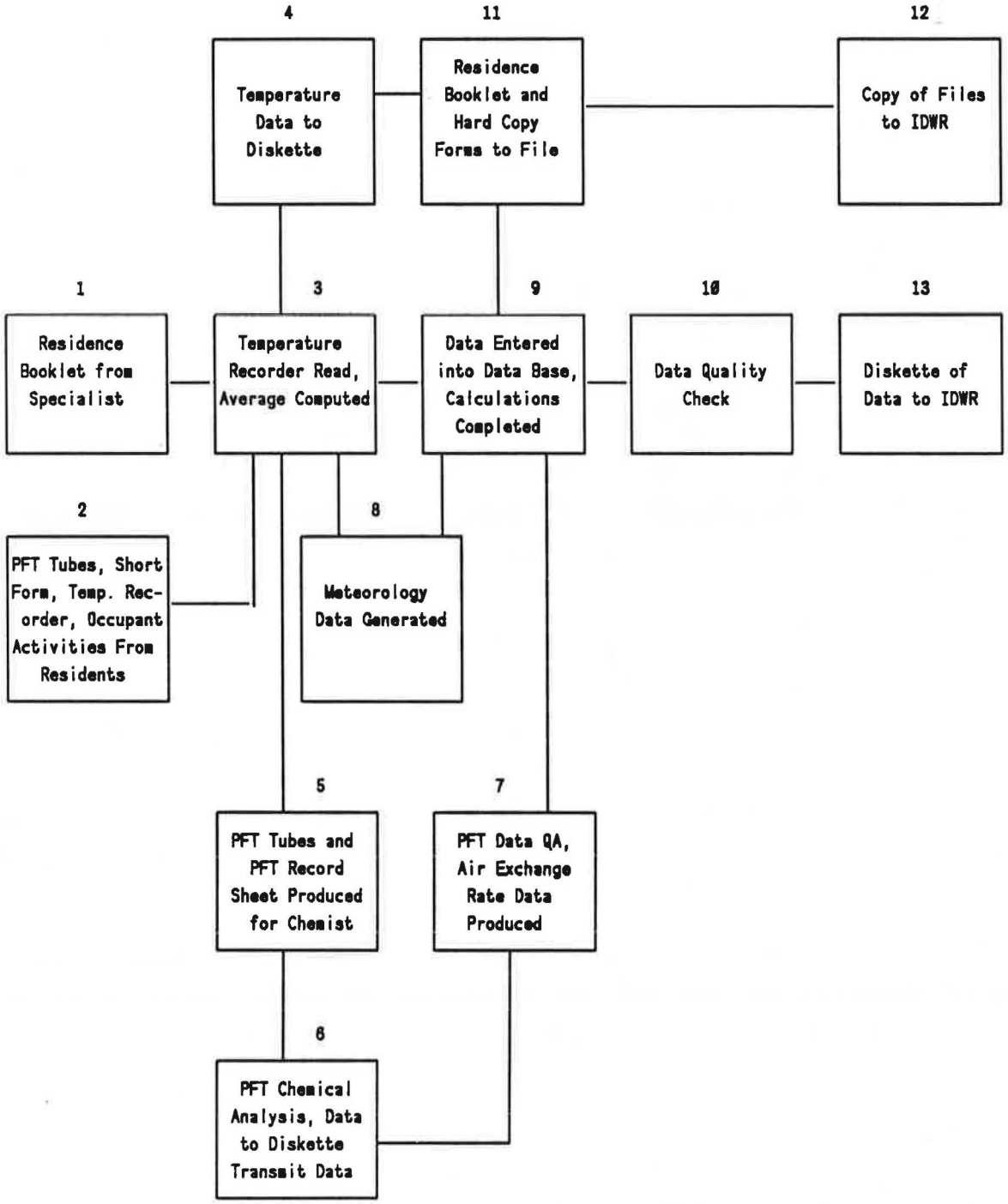


FIGURE 2. Management of Data in NORIS

A copy of the PFT Data Sheet is also given to the meteorologist for determining outdoor temperature and wind speed during the time of the PFT test (Step 8). This data is entered on the PFT Data Sheet and returned to the Battelle data analyst for data entry into the database.

The chemist receives the sample tubes for analysis (Step 5) and keeps a separate data file of sample tube analyses that includes date received and date analyzed as well as the raw chemical analysis (Step 6). The chemical analysis data (hard copy) is given to the Battelle data analyst for entry into the PFT air exchange rate analysis program (Step 7). Temperature data from the PFT Data Sheet and temperature recorder is used in the air exchange rate analysis program for each zone in the home. This program computes the air exchange rates for each zone, produces the Air Exchange Rate Data Sheet (see Appendix F), and stores the data by residence ID number. The PFT air exchange rate data is then transferred to the database (Step 9).

All data is routinely put through a data quality check, particularly the blower door raw and calculated data (Step 10).

A 5¼" diskette with all the data from the database in ASCII format will be transmitted to IDWR at the completion of the work for each heating season (Step 13). Hard copies of all forms and data sheets for each home is filed at Battelle (Step 11) and will be transmitted to IDWR at the end of the project (Step 12).

METEOROLOGICAL DATA COLLECTION

This section describes the meteorological data available to NORIS, and the procedure for assigning applicable meteorological station data to the monitored home.

Available Data

The meteorological data required this project will primarily come from the End-Use Load and Conservation Assessment Program (ELCAP) weather monitoring network, supplemented with data from the National Weather Service (NWS) Class I reporting stations. ELCAP has a network of 60 meteorological stations installed on homes and commercial buildings scattered throughout the region. These homes were purposely selected in regions without other sources of

representative data (i.e., NWS stations) or the home was part of a cluster of other ELCAP monitored homes in the same community or subdivision.

There are 18 available NWS reporting stations, located primarily at airports near the larger cities in the region. These stations routinely report hourly surface weather observations, including temperature and wind speed. Location of the ELCAP and NWS stations in each climate zone are listed in Table 1.

The ELCAP and NWS meteorological data are readily available from the ELCAP meteorological database at Battelle using the standard ELCAP analysis tools. The ELCAP study identifies that the station is located on an RSDP home (RSDP), residential study home (RES-BASE), commercial building (COM), multifamily structure (MFM), or manufactured home (MAN). The ELCAP data is routinely retrieved from the field weekly and the database updated with the most recent data every two weeks. However, for the NWS stations, there is typically a three month delay in obtaining the data from the National Climatic Data Center (NCDC) resulting from the extensive manual QA and data archiving procedures implemented by the NCDC. For example, data for the complete heating season October through April will most likely not be available until mid-July.

Meteorological variables stored in the ELCAP database are shown in Table 2 for both the ELCAP and the NWS stations. The data available represents a computed hourly average for the ELCAP stations while the NWS data is an "instantaneous" observation made approximately 10 minutes before each hour.

Typical Meteorological Year (TMY) data for 16 locations in the Northwest is also available from the ELCAP database. As with the other meteorological data, extraction of the required heating season and/or sampling period data is a routine task using the standard ELCAP analysis tools.

Meteorological Station Assignments

As part of the process of assigning meteorological stations to each of the ELCAP residences, the Northwest region was divided into 23 distinct climate regions. The three corresponding MCS climate zone designations are also given for each site. Table 1 lists the ELCAP and NWS stations with these designations. Each region represents a geographical region with relatively homogeneous weather/climate. Both ELCAP and NWS meteorological stations have

TABLE 1. ELCAP and NWS Stations in Each of the Three Climate Zones and 23 Climate Regions in the Pacific Northwest Region.

MET FLAG	ID	CITY	CLIM REG	CLIM ZONE	ELCAP STUDY
X	AST	Astoria	1	1	NWS
X	UIL	Quillayute	1	1	NWS
X	191	Otis	1	1	RES_BASE
X	279	Seaside	1	1	RSDP
X	512	Forks	1	1	RES_BASE
X	613	Neah Bay (F&W)	1	1	MAN
X	OTH	North Bend	2	1	NWS
X	322	Bandon	2	1	RSDP
X	356	Brookings	2	1	RSDP
X	436	Friday Harbor	3	1	RES_BASE
X	438	East Sound	3	1	RES_BASE
X	471	Camano Is	3	1	RES_BASE
X	490	Sequim	3	1	RES_BASE
X	OLM	Olympia	4	1	NWS
X	SEA	Seattle	4	1	NWS
X	40	Seattle S	4	1	
X	62	Sedro Woolley	4	1	RES_BASE
X	98	Bothel	4	1	RSDP
X	102	Kent	4	1	RSDP
X	341	Tacoma	4	1	RSDP
X	424	Seattle NE	4	1	RES_BASE
X	425	Olympia	4	1	RES_BASE
X	437	Bellingham	4	1	RES_BASE
X	458	Seattle N	4	1	COM
X	466	Marysville	4	1	RES_BASE
X	491	Bremerton	4	1	RES_BASE
X	532	Seattle S	4	1	COM
X	547	Seattle SE	4	1	COM
X	569	Seattle N	4	1	COM
X	EUG	Eugene	5	1	NWS
X	PDX	Portland	5	1	NWS
X	SLE	Salem	5	1	NWS
X	3	Portland SW	5	1	RES_BASE
X	34	Oregon City	5	1	RSDP
X	46	Vancouver NE	5	1	RES_BASE
X	179	Philomath	5	1	RES_BASE
X	313	Eugene	5	1	RES_BASE
X	434	Eatonville	5	1	RES_BASE
X	MFD	Medford	6	1	NWS
X	GEG	Spokane	9	2	NWS
X	50	Spokane E	9	2	RES_BASE
X	56	Newport WA	9	2	RES_BASE
X	198	Spokane N	9	2	RSDP

X	529	Spokane	9	2	MF
X	HMS	Hanford	10	1	NWS
X	PDT	Pendleton	10	1	NWS
X	YKM	Yakima	10	2	NWS
X	39	Richland N	10	1	RES_BASE
X	255	Milton-Freewater	10	1	RES_BASE
X	264	Milton-Freewater	10	1	RES_BASE
X	268	Heppner	10	2	RES_BASE
X	269	Condon	10	2	RES_BASE
X	304	Kennewick	10	1	RSDP
X	582	Richland	10	1	COM
X	LWS	Lewiston	11	2	NWS
X	92	Orofino	11	2	RES_BASE
X	615	Pullman	11	2	MFM
X	RMD	Redmond	12	2	NWS
X	4	Bend	12	2	RES_BASE
X	49	Prineville	12	2	RES_BASE
X	136	Klamath Falls	12	2	RES_BASE
X	324	Bend	12	2	RSDP
X	611	Denio	12	3	MAN
X	BOI	Boise	15	1	NWS
X	66	Weiser	15	1	RES_BASE
X	69	Emmett	15	1	RES_BASE
X	89	Mtn Home	15	2	RSDP
X	362	Twin Falls	16	2	RSDP
X	PIH	Pocatello	17	2	NWS
X	122	Arco	17	2	RES_BASE
X	166	Idaho Falls	17	2	RSDP
X	230	MacKay	18	2	RES_BASE
X	93	Preston	19	3	RES_BASE
X	FCA	Kalispell	21	3	NWS
X	MSO	Missoula	21	3	NWS
X	117	Lolo	21	3	RSDP
X	197	Ronan	21	3	RSDP
X	351	Hamilton	21	3	RES_BASE
X	372	Superior	21	3	RES_BASE
X	381	Kalispell	21	3	RES_BASE
X	429	Troy	21	3	RES_BASE
X	199	Bozeman	22	3	RSDP
X	HLN	Helena	23	3	NWS
X	115	Helena	23	3	RSDP

TABLE 2. Meteorological Variables

VARIABLE	ELCAP	NWS	TMY
Total Horizontal Radiation	x	x	x
Diffuse		x	
Direct		x	
Direct Normal Radiation		x	x
Wind Speed	x	x	x
Wind Direction	x	x	x
Temperature	x	x	x
Relative Humidity		x	
Dew Point		x	x
Atmospheric Pressure		x	x

been identified in each region (some regions have more than one station, others in more remote locations have none). As homes are identified for NORIS, they will be located in a particular climate region and assigned the most representative meteorological data available from that region. In the event there is more than one station, selection will be based on two criteria. First, the similarity of terrain/exposure between the home and the meteorological station, and second, the distance between the home and the station.

QUALITY ASSURANCE

In all steps of the process, care will be taken in handling and recording all the data acquired from the recruitment through the final analysis. The following procedures will be followed in each major step of the study to assure quality data.

STRUCTURE AND BLOWER DOOR DATA

The Homeowner Survey, Walkthrough Survey, and Structure Measurements and Sketches data taken in the field by the specialist will be checked for reasonableness and accuracy prior to entry into the database by the Battelle data analyst. Missing or anomalous data will be flagged and contact will be made with the field specialist or resident to correct if necessary.

The Meteorological Data and Exterior Building Parameters data will also be examined. The wind speed data and corresponding blower door measurements will be examined to determine if another blower door test is necessary based on the guidelines in Appendix C. The photographs will be examined to see if the appropriate shielding class was used.

The Blower Door Measurements will be checked against the computer tape from the blower door test that is enclosed with the booklet for each home. Total calculated home volume will be checked against individual zone volume recorded on the Structure Measurement and Sketches. The data entry has been structured so that the specialist can transfer data from one form to another in a consistent and logical sequence to avoid errors.

PFT DATA SHEETS

The PFT Data Sheets will be examined for completeness by the Battelle data analyst. Zone volumes and temperature data will be checked against the entries on the Structure Measurements and Sketches data sheets. The number and locations of the PFT sources, sampler tubes, and temperature sensors indicated on the PFT Data Sheets will also be compared with the structure measurements and sketches data. The field specialist or homeowner will be contacted if there are any unresolved discrepancies.

LABORATORY ANALYSIS OF PFT SAMPLE TUBES

The analysis of sample tubes will be conducted using well documented procedures and dedicated instrumentation for measuring perfluorocarbon tracers. The analysis task will be supported by a comprehensive quality assurance plan designed to track individual samples, assess sample integrity, and document analyzed performance. In addition to chromatograms generated at the time of analysis, raw chromatographic data for all samples will be routinely recorded on floppy disk to permit reprocessing and integration of analytical peaks. This is a key feature of the analytical system at Battelle since the entire sample is injected into the gas chromatograph and lost to the atmosphere once analyzed.

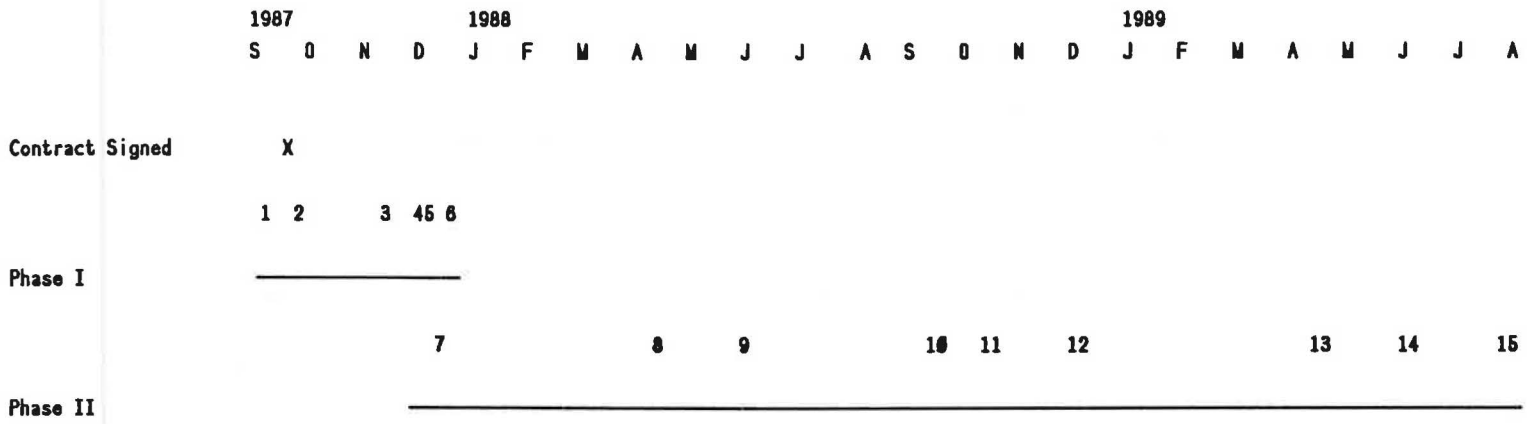
Sample integrity will be assessed by including blank tubes and spiked sample tubes with the tubes shipped to the field technician for placement in the homes. These tubes will be clearly identified as "QA" samples, but in all other respects will be identical to those used for sample collection. Even though these tubes will be shipped with the sample tubes for field deployment, they will remain sealed in the field and returned to the analytical laboratory with the exposed tubes. Analysis of the blank tubes will demonstrate the integrity of the caps used to seal the tubes and the potential for positive interference due to tracer gas permeation of the seal. Analysis of spiked sample tubes will permit an assessment of the behavior of "aged" samples.

The chemist conducting the analysis of field samples is trained in the use of the chromatographic system and calibration equipment. We will follow specifically documented procedures (see Appendix F) and be responsible for maintaining a complete record of all analysis. A Lab Analysis Log (Appendix F) will be used by the chemist to maintain a daily record of chromatographic parameters, calibration checks, and sample analysis.

SCHEDULE

A schedule is given in Table 3 that shows start and end dates for key tasks in the project broken down into Phase I Experimental Design and Phase II Field Data Collection.

TABLE 3. Schedule and Milestones



Milestones:

1. Draft Project Protocol, Draft Recruitment Plan, Subcontracts and Subcontractors List, ELCAP Weather Station List, PFT Licensing Agreement (9/18/87)
2. Draft Project Summary Brochure, Training Session Outline, Special Studies Protocol (9/30/87)
3. Begin Category 1 recruiting (11/25/87)
4. Draft Sample Selection Design (12/01/87)
5. Status Report of blower door training, Final Project Protocol, Recruitment Plan, and Sample Selection Design (12/01/87)
6. Category 1 homes selected (12/15/87)
7. Begin Category 1 home data collection (1/4/88)
8. End Category 1 home data collection (4/15/88)
9. Data from Category 1 homes delivered (approximately 6/1/88)
10. Draft Sample Selection Design and Recruitment Plan for Category 2 homes (9/30/88)
11. Begin recruitment Category 2 homes (10/15/88)
12. Begin Category 2 data collection (12/1/88)
13. End field data collection (4/15/89)
14. Deliver data (approximately 6/1/89)
15. Deliver Final Report (7/31/89)

REFERENCES

Bonneville Power Administration (BPA). 1987. Draft Environmental Impact Statement on New Energy-Efficient Homes Programs - Assessing Indoor Air Quality Options. DOE/EIS-0127, Bonneville Power Administration, Portland, Oregon.

Parker, G. B., D. L. Hadley, and P. A. Morrow. 1988. Northwest Residential Infiltration Survey (NORIS) Recruitment Plan. Prepared for the State of Idaho Department of Water Resources under Contract 2311112709 by Battelle, Pacific Northwest Laboratories, Richland, Washington.

APPENDIX A

FORMS

DATE: ___/___/___

SUGGESTED PFT ZONES

This is a suggested scheme for placement of PFT sources and RATS based on information obtained during the telephone survey. The final placement scheme is up to you and will be recorded on both the STRUCTURE MEASUREMENT AND SKETCHES **and the** *PFT DATA SHEET.*

EST. # OF PFT ZONES IN HOME _____ *EST. # OF RATS IN HOME* _____

ZONE #1 Description _____

Approximate # of RATS (R) _____

Paired: Y N / Location(s) _____

Source Type (S) _____

ZONE #2 Description _____

Approximate # of RATS (R) _____

Paired: Y N / Location(s) _____

Source Type (S) _____

ZONE #3 Description _____

Approximate # of RATS (R) _____

Paired: Y N / Location(s) _____

Source Type (S) _____

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NORIS FIELD MEASUREMENT DATA

A. Site ID# B. Blower Door Test Date ___/___/___

C. Company Number _____
1. Benchmark 2. Quality Conserv. 3. Enspect 4. Sound Conserv. 5. G. Gregg

D. Specialist(s)_____ 1. George 2. Hal 3. David 4. Jim 5. Randy 6. John 7. Jack 8. Toby 9. Other

Be sure to bring in sources before starting!

HOMEOWNER SURVEY

How many adults and children are in your family? M. # adults (>13)____ N. # children (<13)____

O. In what year was your home built? 19_____ **(Stop! Call if before 1980.)**

P. Is there an interior basement door from upstairs to downstairs? yes no (Circle one)

Q. Is it normally closed or open: closed open (Circle one)

R. What is the primary heat source? (Check one)

1. zoned active (fan) _____
2. zoned baseboard _____
3. zoned ceiling _____
4. zoned wall (passive) _____
5. central forced air elec. _____
6. electric heat pump _____
7. oil, gas, coal furnace _____
8. wood stove or insert _____
9. other (describe) _____
10. none _____

S. What is the secondary heat source? (Check one)

1. zoned active (fan) _____
2. zoned baseboard _____
3. zoned ceiling _____
4. zoned wall (passive) _____
5. central forced air elec. _____
6. electric heat pump _____
7. oil, gas, coal furnace _____
8. wood stove or insert _____
9. other (describe) _____
10. none _____

T. Is there more than one thermostat for primary system? yes no (Circle one)

U. Are there major areas of your home that will be closed off 24 hours a day in next 3 weeks?
yes no (Circle one)

V. Which areas? (Note how many)
1. basement _____ 2. bedrooms _____ 3. entire floor _____ 4. other (describe) _____

W. Is the house occupied more than half of the day-time during weekdays? yes no (Circle one)

X. Has any additional weatherization been performed since you moved into the home? Check all that apply
1. caulk/weatherstrip _____ 2. storm windows/doors _____ 3. wall/attic insullation _____

Y. How many hours per day are kitchen, bathroom and other exhaust fans and inside dryer operated?
____ total hours (nearest 1/2 hour)

Z. Have you (the occupant) noticed any odors or moisture problems? (Check one)
0. none _____ 1. odors _____ 2. moisture _____ 3. both _____

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Resident _____ Date _____

WALKTHROUGH SURVEY

Have occupant "tag" along with you

STRUCTURE

AA. Number of Levels (Check one)

1. single level with no basement _____
2. multi-level with no basement _____
3. single level with conditioned basement _____
4. multi-level with conditioned basement _____
5. single-level with unconditioned basement _____
6. multi-level with unconditioned basement _____

AB. Primary exterior wall type: (Check one)

1. framed 2x4 _____ 2. framed 2x6 _____ 3. brick _____ 4. stucco _____ 5. log _____

AC. Primary foundation type (>50%): (split entry [day light basement] is #1) (Check one)

1. slab on grade _____ 2. basement _____ 3. vented crawlspace _____
4. unvented crawlspace (if >50% of vents are closed, it is unvented) _____

AD. Type of basement: (Check one)

1. fully below grade _____
2. daylight (1 or more walls above grade) _____

ROOMS IN HOME (do not count a room twice)

AE. Number of bedrooms _____ AF. Number of bathrooms _____
AG. Number of living/family rooms _____ AH. Number of kitchens _____
AI. Number of dining rooms _____ AJ. Number of utility rooms _____
AK. Other (type and #) _____

EXHAUST FANS (conditioned space)

AL. Number of kitchen exhaust fans _____
AM. Number of bathroom exhaust fans _____
AN. Number of other exhaust fans (incl. dryer) _____

ALL OTHER FANS (Note zone and describe)

HEATING SYSTEMS

AO. What is the primary installed electric heating system type (not necessarily the one used). (Check one)

1. zoned active (fans) _____ 2. zoned passive (baseboard, wall, ceiling-radiant) _____
3. central forced air furnace _____ 4. heat pump _____

AP. Number of stove(s)/insert(s) with outside combustion air _____
AQ. Number of stove(s)/insert(s) without outside combustion air _____
AR. Number of fireplace(s) with outside combustion air _____
AS. Number of fireplace(s) without outside combustion air _____

AT. Specialist (your) observation of odors or moisture (Check one)

0. none _____ 1. odors _____ 2. moisture _____ 3. both _____

Take dimensions, sketch, deploy and secure [Temperature Recorder] and PFT Sources and record room temperature with sources.

Resident _____ Date ___/___/___

STRUCTURE MEASUREMENT AND SKETCHES

WHOLE HOUSE: Record accurate dimensions and PFT zone #s (only) on both sketches.

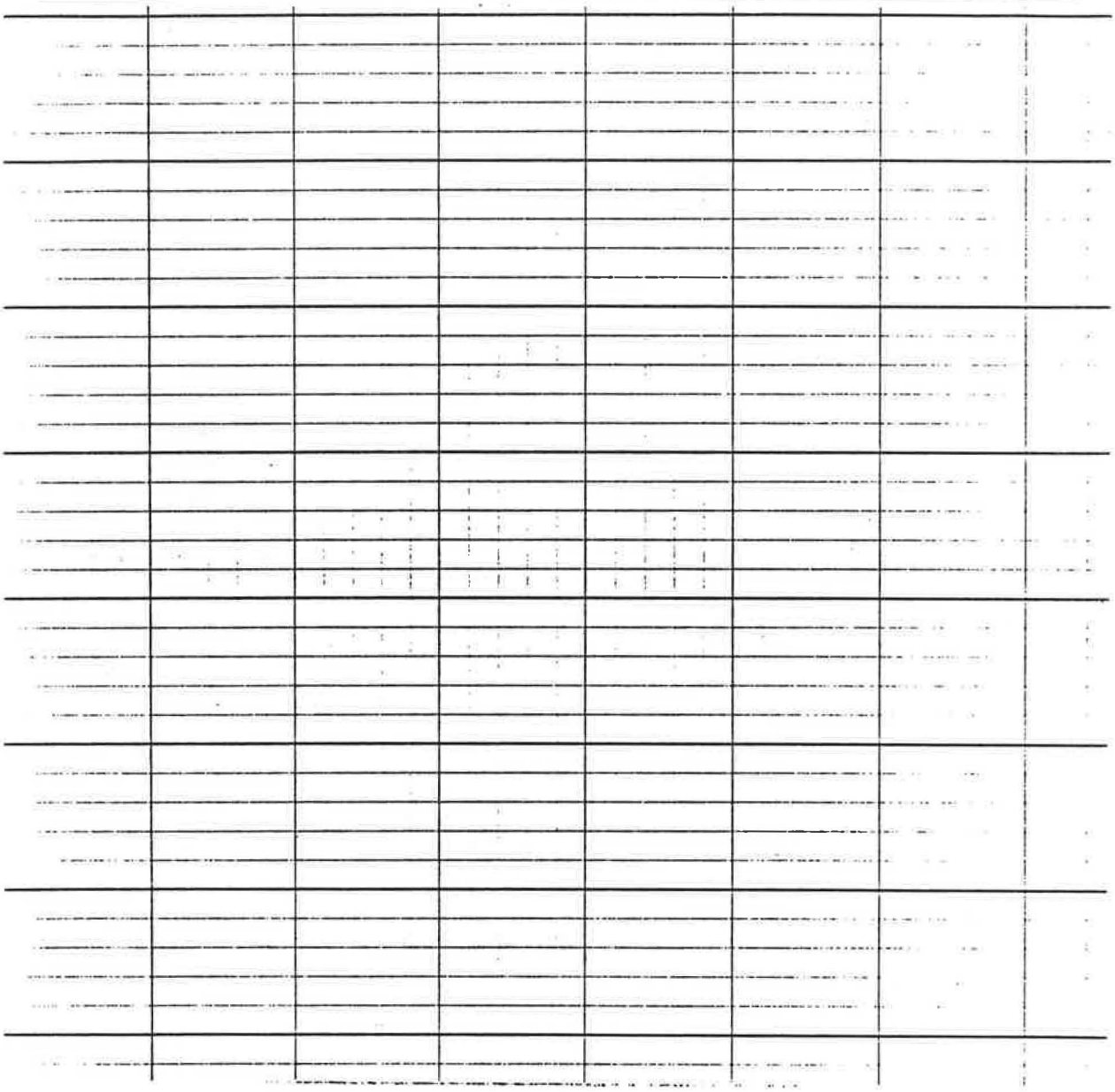
Section Sketch (Show Grade)

Plan Sketch

12/8

Resident _____ Date __/__/__

FIRST PFT ZONE (Plan Sketch)



Avg. Ceiling Height: ____ . ____ ft.

AU. Living Floor Area F1= _____ ft.^{2}

AV. Volume: V1= _____ ft.^{3}

AX. Ave. Zone Temperature: T1 = _____ °F

Show Locations:

(W)	=	Woodstove	▨	=	Forced-Air Return Grill
(T)	=	Temp. Recorder	(F)	=	Fireplace
(S#)	=	PFT Source	t	=	Thermostat
(R#)	=	RATS	f	=	Furnace
			x	=	Closed-Off Room

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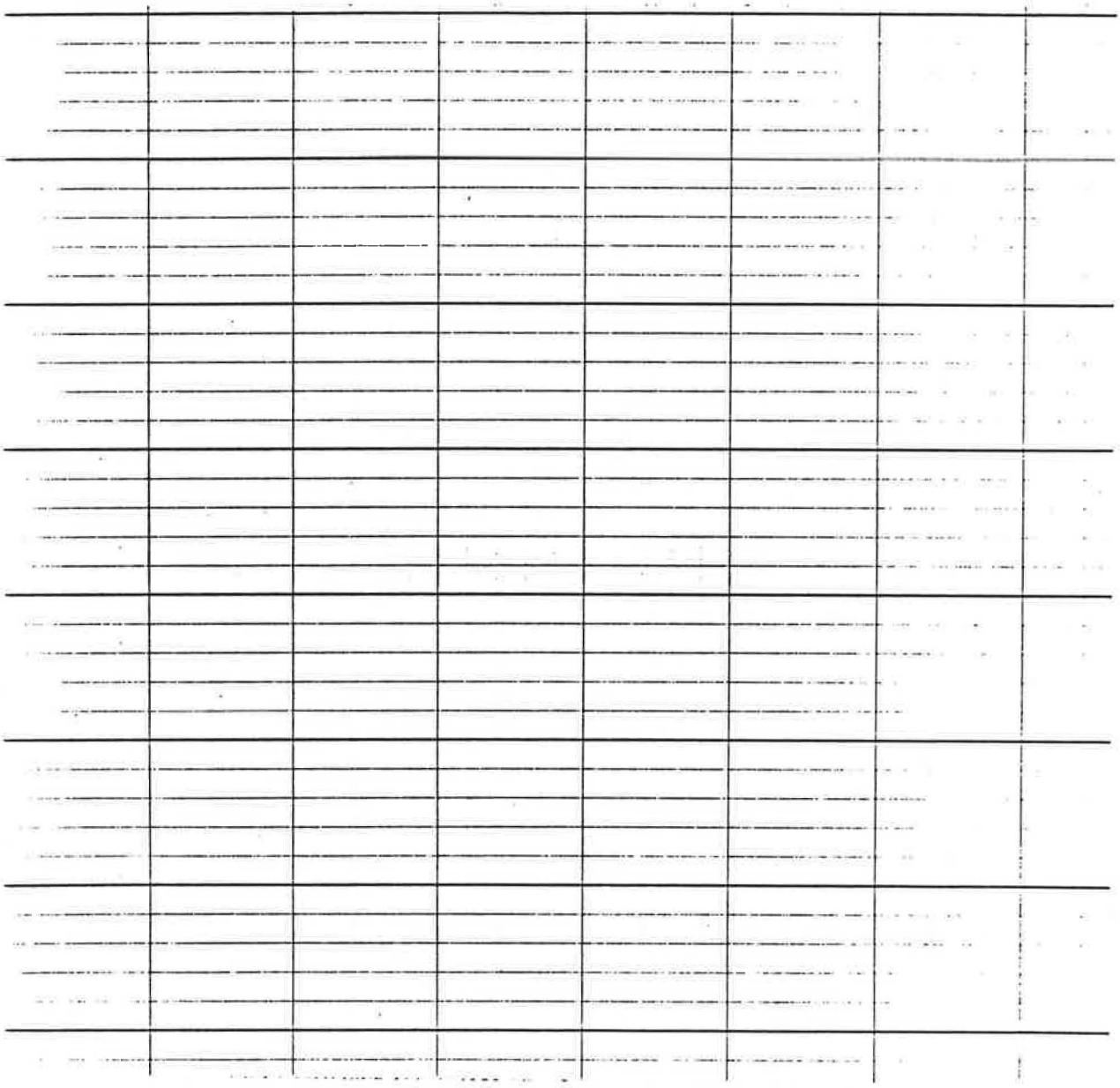
Resident _____ Date __/__/__

SECOND PFT ZONE (Plan Sketch)



Avg. Ceiling Height: _____ . _____ ft.

AY. Living Floor Area F2= _____ $ft.^2$

AZ. Volume: V2= _____ $ft.^3$

BA. Ave. Zone Temperature: T2 = _____ °F

Show Locations:

(W)	=	Woodstove	⊘	=	Forced-Air Return Grill
(T)	=	Temp. Recorder	(F)	=	Fireplace
(S#)	=	PFT Source	t	=	Thermostat
(R#)	=	RATS	f	=	Furnace
			x	=	Closed-Off Room

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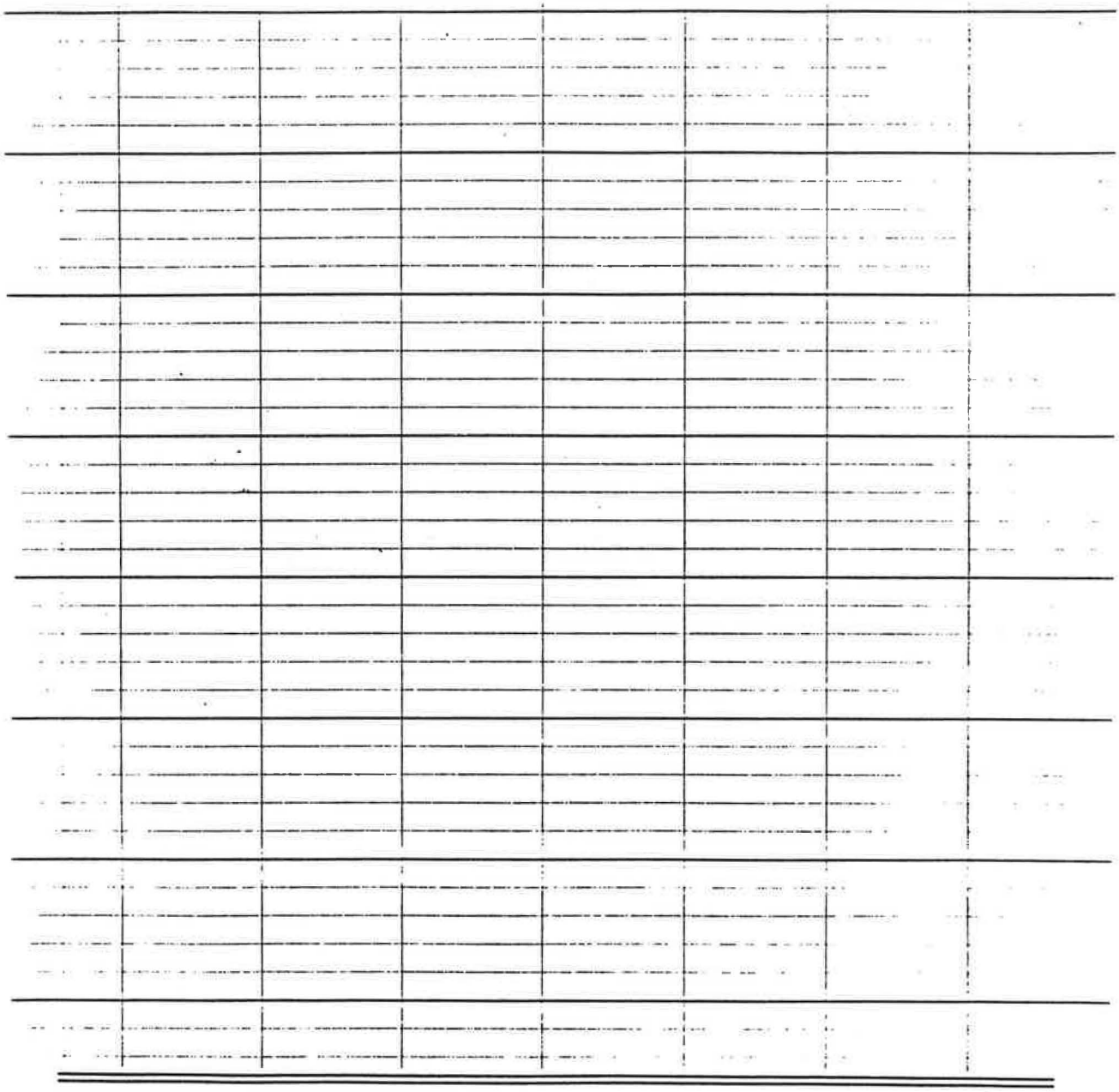
Resident _____ Date __/__/__

THIRD PFT ZONE (Plan Sketch)



Avg. Ceiling Height: ____ . ____ ft.

BB. Living Floor Area F3= _____ $ft.^2$

BC. Volume: V3= _____ $ft.^3$

BD. Ave. Zone Temperature: T3 = _____ °F

Show Locations:

(W)	=	Woodstove	⊘	=	Forced-Air Return Grill
(T)	=	Temp. Recorder	(F)	=	Fireplace
(S#)	=	PFT Source	t	=	Thermostat
(R#)	=	RATS	f	=	Furnace
			x	=	Closed-Off Room

12/8

Resident _____ Date __/__/__

METEOROLOGICAL DATA AND EXTERIOR BUILDING PARAMETERS

Reminder: Return all unused sources to cab of vehicle before completing.

BE. Outdoor Temperature _____ °F.

BF. Uncorrected Station Pressure _____ inches

BG. Blower Door Pressure Setting _____ inches

Site altitude _____ ft. Airport or other FAA site used _____

BH. Ave. OAT _____ °C BI. Ave. windspeed _____ m/s BJ. Met Station# _____

BK. Wind Speed _____ mph (best guess)

BL. Wind gusts to _____ mph (best guess)

BM. Regional Terrain (Circle one) (see Reference Table below)

I II III IV V

BN. Local Shielding Type (Circle one) (see Reference Table below)

I II III IV V

BO. Weather Station Terrain Class.

I II III IV V

BP.. Overall building height (lowest leak to highest leak): _____ ft.

Reminder: Take two Polaroid photos of the exterior of the house from different angles and write house ID# on back of photos.

REFERENCE TABLE

BM. REGIONAL TERRAIN (5 mi):

I	Unobstructed plain, ocean or other water body.
II	Generally flat with some isolated obstacles (well separated buildings or trees).
III	Suburban areas with low buildings, trees, etc.
IV	Urban, industrial, forested area, valley, or lee side of hill.
V	Center of a big city or middle of thick forest of tall trees..

BN. LOCAL SHIELDING TYPE (30 ft):

I	No obstructions or local shielding.
II	Light local shielding with minimal obstructions. Perhaps a few trees or a shed
III	Light local shielding with some obstruction on one side. A thick hedge, solid fence or one neighboring house.
IV	Moderate shielding around much of permiter (buildings or mature trees).
V	Heavy shielding - large obstructions surrounding house perimeter.

Resident _____ Date _____

BLOWER DOOR TEST

BQ. Door Type/Model _____ BR. Avg. Indoor Temp :$\left(\frac{T1+T2}{2} \text{ or } \frac{T1+T2+T3}{3}\right)$ _____ °F

BS. Total Volume (V1+V2+V3)_____ ft³ BT. Total Floor Area: (F1+F2+F3) _____ ft²

Distribution of leakage area	
Fraction of total leakage	
BU. ceiling	_____ %
BV. wall	_____ %
BW. floor	_____ %

Identify the 4-5 greatest leakage sources in home

1. _____
2. _____
3. _____
4. _____
5. _____

BX. Natural△P (offset) _____

First Blower Door Test (Ducts Not Taped)

Depressurization Test

House Pressure Target	Actual	Flow (cfm)
(15) (0.06)		
(18) (0.07)		
(22) (0.09)		
(27) (0.11)		
(33) (0.13)		
(40) (0.16)		
(49) (0.19)		
(60) (0.24)		

Pressurization Test

House Pressure Target	Actual	Flow (cfm)
(15) (0.06)		
(18) (0.07)		
(22) (0.09)		
(27) (0.11)		
(33) (0.13)		
(40) (0.16)		
(49) (0.19)		
(60) (0.24)		

Second Blower Door Test (Ducts Not Taped)

Depressurization Test

House Pressure Target	Actual	Flow (cfm)
(15) (0.06)		
(18) (0.07)		
(22) (0.09)		
(27) (0.11)		
(33) (0.13)		
(40) (0.16)		
(49) (0.19)		
(60) (0.24)		

Pressurization Test

House Pressure Target	Actual	Flow (cfm)
(15) (0.06)		
(18) (0.07)		
(22) (0.09)		
(27) (0.11)		
(33) (0.13)		
(40) (0.16)		
(49) (0.19)		
(60) (0.24)		

Did you seal any exhaust vents prior to depressurization test? yes no (Circle one) If so, how many? ___

Return blower door to vehicle. Take out RATS and holders from hood or bed. Hang the RATS and note UNCAP DATE and TIME on *PFT Data Sheet* and *Short Form*. Also note location of RATS R# on Short Form. *Structure Measurement and Sketches* and *PFT Data Sheet*. BE CONSISTENT ON ALL FORMS.

Resident _____ Date _____

BLOWER DOOR TEST WITH DUCTS TAPED

Depressurization Test
House Pressure

Target	Actual	Flow (cfm)
(15) (0.06)		
(18) (0.07)		
(22) (0.09)		
(27) (0.11)		
(33) (0.13)		
(40) (0.16)		
(49) (0.19)		
(60) (0.24)		

Depressurization Test
House Pressure

Target	Actual	Flow (cfm)
(15) (0.06)		
(18) (0.07)		
(22) (0.09)		
(27) (0.11)		
(33) (0.13)		
(40) (0.16)		
(49) (0.19)		
(60) (0.24)		

Return blower door to vechicle. Take out RATS and holders from hood or bed. Hang the RATS and note UNCAP DATE and TIME on *PFT Data Sheet* and *Short Form*. Also note location of RATS R# on Short Form, *Structure Measurement and Sketches* and *PFT Data Sheet*. BE CONSISTENT ON ALL FORMS.

Resident _____

PFT DATA SHEET

BY. UNCAP DATE: ___/___/___
BZ. UNCAP TIME: _____:_____ am pm
CA. CAP DATE: ___/___/___
CB. CAP TIME: _____:_____ am pm

ZONE #1

Description _____ Ave. Temp(T1) _____ °F Volume(V1) _____ ft³
Temp Recorder Serial # _____ Location _____

RATS (R)

ID# (4 digit)	Room	Hung From	R#

Sources (S)
Source Code ____ # Sources ___

Room	Located on

ZONE #2

Description _____ Ave.Temp(T2) _____ °F Volume(V2) _____ ft³
Temp Recorder Serial # _____ Location _____

RATS (R)

ID# (4 digit)	Room	Hung From	R#

Sources (S)
Source Code ____ #Sources ___

Room	Located on

ZONE #3

Description _____ Ave. Temp(T3) _____ °F Volume(V3) _____ ft³
Temp Recorder Serial # _____ Location _____

RATS (R)

ID# (4 digit)	Room	Hung From	R#

Sources (S)
Source Code ____ # Sources ___

Room	Located on

Source Code:
Red = 2
Blue = 4
Black = 5

CHECKLIST

Please indicate by a check mark that each item has been completed before you leave the home.

[ ] COMPLETED HOMEOWNER SURVEY.

[ ] COMPLETED ***WALKTHROUGH SURVEY*** AND NOTED ZONES, CLOSED OFF ROOMS, AND LOCATIONS OF PFT SOURCES S , AND TEMPERATURE RECORDER T ON ***STRUCTURE MEASUREMENT AND SKETCHES*** FORM.

[ ] PLACED PFT SOURCES AND (OPTIONAL) TEMPERATURE RECORDER. ACTIVATED RECORDER.

[ ] RECORDED METEOROLOGICAL DATA AND EXTERIOR BUILDING PARAMETERS.

[ ] TOOK PHOTOGRAPH OF OUTSIDE OF HOME, LABELED IT AND PLACED IT IN BOOKLET.

[ ] COMPLETED ***BLOWER DOOR TEST*** AND REMOVED ALL SEALING MATERIAL, COMPLETED TABLES AND INCLUDED COPY OF CALCULATIONS TAPE IN BOOKLET.

[ ] HUNG RATS, R, UNCAPPED NUMBERED END OF TUBE AND PUSHED BACK RED CAP FROM END OF THE TUBE.

[ ] RECORDED ALL INFORMATION ON ***PFT DATA SHEET*** IN BOOKLET.

[ ] FILLED IN YOUR PART OF THE OCCUPANT'S ***SHORT FORM*** AND PLACED IN MAILER, AND EXPLAINED ***OCCUPANT ACTIVITY RECORD*** AND LEFT 4 OF THESE WITH OCCUPANT.

[ ] LEFT MAILER, SPARE RED CAPS AND ***INSTRUCTIONS FOR THE RESIDENT*** AND DEMONSTRATED CORRECT RECOVERY AND MAILING PROCEDURES.

[ ] CLEANED UP ANY DIRT/DEBRIS.

[ ] THANKED THE RESIDENT FOR THEIR COOPERATION.

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OCCUPANT ACTIVITIES RECORD

Please record the following events on a daily basis each week of PFT testing.

Week of _____	*Mon*	*Tue*	*Wed*	*Thur*	*Fri*	*Sat*	*Sun*
1. Hours of Woodstove Use							
2. Hours of Fireplace Use							
3. Hours of Opened Windows							
4. Minutes of all Exhaust Fan Use:							
5. Minutes of Clothes Dryer Use (inside home only)							
6. Unusual Events (Place number under appropriate day and indicate below the event and its impact)	*1.*						

(Example: 1. Party with several guests.)

SHORT FORM

Total # RATS in home _____

To be Filled in by Occupant

UNCAP DATE	UNCAP TIME		CAP DATE	CAP TIME	
___/___/___	___:___	(Circle One) am pm	___/___/___	___:___	(Circle One) am pm

(R#)	Room/Location
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

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SHORT FORM

Total # RATS in home _____

To be Filled in by Occupant

UNCAP DATE	UNCAP TIME		CAP DATE	CAP TIME	
___/___/___	___:___	(Circle One) am pm	___/___/___	___:___	(Circle One) am pm

(R#)	Room/Location
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

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INSTRUCTIONS FOR THE RESIDENT

These instructions will guide you in the recovery of the PFT (GLASS) sample tubes that are hanging from your ceiling in foam holders. Instructions are also provided for recovery of a TEMPERATURE RECORDER. (if one was placed in your home)

Battelle will be calling you in a few weeks when it is time to recover the sample tubes and/or temperature recorder. Please follow the instructions carefully. If at any time you do not understand a step, STOP and give us a call COLLECT at (509) 375-3799.

STEP #1 Take down all of the foam holders containing the GLASS sample tubes. We will tell you at the time we call you where we think each foam holder is located and the total number of tubes.

GLASS TUBE

NOTE: DO NOT REMOVE the small colored metal capsules that are secured with putty. Never place the glass tubes near the metal capsules when handling tubes. We will call you and ask you to remove and mail the capsules.

CAPSULE

STEP #2 Leave the glass tubes in the foam holder and slip the red cap at the end of the tube over the open end and secure. If the red cap is missing, use one of the extra caps supplied in the mailer.

STEP #3 Record the DATE and TIME you finished CAPPING the tubes on the ***SHORT FORM*** that is found inside the mailer. Record the time to the NEAREST ONE-HALF HOUR (i.e. 4:30 pm, 5:00 pm, 5:30 pm, etc.) Place the ***SHORT FORM*** back inside the mailer.

STEP #4 Place your up-to-date ***OCCUPANT ACTIVITY RECORDS*** you have been keeping in the mailer. If you can't locate all the activity records, mail them to us later.

STEP #5 Wrap the string on the holder around the glass tubes and holders to secure tubes. Place the foam holders containing the sample tubes in the mailer in a single layer.

ADDITIONAL STEP FOR HOMES WITH A TEMPERATURE RECORDER

(We will inform you if you have a temperature recorder and where we think it is)

STEP #6 Remove the recorder from its location and place it in the mailer also. YOU DO NOT HAVE TO TURN IT OFF, PLEASE DO NOT EVEN TRY.

LAST STEP Seal the mailer and place package outside in your mailbox as soon as possible. NO POSTAGE IS REQUIRED.

Thank you for assisting us.

11/87

APPENDIX B

PROCEDURES FOR PLACEMENT AND RECOVERY OF PERFLUOROCARBON TRACER (PFT) SOURCE CAPSULES AND SAMPLE TUBES

APPENDIX B

PROCEDURES FOR PLACEMENT AND RECOVERY OF PERFLUOROCARBON TRACER (PFT) SOURCE CAPSULES AND SAMPLE TUBES

This Appendix describes the procedures that are to be followed in the handling, placement, and recovery of perfluorocarbon tracer (PFT) source capsules and passive sample tubes in homes. The procedures closely follow those recommended by Brookhaven National Laboratory (BNL) (Dietz 1986). The theory of PFT air exchange measurements can be found elsewhere (Dietz et al. 1985).

TERMINOLOGY AND EQUIPMENT DESCRIPTION

Hereinafter, the PFT metal source capsules containing PFT will be known as "sources" and the glass sample tubes used to capture the PFT vapor will be known as "RATS" (Red Adsorption Tube Samplers). The RATS are 1/4-in. diameter glass tubes packed with carbon-based absorbent. They are numbered (4-digit) on one end and capped with a red cap (with collar) on this numbered end and a black cap on the other (unnumbered) end. The metal sources are also approximately 1/4-in. diameter, solid on one end with a rubber plug on the other end. They contain a small volume of liquid PFT of a unique chemical compound that diffuses through the plug at a known rate at a given temperature.

PRINCIPLES FOR PFT DEPLOYMENT

Information about the heating system(s) and architecture of the homes to be monitored in this study will be obtained from the telephone survey. This information is important for estimating the number of air flow zones in the home and, therefore, the type and number of PFT sources and RATS to be deployed in each home. This is done prior to assigning a home to the field technician to guide the technician toward making the final decision about source and sample tube placement. Battelle will suggest the PFT source and RATS configuration in each home in the study based on this information, however,

the final placement of the sources and RATS is up to the field specialist in consultation with the homeowner.

ZONING

Every home in the study will be monitored for air exchange rate using PFT in a minimum 2-zone configuration. This will require two different PFT types in each home, one PFT type per zone. A maximum of three different PFT types will be deployed in this study, correspondingly limiting the number of zones to be studied in any home to three. The following principles apply to determining the zones in a home:

- Each level of a home is a zone unless there is free air circulation with another level (e.g., lofts).
- Attached garages, carports or crawlspaces (vented or unvented) are not considered zones.
- All single level (one story) homes will be a minimum of two-zones with very large (> 3000 ft2) single story homes three-zones.
- The bedroom (sleeping) area of a home is usually considered a single zone.
- All basements, including "daylight" basements (conditioned or not) are considered a single zone.
- A two-level home is a three-zone home.
- A two-level home with a basement is a three-zone home (with the basement a single zone).

Source Deployment

The three types of PFT sources used in this study are designated as follows:

Type Number	Capsule Color	Compound(a)
2	Red	PMCH

(a) PMCH = perfluoromethylcyclohexane
o-PDCH = ortho-perfluorodimethylcyclohexane
p-PDCH = para-perfluorodimethylcyclohexane

4	Blue	o-PDCH
5	Black	p-PDCH

One source type is deployed in each zone. Because it is important to ensure that the PFT is well mixed in the home in each zone, the following deployment strategy will be followed.

- A minimum of one source (capsule) will be placed in every zone in every room greater than 80 ft^2 that has a door even if the room is closed off.
- One source will be placed every 500 ft^2 in large rooms (areas) of zoned-heated homes.
- One source will be placed every 750 ft^2 in large rooms (areas) of centrally-heated homes.

Each source type exhibits a different mass emission rate from the capsules and therefore they must be deployed according to their emission rate. It is necessary to place the source type with the highest emission rate in the highest zone of the home to insure that sufficient tracer migrates to, and is detected, in the lowest zone of the home. Therefore, the following principles will be followed for choosing the source type for each zone. Generic house diagrams are provided to illustrate these principles.

- All basements and ground floors will have Type 5 (black) sources.
- Type 4 sources should not be used in a zone with several rooms requiring sources due to the limited number of this type of source.
- A one-level home without a basement that is two-zone will have Type 2 (red) and Type 5 (black) sources in the ground floor (see Figure B.1).
- A two-level home without a basement is three-zone and will have Type 2 (red) sources in the first floor above the ground floor and both Type 4 (blue) and Type 5 (black) sources in the ground floor (see Figure B.2).
- A one-level home with a basement is three-zone and will have Type 5 (black) sources in the basement and Type 2 (red) sources and Type 4 (blue) sources in the ground floor (see Figure B.3).
- A home with a daylight basement with two levels above the daylight basement, is three-zone and will have Type 5 (black) sources in the

daylight basement, Type 4 (blue) sources in the first floor and Type 2 (red) sources in the second floor (see Figure B.4).

- A home with one level above the ground floor and with a basement is three zone and will have Type 5 (black) sources in the basement, Type 4 (blue) sources in the ground floor and Type 2 (red) sources in the first floor (above ground floor), (see Figure B.5).

Source Locations

The sources should be placed near an exterior wall in the extremities of the zone. This is to insure that the source is carried into the room or zone by the air that is normally infiltrating into the home from exterior wall areas. The sources should be placed no less than approximately 2 ft. from the floor.

Good locations for sources are on objects that are not easily moved or normally relocated, including: shelves, picture frames, door frames, cabinet tops, plants (not buried however), counter tops, and large furniture (legs, under the tables and ledges). The sources should be hidden if possible and secured with poster putty to keep them from rolling or falling on the floor where they could be picked up and swallowed by children, kicked around or vacuumed.

The sources should be placed no closer than 3 to 5 ft. from items that emit heat or ventilation air. These include: any vent/grill (including window air conditioners), window (whether it opens or not), exterior/garage/basement door, wood stove/fireplace, refrigerator/freezer/microwave and not above a baseboard/wall heater or lamp. The sources should also not be placed in the direct or indirect sun.

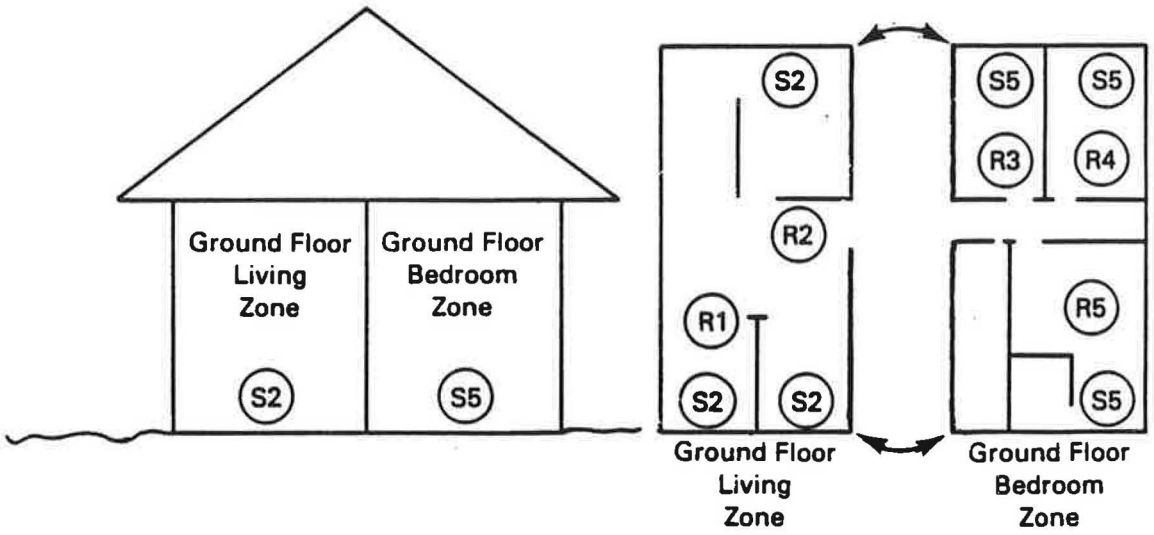

FIGURE B.1. PFT Placement Scheme For a 1 Level Home Without a Basement

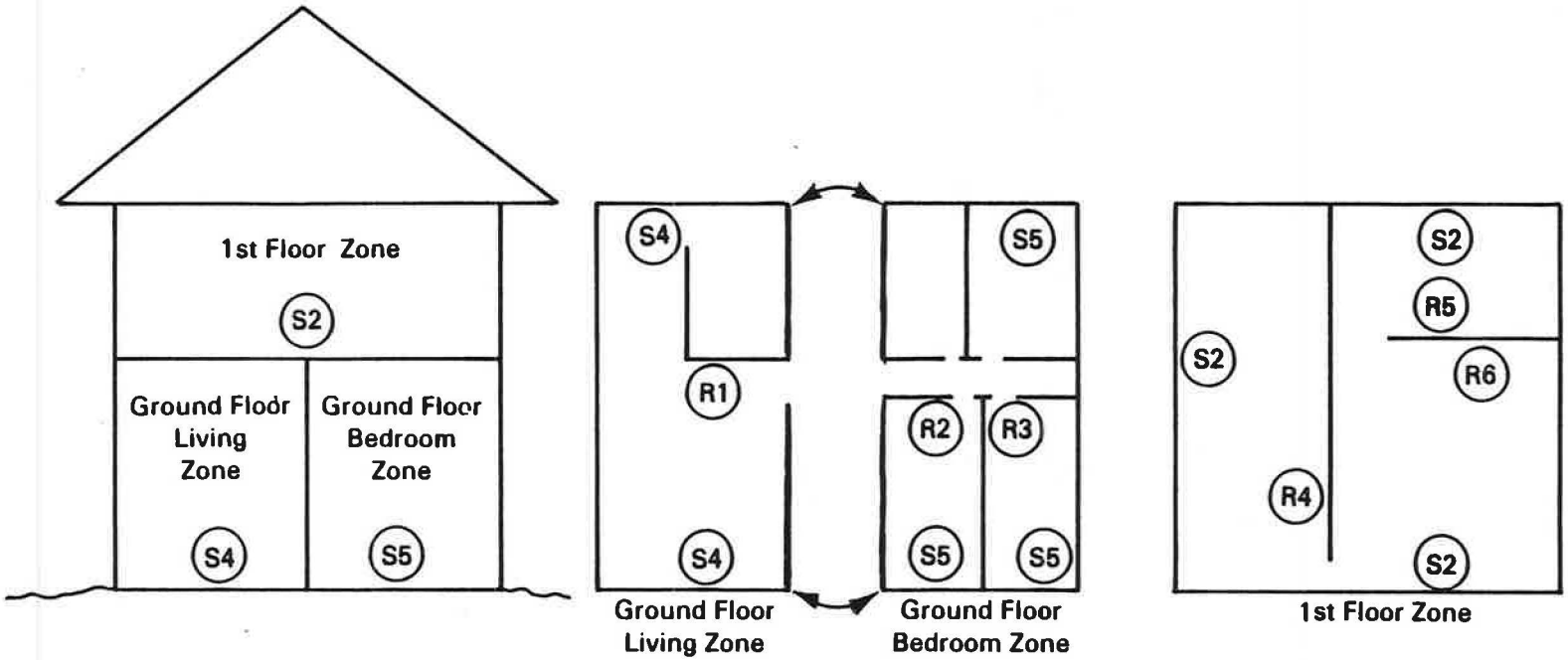

FIGURE B.2. PFT Placement Scheme For a 2 Level Home Without a Basement

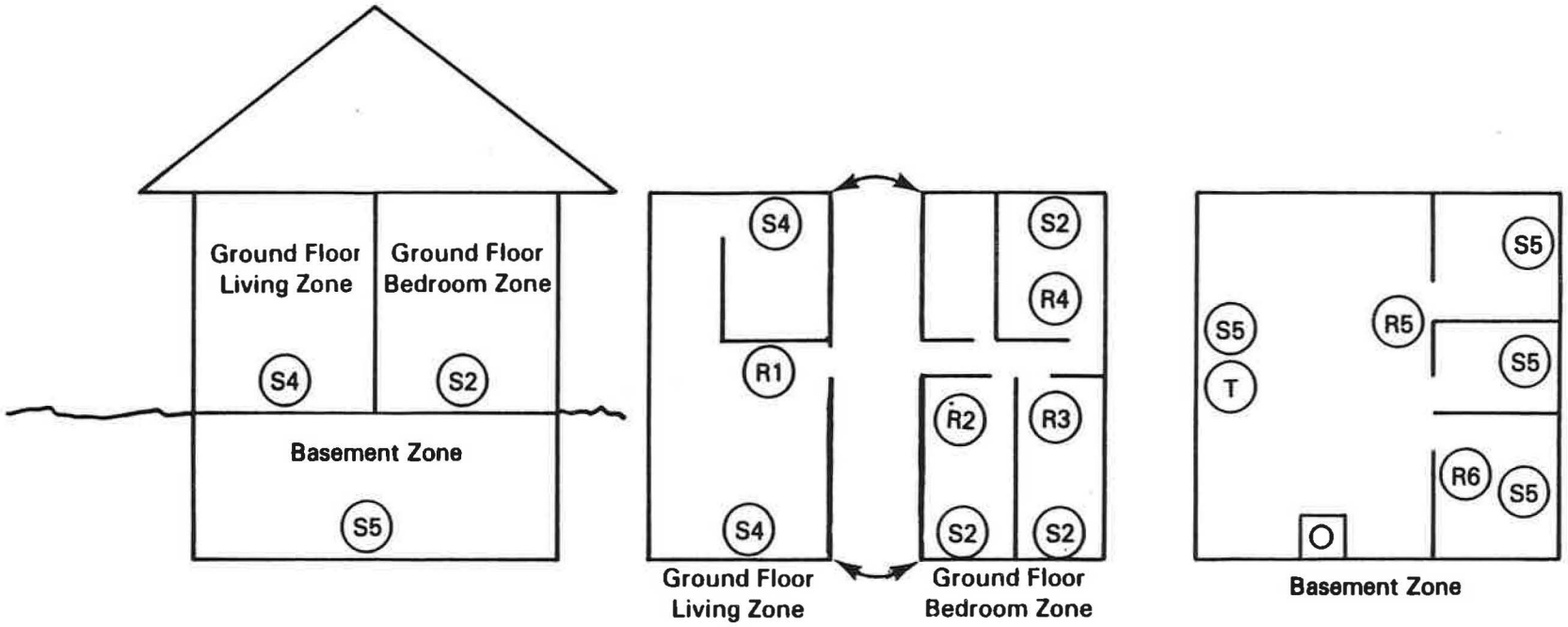

FIGURE B.3. PFT Placement Scheme For a 1 Level Home With a Basement

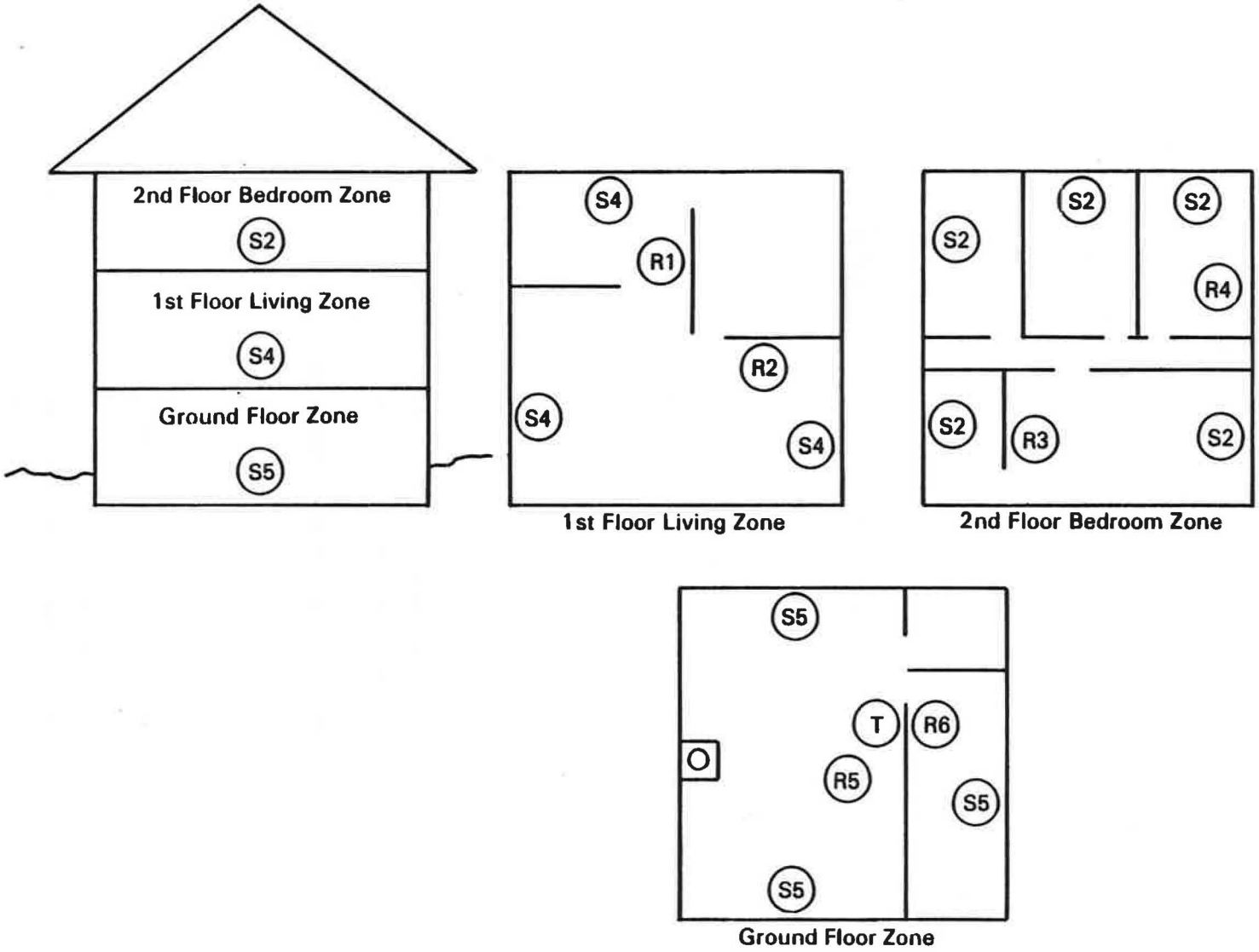

FIGURE B.4. PFT Placement Strategy For a Home With 2 Levels Above the Ground Floor

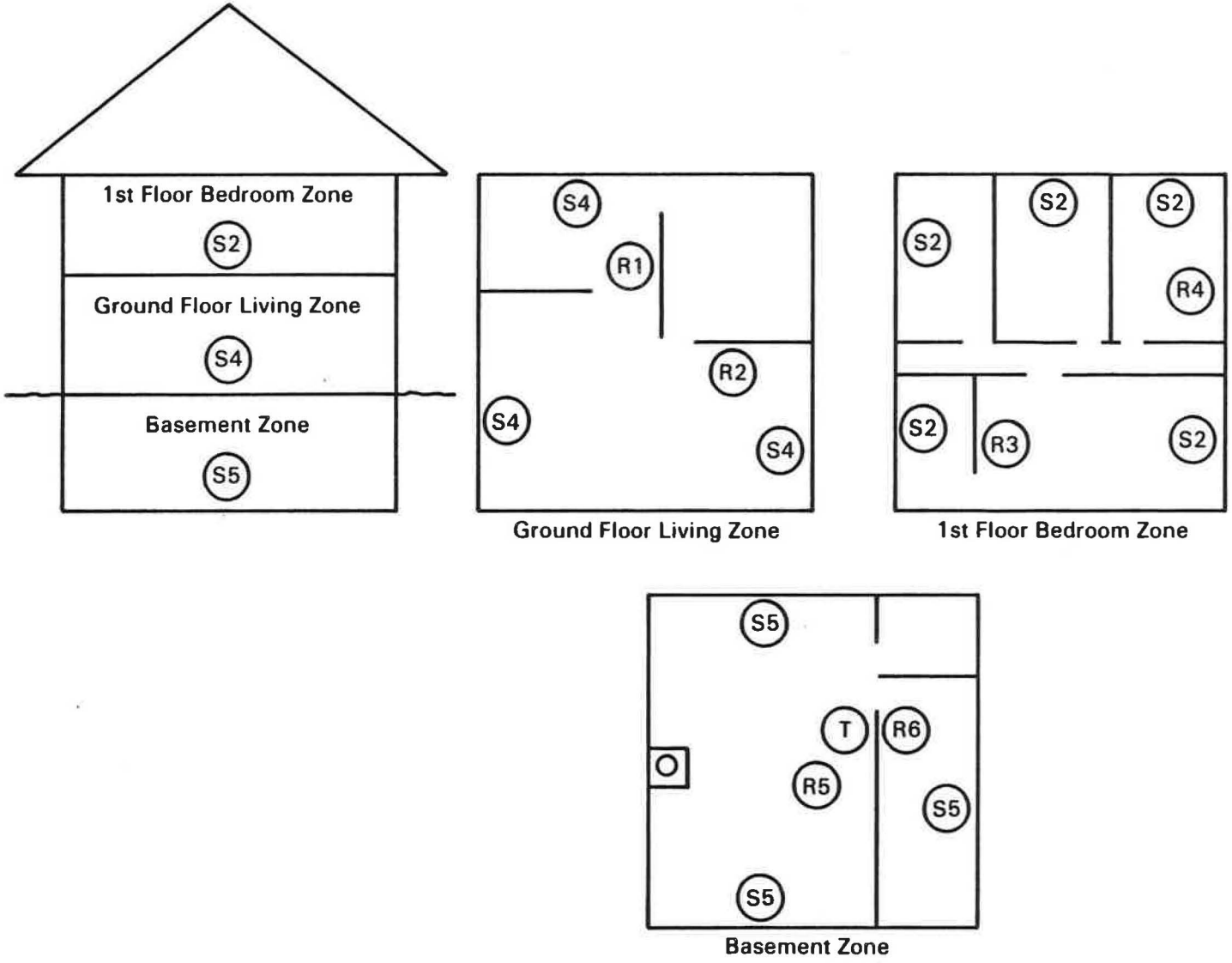

FIGURE B.5. PFT Placement Strategy For a Home With 1 Level Above the Ground Floor and With a Basement

Rats Deployment

An average of five RATS will be deployed in each home. Generally, the larger the home, the greater the number of RATS used. In some homes, we will deploy one or two additional RATS but not uncap them to examine leakiness of the caps. In a few selected homes, we will deploy RATS in replicate pairs and send one RATS to BNL for analysis as a quality check. The actual deployment strategy for these special cases will be coordinated with the blower door specialists.

The following RATS deployment strategy applies to all homes in the study including the special study homes to be tested during the 1988/1989 heating season.

- A minimum of one RATS will be placed in every zone of the home.
- A minimum of two RATS will be placed in large zones (>500 ft^2) spatially separated.
- approximately two to three RATS will be placed in the bedroom zone, one each in two rooms (one room likely the master bedroom).
- No RATS will be placed in rooms that are closed off during the day. (RATS are, however, placed in basements even if they are closed off during the day - see first deployment principle above.)

Rats Locations

RATS are placed in a foam holder and hung from the ceiling using a tack punched through the string that is glued to the holder. Each foam holder is capable of holding two RATS.

The following guidelines are to be followed for locating the RATS in the homes. The final decision on RATS locations is up to the specialist in agreement with the resident.

- RATS should not be placed near (< 5 ft) a PFT source capsule.
- RATS should be hung in a central part of the zone.
- RATS should be hung at least 8 in. from the wall and no closer than 5 ft. from a vent/grill, window, or exterior door.

PRINCIPLES FOR TEMPERATURE RECORDER DEPLOYMENT

Each blower door field specialist will be given several credit card size battery-operated temperature recorders to be used in homes to record time series temperature data during the time of the PFT test. The emission rate of the PFT sources is temperature dependent, and therefore, it is important to know (record) the average temperature in zones of homes that will experience wide diurnal fluctuations in temperature during the time of the PFT test.

A limited number of recorders are available for the study and therefore recorders cannot be placed in all homes. The recorders can be reused and will be returned to the specialist for reuse once the data from a home is extracted from the recorder. The following principles apply for temperature recorder deployment.

- Generally only one recorder should be deployed in a home.
- The recorder should be placed in a zone of a home that experiences the greatest range of diurnal temperatures. These include zones that are heated with wood (especially if the wood stove is allowed to die out overnight), and homes that have a central HVAC system and the residents use the setback feature on the thermostat. (Note that heat pump homes will not normally use the set back feature.)

Temperature Recorder Locations

All the recorders are equipped with magnetic strips on the back and can therefore be mounted on magnetic material. In most cases this will not be possible and other "secure" locations must be found. The poster putty supplied for the sources can be used to securely mount the recorder. The following guidelines apply:

- Locate the recorder near (< 5 ft) the source in that zone if only one source capsule is used. If more than one source capsule is used in the zone, locate the recorder in a central area of the zone.
- Place the recorder in any position, but at the same elevation as the source(s).
- Secure the recorder and place away from children and pets.

- Do not place the source on the recorder. We do not want the resident to mail the source with the recorder.
- Place the recorder on or near the set-back thermostat if locating in the zone with the thermostat.

DEPLOYMENT TACTICS

The blower door subcontractor field specialists will be trained by Battelle in PFT placement and recovery principles and tactics during the prefield tests in late October, 1987.

For the field study, the field specialists will be supplied sufficient number of sources, RATS, holders, forms, and mailers for the homes they will be testing, prior to entering the field. The sources will be shipped and stored in metal tins labeled with the source code. The sources should be kept at room temperature at all times by the field specialists. This includes overnight; the sources are taken inside at the end of each day. This is to insure that the sources maintain an equilibrium emission rate at near typical home temperatures at all times.

The RATS will be supplied in special holders to avoid possible breakage. Activated charcoal will be supplied in each holder to absorb any fugitive PFT. The sources and RATS will never be shipped or stored in the same environment. During transport in an automobile, the sources should be kept in the passenger compartment and the RATS kept in the hood or in the pickup bed, but never in the trunk or in the back end of a van.

Source Placement

The field specialist carries (in their pocket) several sources of each type into the home immediately upon arrival. The sources are placed (according to the principles above) in the appropriate locations during the completion of the Structure Measurement and Sketches Form (see Appendix A). The location of each source in each zone is recorded by an S followed by the Type number circled on the Structure Measurement and Sketches form. Locations of each source and type will also be recorded on the PFT Data Sheet (see Appendix A). All sources are returned to the vehicle prior to performing the blower door test.

Temperature Recorder Placement

The temperature recorder is placed (if needed) at the same time that the sources are deployed. The recorder is switched on by the field specialist and the specialist records the location with a "T" inside a circle on the structure measurement and sketches. The ID number and location of the recorder is also recorded on the PFT Data Sheet in the appropriate zone.

Rats Placement

The RATS will be brought into the home after the blower door test is completed. The RATS will be placed in the zones according the strategy given above. The field specialist will record the location of each RATS on the Structure Measurement and Sketches with an R followed by an arbitrarily assigned number and circled. This "R" number is written on the Short Form (see Appendix A).

This single character "R" number is independent from the four-digit the ID number etched on each RATS. The four-digit RATS ID number and location is recorded for each zone on the PFT Data Sheet by the field specialist.

Each RATS is uncapped at one end (the numbered end with red cap and sleeve) at the time of deployment. The red cap is pushed a short distance up the tube to clear the cap end from the end of the tube. The date and time of uncapping is recorded on the PFT Data Sheet. Since all the RATS are normally uncapped within one-half hour of one another, only one uncap time needs to be recorded for all the RATS on the PFT Data Sheet. This same uncap date and time is recorded on the Short Form that is left with the resident. See Figures B.1 to B.5 for typical house diagrams showing sources, RATS and temperature recorder locations.

SOURCES, RATS, AND TEMPERATURE RECORDER RECOVERY TACTICS

The uncapped RATS are left in the home for 2 to 4 weeks. At the end of this time period, Battelle will contact the resident by telephone and request that the RATS be taken down, capped and mailed to Battelle in the mailer left by the field specialist.

The resident will also be asked to record the date and time of recovery and capping on the Short Form and include it in the mailer. If the resident is contacted at home, we will request the resident, if possible, cap the tubes and place them in the mailer while we remain on the phone in order to aid them in any way. With this procedure, we can make sure that the correct number of RATS are capped and collected since we will have a record of number and location of the RATS. We will, at this time, likewise record the date and time of capping on the PFT Data Sheet that was returned in the booklet by the field specialist.

The capped tubes will remain in the foam holder offering an extra measure of cushion during transport. Each mailer will contain a small charcoal filter to absorb any fugitive PFT vapor that may come in contact with the mailer.

The resident will also be requested to mail the temperature recorder in the mailer used for the RATS. The resident will not need to turn the recorder off prior to mailing.

The recorder will be read by Battelle immediately upon receipt at the Laboratory and used for the PFT air exchange rate analysis. The average source temperature over the time period that the RATS were uncapped will be entered on the PFT Data Sheet. The record of temperature will be saved on a diskette and the recorder reset. The recorder will be immediately mailed back to the field specialist for reuse.

Once the RATS are received at the Laboratory, they are logged into the PFT Air Exchange Rate Analysis program and submitted for analysis. The PFT laboratory analysis (see Appendix A) is returned to the Battelle data analyst and the final PFT analysis data entered into the PFT Air Exchange Rate Analysis program. The PFT air exchange rate and flow numbers are then entered into the database.

The resident will be instructed to return the sources at the end of experiment, or sooner, if needed. We will provide mailers for the sources that contain charcoal packets to absorb PFT released from the sources during mailing. In order to avoid contamination with the RATS, the sources will be mailed to a Battelle staff member's home.

TACTICS FOR SPECIAL STUDY HOMES

Approximately 25 homes will be selected to participate in a special study during the 1988/1989 heating season. This study will involve two blower door tests (before and after the PFT tests) and 2 to 4 week PFT tests for several consecutive weeks. These tactics may be modified based on the results and evaluation of the testing during the first heating season. A detailed description of the special study protocol is presented in Appendix D.

The principles and tactics given above are the same for special study homes except for the following modifications:

- Field specialists will leave sufficient RATS for the entire measurement period (12 to 16 weeks) with the resident. These RATS will separated into discreet packages and labeled as test 1, 2, 3, etc. A package will be used for each measurement period.
- The resident will store the RATS outside the conditioned space. The RATS will be stored with activated charcoal to absorb any fugitive PFT. Spare RATS will be included in each package in case of breakage. These spare RATS will remain capped (unless used) and will be returned with each package. The spare tubes will be analyzed as a check for possible contamination.
- At a minimum, the RATS are placed in pairs at each sampling location in each zone. One of the RATS of the pair will remain for the entire measurement period; the other RATS in each pair will be replaced every 2 to 4 weeks. The RATS to be left in the holders the entire time will be taped to the holder by the field specialist so that the resident cannot easily remove them during the measurement period.
- The resident will receive special instructions from the specialist concerning placement and recovery of RATS. The PFT Data Sheet for the first measurement period will be filled out by the field specialist. Subsequent PFT Data Sheets will be filled out by the resident. The field specialist will instruct the resident how to fill out the data sheets.
- Battelle will notify the resident each time the RATS are to be replaced, capped, and mailed. The capped RATS will be mailed to Battelle immediately after recovery.

- Temperature recorders will likely be used in the special study homes. Recorders will be left in the home the entire 12 to 16 week measurement period. They will be mailed to Battelle at the end of the measurement period and we will recover, record and analyze the temperature data. We will not wait for this temperature data to perform the sample tube chemical analysis; however, the PFT air exchange rate analysis will not be completed until the interior temperature data is available at the end of the measurement period.

REFERENCES

Dietz, R. N. 1986. Instructions: Brookhaven Air Infiltration Measurement System. Brookhaven National Laboratory; Upton, New York.

Dietz, R. N., Goodrich, R. W., E. A., Cote, and Wieser, R. F. 1985. Detailed Description and Performance of a Passive Perfluorocarbon Tracer System For Building Ventilation and Air Exchange. BNL 36327; Brookhaven National Laboratory; Upton, New York.

APPENDIX C

BLOWER DOOR TEST PROTOCOL

APPENDIX C

BLOWER DOOR TEST PROTOCOL

This Appendix describes the protocol to be used in conducting fan pressurization (blower door) tests for the NORIS Project. These procedures are based on the American Society for Testing and Materials (ASTM) Standard Test Method E779-87 Determining Air Leakage Rate by Fan Pressurization (attached). Salient features of the Standard Test Method that are of particular importance to NORIS include:

- The acceptable test apparatus and the required accuracy of instrumentation (Section 6).
- The preferred meteorological conditions indicating wind speed not to be greater than 4 mph and ambient temperature not less than 35°F (Sections 8 and 12).
- The procedures for preparation of the building envelope and HVAC system. Interconnecting doors will be open and closet doors closed. HVAC dampers and registers will not be adjusted. Fireplace dampers will be closed but not sealed. Exhaust fans will likewise not be sealed unless they have a functioning damper.
- A definition of the building volume that is included in the calculation of air change rate. Interior volume is defined as conditioned space, generally excluding attics, basements, and garages, unless the spaces are connected to the heating and air conditioning system (Sections 3 and 4).
- The equations for the calculation of leakage area (Section 9). The assumed reference pressure for Effective Leakage Area (ELA) calculation is 4 Pa. This calculation will be performed by Battelle using blower door raw data.

Certain deviations from ASTM E779-87 are recommended due to the number of homes to be tested and the inclusion of PFT measurements in this study. Generally requirements will be as stringent as those in the Standard.

Exceptions or extensions to ASTM E779-87 for this study are:

- Only blower doors manufactured by a recognized, reputable manufacturer will be allowed. All blower doors used will be of the orifice flow measurement type; no RPM type blower doors will be used.
- Blower door tests may occasionally be performed under other than the preferred wind and temperature conditions. The field specialist will be advised to avoid driving to the home on windy days, but once at the site, they will perform the blower door test and deploy PFT materials regardless of weather conditions. Onsite wind speed and temperature will be recorded on the Blower Door Test form (see Appendix A), and arrangements for a second test will be made if test conditions were unfavorable. The second test will be performed at the time of PFT test equipment recovery and the more accurate test data will be entered into the database.
- All raw data will be kept in the database and the calculation of C and n will be performed within the database by Battelle. The ELA will likewise be calculated in the database using the Lawrence Berkeley Laboratory (LBL) model.
- All flow data will be corrected to standard conditions using on-site temperature and uncorrected station pressure data. Battelle will determine the actual station pressure for the day of the testing from other sources of information. The specialist will record the value used in their onsite calculations.
- The indoor temperature used to calculate air density for the test will be the average of the temperatures in the various house (PFT) zones. These temperatures, as well as outdoor temperature and wind speed, will be measured once, before flow and pressure data are taken. Relative humidity and wind direction will not be measured as they are not required in any calculation.
- Test accuracy will be based on the correlation coefficient. A correlation coefficient of 0.998 or higher will be sought as determined from onsite program analysis results. If not attained, the test will is repeated. No more than two tests are conducted.

- Target test pressures will range logrithmically from 12.5 Pa to 60 Pa (0.06-0.24 in.) rather than 12.5 to 75 Pa as recommended by ASTM. The target pressures in the range are only guidelines; the specialist will record the actual pressures attained at the time of the test(s). A minimum of eight flow data points are taken.
- Both depressurization and pressurization tests will be performed. However, on some occasions, it may be impossible to perform a depressurization test required by ASTM E779-87, due to the risk of entraining wood ashes into the home. In this case, only a pressurization test will be performed.
- Duct work leakage will be measured in selected homes with centrally-ducted systems. This is done during the depressurization test only.
- The test report will not include all of the information listed in Section 10 of the Standard. Specifically, Sections 10.1.1.2 Condition of Openings in Exterior Shell, 10.1.1.3 HVAC System, and 10.1.2 Pressurization Measurements will be modified for this study. The information sought in these sections of the Standard is not used in any calculation and cannot be readily entered into a numerical database.
- The data recorded for each home will include a considerable amount of information beyond that required by the Standard. All parameters (raw data) needed to estimate the seasonal ACH using the LBL model will be recorded. Specialists will be trained to recognize and identify the local shielding and terrain coefficients for the LBL model.
- Because of the time and cost limitations, it is not possible to use a smokestick to determine the leakage distribution in the structure between the floor, wall and ceiling. Instead, the specialist will record four to five greatest leakage locations in the home on the Blower Door Test form based on their best professional judgement. Battelle will assign leakage values for the modeling.
- The natural pressure differential across the building envelope will be measured and recorded before beginning the fan testing.

APPENDIX D

SPECIAL STUDIES PROTOCOL

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SPECIAL STUDIES PROTOCOL

A special study will be conducted by Battelle as part of NORIS that involves measuring the air exchange rate for an entire heating season (4 to 6 months) in approximately 25 homes in the region. The air exchange rate will be measured using the PFT technique in each home for consecutive 2 to 4 week periods. Coincidentally, a single PFT measurement will be made in each home for the entire heating season. In addition, a blower door test will be conducted on the home at the start of the PFT measurements and at the end of the PFT measurements.

The purpose of this study is to examine the potential variations in air exchange rate over a heating season and evaluate the reliability of a one-time 2 to 4 week measurement to characterize the average heating season air exchange rate of a residence.

HOME SELECTION

The homes for this study will be selected from among the approximately 235 randomly-selected homes participating in the field study over the 1987/1988, and 1988/1989 heating seasons. The homes will be chosen from the Category 1 and 2 homes, and be distributed throughout the region. It may be desirable that these homes be selected near a weather station (preferably an ELCAP station) to assure representative weather data for the sites.

Approximately 20 of the homes will be Category 1 (current practice) homes and five of the homes will be Category 2 (MCS) homes. The sampling procedure for the special study homes will be developed after all homes for the first year's study have been selected, measurements initiated and data examined. It is expected that the sample for the special study will include homes in each state representing different heating system types, vintage, and architecture. The sample of homes in the special study will, however, primarily depend upon willingness of the resident to volunteer to participate.

TESTING PERIOD

The homes for the special study will be tested starting approximately November 1, 1988, and will continue to be tested until April 15, 1989. Both Category 1 and 2 homes will be tested simultaneously in the special study.

PROCEDURES

The field protocol for the special study homes will follow the field protocol for the large field study with the following modifications.

- Each home will be blower door tested at the end of the PFT measurements, as well as, at the start of the PFT measurements.
- The blower door specialists will leave a sufficient number of sample tubes (RATS) for the entire heating season with the resident. These tubes will be separated into packages and labeled as Test 1, 2, 3, etc. A package will be used for each measurement period.
- The resident will store the RATS outside the home, if possible. The RATS are stored with activated carbon to absorb any fugitive PFT. Spare tubes will be included in each package along with "spiked" and "blank" RATS that are not to be deployed. The spiked and blank RATS will be returned to Battelle for analysis along with the exposed sample tubes.
- The RATS will be placed in pairs at each sampling location in each zone of the home. One of the RATS will remain for the entire heating season; the other sample tube will be replaced every 2 to 4 weeks throughout the heating season. The RATS to be left in the holder for the entire heating season will be taped to the holder so that the resident cannot easily remove them during the measurement period. At the end of the heating season, all the RATS remaining in the home will be returned for analysis.
- The resident will be requested to place and recover RATS and mail exposed RATS to Battelle each measurement period. Battelle will notify the resident each time the tubes are to be recovered and new tubes deployed. PFT deployment and recovery procedures for special study homes are described in Appendix B. The blower door specialists will be required to explain these procedures and supply the resident with forms and mailers.

The PFT Data Sheet for the first measurement period will be filled out by the specialist. Subsequent PFT Data Sheets will be filled out by the resident each time RATS are recovered and deployed.

- The occupants will be requested to complete an Occupant Activity Record each measurement period and mail these to Battelle with the exposed RATS.
- A temperature recorder will be placed in each special study home and left for the entire time period of the measurement (the entire heating season). This will enable more accurate determination of PFT source rate over the measurement period.

DATA

The data from the special study will be examined and delivered to IDWR according to the schedule for the data for the large field study.

APPENDIX E

DATABASE FEATURES

APPENDIX E

DATABASE FEATURES

The data for the project will be stored in a Lotus 1-2-3^{R} work sheet and needed calculations performed within the work sheet itself. It is expected that the data will ultimately be analyzed using Lotus as well, though it may be necessary or desirable for certain statistical functions to use a different software package. Lotus allows output of an ASC11 file compatible with other applications. All data will be stored on a 5-1/4 in. diskette. The database will include information from seven sources:

- Telephone Survey/Cooperative Agreement
- Homeowner Survey and Walkthrough Survey
- Structural Measurements and Sketches
- Meteorological Data and Exterior Building Parameters
- Blower Door Test
- PFT Data Sheet
- PFT Air Exchange Rate Analysis
- Occupant Activity Record.

The data will be entered in this order to facilitate data entry. Any desired rearrangement can be easily done with Lotus. All of the data will be in a numerical format suitable for such statistical functions as mean, standard deviation, linear and nonlinear regression, graphing, and frequency. Numbers will be separated by two or more blanks, depending on the number of digits in the value. Values will be right justified in each field (column) and no extraneous zeroes added. To illustrate, the number 9909 in a field seven spaces wide will be stored as bb9909b, where b indicates a blank space.

Missing data will be entered as a -99. These values will be stripped from the database when calculating averages, statistical functions, (regressions) or analysis with other software. An example of missing data likely to occur

is a nonexistent building parameter such as the basement volume of a home without a basement.

HOUSE NUMBERING SYSTEM

The first field (column "A") of the database will contain the house ID number according to the following project house numbering system. Battelle will assign the last three digits of the ID number, the first five digits are generated from the study and house location/characteristics.

1. Position 1: Number(s): 5
   5 is used to identify the program (NORIS)

2. Position 2: Number(s): 1 to 8
   Used to identify state and climate zones i.e., Idaho is 1, 2 or 3; Montana is 4; Oregon is 5 or 6 and Washington is 7 or 8.

3. Position 3: Number(s): 1 to 5
   Used to identify house category i.e.:
   - 1 is 1980 Current Practice homes
   - 2 is New "1987" MCS homes
   - 3 to 5 is currently unused.

4. Position 4: Number(s): 1 to 6
   Used to identify house type:
   - 1 is single level no basement
   - 2 is multilevel no basement
   - 3 is single level with conditioned basement
   - 4 is multilevel with conditioned basement
   - 5 is single level with unconditioned basement
   - 6 is multilevel with unconditioned basement.

5. Position 5: Number(s): 1 to 4
   Used to identify electric heating system type installed:
   - 1 is zoned active

- 2 is zoned passive
- 3 is central forced air furnace
- 4 is heat pump.

6. Positions 6, 7 and 8: Number(s): 1 to 998
   Individual house number.
   These numbers will run consecutively with no repeat.

SUMMARY OF REMAINING DATA ENTRIES

Column B in the database will contain the date of the blower door test in a yy-mm-dd format (e.g., 880101 for Jan. 1, 1988). This format facilitates regression or sorting on the column, which may be useful in analyzing data bias. The next four columns will contain component values of the ID number as individual entries. Climate zone, house category, house type, and heating system type will be repeated here to allow easy analysis. Other pertinent numerical data (undefined at this stage) will appear in the next six columns.

The next major sections of the database will contain information from the Homeowner Survey (12 columns) and building characteristics gathered by the technician during the Walkthrough Survey and Structure Measurement and Sketches (24 columns). This will include zone temperatures and volumes to be used in the calculations of air change rates.

Data from the Meteorological Data and Exterior Building Parameters taken at the time of the blower door test and TMY meteorological data will occupy the next eight columns.

The final portion of the database will consist of calculated values of ELA and air exchange rates. ELA will be calculated for both 4 Pa and 50 Pa flows (average of pressurization and depressurization) determined from the regression equations created from the blower door raw data.

All parameters needed for the LBL infiltration model will be entered into the database from the field data. These parameters will also be appended to a program that will calculate the LBL air exchange rate. However, raw data from the blower door test will <u>not</u> be entered into the database; rather, linear regression of the logarithms of flow and pressure will be performed from the

raw blower door data and stored as a separate file for each home. The database will include only the regression coefficients n and C (slope and intercept, respectively), r-squared correlation coefficient, regional terrain, local shielding, weather station terrain, and building height. All flows will be corrected to standard conditions.

PFT raw data will include the RATS 4-digit ID number, date and time of recovery, date and time of deployment, number of zones and sources of each type in each zone, and temperature in each zone.

Blower door seasonal change air change rates and PFT air exchange rates are the last entries into the database. The LBL air exchange rates are calculated using the LBL algorithm using TMY data for that site, and also using representative (local) meteorological data during the time of the PFT test. The meteorology used to calculate these numbers will be acquired from a nearby meteorology site and will be retained as raw data in the LBL air exchange programs whether it is average, monthly, or hourly data.

Intermediate calculations will be displayed if they are useful for quality assurance purposes. It may be prudent to repeat the calculated air change rates near the beginning of each row (near the house ID number) for ease in performing data analysis.

APPENDIX F

LABORATORY ANALYSIS OF PERFLUOROCARBON TRACERS COLLECTED WITH ADSORPTION TUBE SAMPLERS

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LABORATORY ANALYSIS OF PERFLUOROCARBON TRACERS COLLECTED WITH ADSORPTION TUBE SAMPLERS

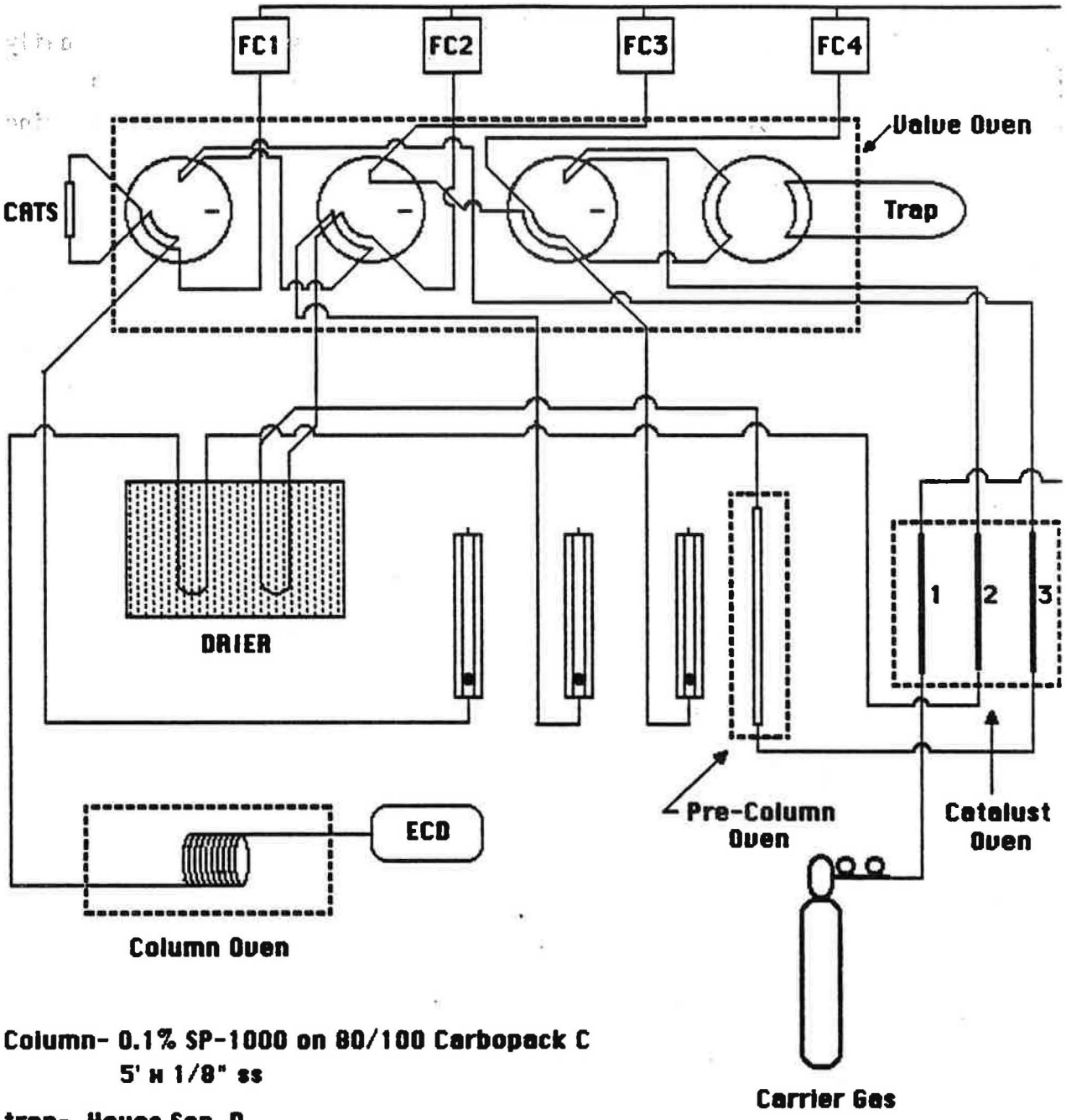
Perfluorocarbon tracer (PFT) samples are analyzed using a dedicated gas chromatographic system consisting of an especially designed sample injection module interfaced with a gas chromatograph equipped with an electron capture detector (ECD). Samples, collected on tubes containing Ambersorb adsorbent, are capped at the end of the sampling interval and returned to the laboratory for analysis. Following receipt by the laboratory, samples are logged in, labeled for identification and placed at a location reserved for sample storage. the storage location is maintained at room temperature and is isolated from activities which might contribute inadvertent exposure to potential contaminants. Sample analysis is completed within three weeks of receipt.

CHROMATOGRAPHIC SYSTEM

The laboratory chromatograph utilizes a Shimadzu Model CR-3A Recording Data Processor to record and print sample reports. Reports, generated at the time of analysis, include chromatograms and measure peak areas and retention times. The detector signal is also recorded on floppy disk for reanalysis and processing.

A schematic of the gas chromatographic system is shown in Figure F.1. Specific operational parameters employed for analysis are listed in Table F.1. Analyzer calibration is conducted using gas mixtures prepared for the ANATEX (Across North America Tracer Experiment) study. These mixtures contain perfluoromethylcyclopentane (PMCP), perfluoromethylcyclohexane (PMCH), ortho-perfluorodimethylcyclohexane (O-PDCH), para-perfluorodimethylcyclohexane (p-PDCH) and perfluorotrimethylcyclohexane (PTCH). Nominal concentrations are 1 ppt, 100 ppt, 10 ppb and 1 ppm. Clean, purged sample tubes are spiked with a measured volume of a standard gas mixture to generate calibration curves (pl PFT vs. peak area) for the respective tracers. Calibration standards are

prepared over the PFT range observed with field samples and are analyzed daily (approximately 1 standard per 10 field samples) to monitor and correct for small changes in analyzer performance. A representative chromatogram, obtained for a spiked sample is shown in Figure F.2.



Column- 0.1% SP-1000 on 80/100 Carbopack C
5' x 1/8" ss

trap- Hayes Sep. D

Catalyst- 5% Pd on 30/35 Molecular Sieve

FIGURE F.1. Schematic of Gas Chromatograph for PFT Analysis

TABLE F.1. Operational Parameters for PFT Analysis

Column- 01.%SP-1000 on 80/100 Carbopack C (max. temp. 225°)
5' x 1/8" OD ss column, M968094, (Cat. No. 1-2-537)

Carrier Gas- 5%H_2 in N_2, ~21 cc/min, 50 psi

Actuator gas- nitrogen or air, 60 psi

Temperature Zones-

#1- valve oven	140°
#2- catalyst	200°
#3- trap desorb	250°
#4- pre-column	150°
#5- column	150°
#6- ECD	200°

Flow Controls

FC-1	100
FC-2	300
FC-3	070
FC-4	300

Valve Timing

Interval 1-	40 seconds
Interval 2-	6.5 minutes
Interval 3-	60 seconds
Interval 4-	6.0 minutes

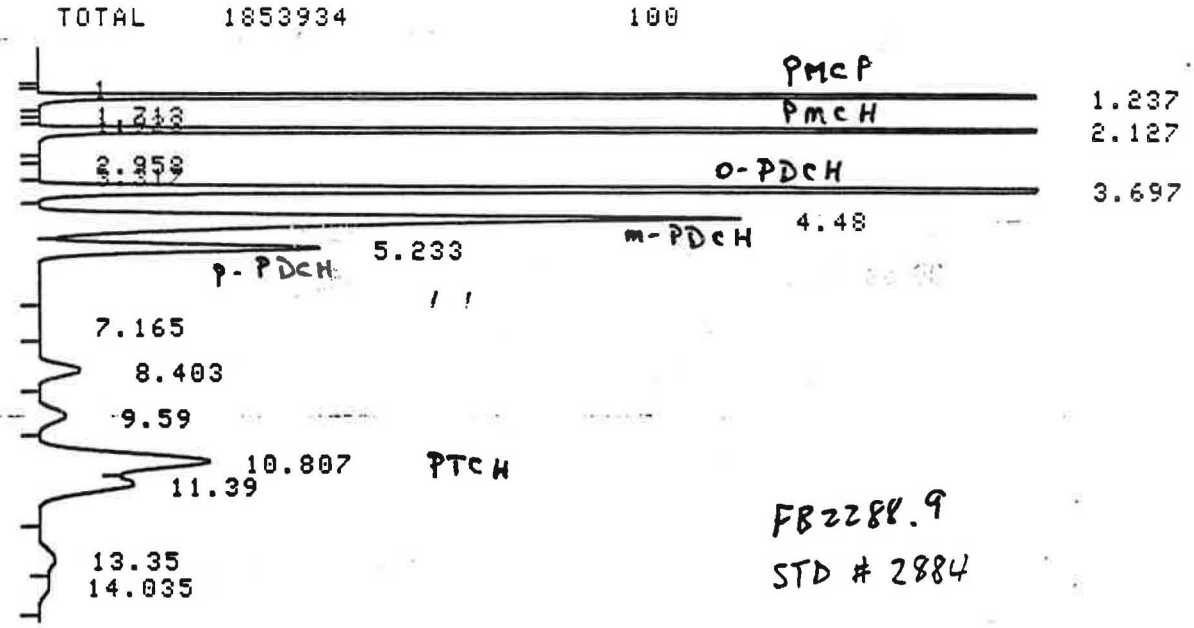


FIGURE F.2. Sample PFT Chromatogram

SAMPLE ANALYSIS

Sample analysis is conducted by inserting the adsorption tube in the carrier gas stream of the gas chromatograph and heating to approximately 400°C via resistance heating with a 10-turn nichrom wire. PFTs released to the carrier are reconcentrated on a second adsorption trap before thermal desorption and injection for gas chromatographic analysis.

The quantities of the respective tracers in field samples are calculated from calibration curves developed from multi-point calibrations spanning the range from about 10 to 1500 picoliters[a]. As indicated above, daily checks are conducted with spiked samples to demonstrate consistent chromatograph performance and calibration curves are updated as required. Tracer loading on tubes returned from the field (expressed in pL) are recorded on the BNW-PFT Analysis Sheet (see Figure F.3) and the results submitted to the Data Analyst for inclusion in the NORIS data base.

(a) $pL = 1\text{-}12v/v$

Date ___/___/___ Page _____ of _____

Analyst _____

System Operating Conditions

Carrier:
Cyl. ID:
Pressure:
FC1:
FC2:
FC3:
FC4:

-Zone Temperatures-
Trap Desorb.:
Catalyst:
Pre-column:
Column:
ECD:

-Analysis Cycle-
Step 1: min.
Step 2: min.
Step 3: min.
Step 4: min.

Carrier Flow: cc/min

Column ID:
Trap ID:

Calib. Standards

Inject. No.	Data File	CATS ID	Std. Vol., cc

Diluent Gas _____
Cylinder ID _____
Diluent Flow _____
Perm. Oven Temp. _____

Perm. Tube ID _____, ng/min
_____, ng/min
_____, ng/min

Notebook Ref. _____

Sample Analysis

Injection #	Data File	Sample ID #	Injection #	Data File	Sample ID #

FIGURE F.3. PFT Laboratory Analysis Form