




Montana Asbestos-Safe Weatherization Demonstration Project

Final Report - June 30, 2010

Funded By:
Residential Energy Assistance Challenge Program (REACH)
Low Income Home Energy Assistance Program
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Grant Recipient:
Montana Department of Public Health and Human Services
Intergovernmental Human Services Bureau
Contact: Kane Quenemoen, HRDC Services Section Chief

Prime Grant Administrator:
National Center for Appropriate Technology
Contact: Dale Horton, Sustainable Energy Program Manager

Asbestos Testing and Monitoring Contractor:
Montana Tech of the University of Montana Safety Health & Industrial Hygiene Dept.
Contact: Dr. Terry Spear, Department Head

Evaluation Contractor:
Montana State University Housing and Environmental Health Program
Contact: Barb Allen, Program Manager
Note: The evaluation report is submitted under separate cover.

Acknowledgements and Contact Information

This project grew from a desire on the part of several weatherization agencies in Montana to provide weatherization services, despite the presence of asbestos in the home. The District XII Human Resource Council in Butte; District XI Human Resource Council, Inc. in Missoula; Northwest Montana Human Resources, Inc. in Kalispell; National Center for Appropriate Technology (NCAT); and Montana State University Extension Housing and Environmental Health Program were heavily involved in the early planning of the project. NCAT developed the project proposal and was the primary implementation contractor. The Montana Department of Public Health and Human Services was instrumental in supporting the development and implementation of the project.

Key partners and their roles:

Montana Department of Public Health and Human Services
Intergovernmental Human Services Bureau
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P.O. Box 202956
Helena, MT 59620-2956
Phone: 406-447-4267

The Montana Department of Public Health and Human Services, Intergovernmental Human Services Bureau, is the grant recipient and was responsible for project oversight. Jim Nolan is the Bureau Chief. Kane Quenemoen, Human Resource Development Councils Services Section Chief, was the primary contact for the project.

National Center for Appropriate Technology
P.O. Box 3838
Butte, MT 59702
Phone: 406-494-4572

NCAT served as project administrator. NCAT was responsible for day-to-day administration of all project activities, including contracting with the Human Resource Development Councils, subcontractors and other project partners; preparing budgets; submitting project and financial reports; coordinating meetings; tracking project progress; recruiting project participants; developing project implementation procedures; and assisting with developing asbestos weatherization protocols resulting from lessons learned during the project. NCAT worked closely with Montana Department of Public Health and Human Services and other project partners to ensure that all project deliverables were met. Dale Horton, Sustainable Energy Program Manager, was responsible for overseeing the project. Cathy Svejkovsky was the person who held the project team together. She usually had the toughest jobs.

Human Resource Development Councils
The grant provided funds to the project's three Human Resource Development Councils

to deliver services under this project. The three, identified below, are currently Montana Department of Public Health and Human Services sub-grantees for the Low Income Home Energy Assistance Program, the Department of Energy Weatherization Assistance Program and the Community Services Block Grant.

- **District XII Human Resource Council in Butte, Montana**
  P.O. Box 3486
  700 Casey Street, South Entrance
  Butte, MT 59701
  Phone: 406-496-4975
  Serving Beaverhead, Deerlodge, Granite, Madison, Powell and Silver Bow counties
  Dan Wood, District Energy Auditor

- **District XI Human Resource Council, Inc., in Missoula**
  1801 S. Higgins
  Missoula, MT 59801
  Phone: 406-728-3710
  Serving Mineral, Missoula and Ravalli counties
  Jim Morton, Executive Director
  Jim Wilson, Energy Conservation Programs Director

- **Northwest Montana Human Resources, Inc., (NMHR) in Kalispell**
  214 Main Street
  P.O. Box 8300
  Kalispell, Montana 59904-1300
  Phone: 406-752-6565
  Serving Lake, Lincoln, Sanders and Flathead counties
  Douglas Rauthe, Executive Director
  Margie Jones, Weatherization Director

Special recognition goes to the District XII Human Resource Council (Butte), which volunteered to have staff trained as licensed asbestos supervisors in order to conduct weatherization in homes with asbestos. In addition, the District XII Human Resource Council weatherization crews traveled extensively in order to perform weatherization outside their own service area. Five District XII Human Resource Council employees underwent 40 hours of intensive training at the end of June 2008 to become certified as asbestos Contractor/Supervisors. This level of certification meets both State of Montana and OSHA requirements. The training was provided by BCI Consulting of Butte. Once training was complete and the workers certified, the HRC conducted all auditing and weatherization activities in participating homes.

It is worth noting that the District XII HRC has wide-ranging experience in the areas of health and safety, participating in collaborations that were beneficial to this Residential Energy Assistance Challenge Program project. For example, the HRC has partnered with the Butte-Silver Bow Health Department to develop procedures for weatherizing homes in the uptown Butte area that contain arsenic dust in their attics. The Health Department tests homes for arsenic dust; if found to be above a certain action level, the homes must be mitigated before weatherization can begin.

Montana Tech of the University of Montana
1300 W Park St
Butte, MT 59701
Phone: 406-496-4445

The Montana Tech team, led by Dr. Terry Spear, collected air and surface samples in participant homes, as well as personal breathing zone samples. Montana Tech also analyzed lab test results, refining sampling and weatherization procedures as necessary. Dr. Spear and his staff developed testing and monitoring procedures, and developed recommended protocols for asbestos weatherization activities. Julie Hart, CIH, Associate Professor, Safety Health and Industrial Hygiene at Montana Tech, assisted Dr. Spear and played a major role in developing testing and implementation protocols. Dr. Spear and Ms. Hart were assisted by five Montana Tech graduate students: Mohamed Elashheb, Tessa Spear, Molly Loushin, Kristopher Hutchings, and Natalie Shaw.

Dr. Spear has considerable experience and knowledge of weatherization activities, having worked closely with weatherization agencies while conducting weatherization-related research projects over the last several years. His first study, titled *Lead Exposure Associated with Weatherization Activities in Homes Containing Lead Based Paint,* evaluated both worker exposure and lead surface contamination in ten homes in Butte, Montana. A second study, titled *Characterization of Metals from Paint Wipes, Paint Chips, and Attic Wipes in Silver Bow County Homes,* evaluated the bioavailability of metals associated with lead-based-paint.

Montana State University Extension Service Housing and Environmental Health Program
P.O. Box 173580
Bozeman, MT 59717-3580
Phone: 406-994-3451

The Montana State University Extension Housing and Environmental Health Program served as Project Evaluator. Montana State University is the Montana Land-Grant University established in 1893. Since 1982, the MSU Extension Service Housing and Environmental Health Program has been involved with training of weatherization contractors and sub-grantees of the Montana Low-Income Weatherization program. In 1991, the MSU program, in partnership with the Montana Department of Public Health and Human Services, established weatherization training guidelines and certification criteria for the State of Montana. Since 1991, the MSU Extension Service has provided coordination and oversight of this training and certification initiative. Dr. Michael Vogel, Program Director, helped develop the proposal. Barb Allen, Program Manager, consulted on the project throughout and compiled the evaluation report. The evaluation report was submitted to the granting agency under separate cover.

The evaluation focused on the following elements:

- Review logic model of project and suggest refinements to project design and outcomes
- Develop home profile and quality assurance checklists based on project procedures developed for testing and monitoring personnel and implementation contractor
- Conduct post-project interviews with weatherization crews and asbestos facilitators
- Conduct quality assurance inspections
- Evaluate the project's education component
- Evaluate documentation and reporting

Dale Stephenson, PhD, Director of Environmental and Occupational Health Dept.
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Dr. Stephenson provided expert review and comment regarding baseline sampling, clearance criteria, proposed study procedures, and regulatory reporting requirements for asbestos containing materials. Dr. Stephenson also provided review and comment for the project's final report.

Montana Department of Environmental Quality Asbestos Control Program
1520 E. Sixth Avenue
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Helena, MT 59620-0901
Phone: 406-444-2690

The Asbestos Control Program is responsible for enforcing the Asbestos Control Act, the rules implementing the Act, including the U.S. Environmental Protection Agency National Emission Standards for Hazardous Air Pollutants regarding asbestos. John Podolinsky, Asbestos Program Lead, was very gracious in assisting with this project.

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List of Abbreviations

ACM	Asbestos Containing Materials
AHERA	Asbestos Hazard Emergency Response Act
AIHA	American Industrial Hygiene Association
AS	Analytical Sensitivity
ASTM	American Society for Testing and Materials
CC	Cubic Centimeters
ATSDR	Agency for Toxic Substances and Disease Registry
DPHHS	Montana Department of Public Health and Human Services
EPA	Environmental Protection Agency
f/cc	Fibers per cubic centimeter of air
HRDC	Human Resource Defense Council
LAAC	Licensed Asbestos Abatement Contractor
LOD	Limit of Detection
NCAT	National Center for Appropriate Technology
NIOSH	National Institute for Occupational Safety and Health
NMAM	NIOSH Manual of Analytical Methods
NVLAP	National Voluntary Laboratory Accreditation Program
OSHA	Occupational Safety and Health Administration
PBZ	Personal Breathing Zone
PCM	Phase Contrast Microscopy
PLM	Polarized Light Microscopy
PPE	Personal Protective Equipment
s/cc	Structures (asbestos) per cubic centimeter
s/cm2	Structures (asbestos) per square centimeter
s/mm2	Structures (asbestos) per square millimeter
SD	Standard Deviation
s/cm2	Structures (asbestos) per square centimeter surface area
s/cc	Structures (asbestos) per cubic centimeter of air
TEM	Transmission Electron Microscopy
TWA	Time Weighted Average
VAI	Vermiculite Attic Insulation

EXECUTIVE SUMMARY

The Montana Asbestos Safe Weatherization Demonstration Project accomplished two important goals: 1) to provide much-needed weatherization in low-income homes with asbestos; and 2) to develop, test, and refine draft protocols for safely weatherizing homes with asbestos based on extensive asbestos testing and monitoring. After the presence of asbestos was confirmed via bulk sampling in individual homes, the homes were tested for asbestos fibers in the living spaces before being fully weatherized.

The project weatherized 37 homes, less than was originally anticipated. The most significant factor influencing the lower number of homes weatherized was the number of homes that needed cleaning either prior to weatherization or after weatherization. This added significantly to the average cost to weatherize a house.

The original project work plan called for eliminating all homes from the project that were contaminated with asbestos above acceptable background levels, as determined by baseline testing. However, due to difficulty in finding participant homes, a licensed asbestos abatement contractor was hired to clean asbestos from some of the homes in order to allow the homes to continue in the project. Of the 37 homes weatherized, 22 required pre-weatherization asbestos decontamination cleaning. Costs for this asbestos cleaning ranged from $2,000 to $4,675 per house. The average cost was $3,400 per house.

District XII Human Resource Development Council in Butte volunteered to have their staff trained to perform asbestos work. Five of the Human Resource Development Council's staff received a week of asbestos training by a state-certified trainer and are now each certified as Asbestos Contractor Supervisors.

Project results revealed that performing weatherization measures has the potential to disturb asbestos-containing materials and disperse asbestos fibers into the living space. This presents a risk to weatherization workers and home occupants. The majority (79% and 67%, respectively) of high-volume air and personal breathing zone air samples from this study did not reveal detectable airborne concentrations of asbestos. However, enough test samples did reveal detectable concentrations that careful consideration should be given when performing weatherization work in homes with asbestos. Significantly, airborne asbestos was detected during numerous weatherization measures, suggesting that weatherization practices as a whole, not single weatherization activities, may contribute to the disturbance and dispersal of asbestos fibers into the air.

Other significant findings include:

- Baseline surface sampling revealed that the living spaces of the majority of homes in the study were contaminated with asbestos above acceptable background levels.

- The majority of participating homes with asbestos in either vermiculite or thermal system insulation needed to be cleaned for asbestos before weatherization activities began.

- The significant additional costs associated with weatherizing homes that contain asbestos in vermiculite or thermal system insulation are for asbestos testing and cleaning the living spaces.

- Testing of a limited number of wall cavities suggests that when a house has asbestos siding, the wall cavities will be contaminated with asbestos.

- There is a two- or three-day wait for Transmission Electron Microscopy (TEM) sample lab results. This added significantly to the length of time the occupants were required to be out of their house.

- When homes contained both vermiculite-containing asbestos from Libby, Montana, and thermal system insulation containing asbestos, living space contamination was almost always of the type associated with thermal system insulation.

- The living spaces of several houses were contaminated with chrysotile asbestos, despite no source of chrysotile asbestos being identified in the home.

- Keeping occupants from re-entering their homes prior to final clearance, despite their signed agreements to do so, was a major problem and will be a major logistical challenge with asbestos home weatherization efforts in the future.

- Weatherization agencies should use caution if they choose to blow wall insulation in homes with asbestos. Blowing wall insulation clearly has the potential to add asbestos fibers to living space air, regardless of the location and type of asbestos.

The Asbestos Safe Weatherization Protocols developed for this project include the following actions that are not currently included in weatherization practices:

- A comprehensive asbestos survey of the home
- Bulk sampling (already performed by some agencies) of all identified materials that potentially contain asbestos
- Baseline testing of potential living space contamination
- Cleaning homes where baseline testing reveals asbestos contamination above acceptable background levels
- Requiring house occupants to vacate house for the period of weatherization work from when the initial blower door test is conducted until the results of a satisfactory clearance test are known
- Removal and appropriate cleaning or disposal of belongings stored in areas contaminated by asbestos, commonly attics, basements and crawlspaces

- Personal Breathing Zone air sampling for weatherization workers
- Pre-blower door test attic bypass sealing
- Blower door test performed under positive pressure
- Prior to drilling the walls for an interior wall insulation blow-in, the condition of the interior walls should be evaluated to ensure that they will be able to withstand the pressure created in the wall cavity
- Construct containment areas inside house if an interior wall insulation blow-in is to be performed
- Final asbestos clearance test

While the Department of Energy Weatherization Assistance Program does not forbid states and weatherization agencies from working in homes with asbestos, there is a general understanding that expenditures for asbestos must be very limited. Unfortunately, the protocols recommended in this study call for testing and, when necessary, cleaning of homes that would in all likelihood exceed the Weatherization Assistance Program guidelines.

The project concludes that all homes with either vermiculite or thermal system insulation with asbestos require baseline testing, especially since more than half of the homes evaluated via baseline sampling required cleaning by a licensed asbestos abatement contractor.

Baseline testing to determine the character of the potential health risk to workers may be considered mandatory according to some interpretations of current OSHA regulations for homes with asbestos. Unless funding can be found for testing, weatherization agencies have no choice but to walk away from homes with asbestos. Cleaning of the living spaces also may be required based on the results of baseline testing. Without a source of funds for potential cleaning, it would be imprudent for a weatherization agency to proceed with weatherization activities in a house with asbestos even if tests show no contamination of living spaces.

Unfortunately, over the course of this project no alternative funding sources to assist either weatherization agencies or home owners and occupants with the costs of asbestos testing and cleaning were identified.

The results of this study suggest that homes with asbestos can be safely weatherized but to do so while safe-guarding worker and occupant health requires revised weatherization procedures, added costs for asbestos testing, and in many cases added costs for cleaning asbestos contamination in the homes.

SECTION 1: INTRODUCTION

Project Background

Each year, the Montana Department of Public Health and Human Services (DPHHS) and its Human Resource Development Council (HRDC) weatherization agencies must deny weatherization services to at least 200 high-energy-burden Low Income Energy Assistance Program recipient households due to the presence of asbestos-containing materials in their homes. Asbestos is found in these homes either as loose-fill insulation in attics; in pipe or duct insulation; or in certain wall, ceiling and siding materials. Due to potential health and safety hazards to residents and weatherization workers, the U.S. Department of Energy (DOE) weatherization rules limit expenditures for asbestos removal and mitigation, effectively preventing weatherization agencies from weatherizing homes with vermiculite insulation containing asbestos or with other asbestos containing building materials that are friable or brittle and could potentially become airborne.

Important Note on Terminology

Asbestos-Containing Material (ACM) – As defined by the Environmental Protection Agency (EPA) and the Occupational Safety and Health Administration (OSHA), this term refers to any material that contains more than one percent asbestos.

Non-Vermiculite ACM – Non-vermiculite ACM refers to any asbestos material, excluding vermiculite insulation, that contains more than one percent asbestos. In this report, *non-vermiculite ACM* usually refers to commercial thermal system insulation such as pipe, duct, and boiler insulation. Other materials that are non-vermiculite ACM include some ceiling textures, floor tiles, exterior siding, and other building materials. Other than wood, glass, and metal, almost every building material is a suspect ACM. While chrysotile is a type of asbestos commonly found in most commercial building products such as thermal system insulation, amphibole asbestos also can be present in these materials. Refer to Page 12 for a discussion of asbestos terms such as chrysotile and amphibole.

Vermiculite Insulation - EPA and the National Institute for Occupational Safety and Health have determined that any disturbance of vermiculite insulation, even with less than one percent asbestos, has the potential to release harmful asbestos fibers into the air. Therefore, the simple presence of asbestos in vermiculite, at whatever concentration, should be treated as ACM and disturbance should be minimized. While vermiculite insulation most often is found in the attic, it also may be found in wall cavities. The type of asbestos found in vermiculite from Libby, Montana, is a mixture of amphibole asbestos. Some health scientists believe that asbestos fibers from Libby amphiboles may be more likely to cause lung disease than fibers from chrysotile asbestos.

The original impetus for this project was borne from the frustration of a number of weatherization agencies of having to walk away from homes with asbestos. Because Montana's HRDCs are unable to weatherize low-income homes with non-vermiculite ACM or vermiculite insulation, low-income residents therein are prevented from receiving the benefits of the federally funded weatherization program. In addition, the house occupants may be exposed to on-going health hazards, specifically an increased risk of asbestos-related diseases. Because these homes cannot be weatherized and made more energy-efficient, potential energy savings, which can be as great as 24 percent of natural gas usage and 30 percent of electricity usage, are forfeited.

These low-income residents are more likely to have higher energy bills, higher arrearages, increased potential for utility service terminations and/or homelessness, and a greater reliance on LIEAP with less opportunity to attain energy self-sufficiency.

Report Organization

The four sections of this report contain the most pertinent information resulting from this project. The appendices include more detailed information about a number of topics related to asbestos and weatherization. The appendices also include more detailed information about the weatherization and asbestos testing performed on project homes.

Montana Asbestos-Safe Weatherization Demonstration Project Report Organization

1	**Introduction** Describes how the project began, including project objectives and approach. An introduction to asbestos also is provided.
2	**Protocols for Weatherization of Homes with Asbestos** Recommended practices resulting from the project are detailed.
3	**Asbestos Testing Methodology** Approach to asbestos testing and monitoring is detailed, including sampling methods and acceptable background concentrations adopted for this project.
4	**Asbestos Testing – Results and Conclusions** Results of the testing and monitoring are described and discussed. The conclusions derived from these test results are explained.
A	**Appendix A. Project Implementation and Participation** Includes Weatherization Assistance Program information and federal, state, and WAP regulations that relate to asbestos. Information is also provided about project weatherization practices.

B

Appendix B. Participating Homes Summary Information

Describes the participating homes and the weatherization activities the project activities that took place in each house.

Project Funding and Administration

The DPHHS Intergovernmental Human Services Bureau was the recipient of a Residential Energy Assistance Challenge Program grant from the Low Income Home Energy Assistance Program of the U.S. Department of Health and Human Services.

DPHHS contracted with the National Center for Appropriate Technology (NCAT) to administer and coordinate the project. NCAT in turn developed a project team that included three Community Based Organizations, which received funds to deliver services under this proposal. The three Community Based Organizations are currently DPHHS sub-grantees for Low Income Home Energy Assistance Program, the Department of Energy Weatherization Assistance Program (DOE WAP) and the Community Services Block Grant.

The three Human Resource Development Councils are: District XII Human Resource Council in Butte, Montana; District XI Human Resource Council, Inc., in Missoula, Montana; and Northwest Montana Human Resources, Inc., (NMHR) in Kalispell, Montana. District XI HRDC serves Mineral Missoula and Ravalli counties; District XII serves Beaverhead, Deerlodge, Granite, Madison, Powell and Silver Bow counties; and NMHR serves Lake, Lincoln, Sanders and Flathead counties.

The HRDC contracts with these nonprofit Human Resource Development Councils to operate the above three federally-funded programs, as well as other programs that empower low-income families and individuals to obtain the skills, knowledge, motivation and opportunity needed for them to become self-sufficient.

The Montana DPHHS and its Human Resource Development Councils, which comprise Montana's Low Income Home Energy Assistance Program and weatherization network, are uniquely qualified to take the lead in addressing the health and safety hazards of asbestos in low-income homes. A decade ago, Montana's weatherization network was proactive in recognizing and addressing problems in low-income, lead-contaminated homes. The end result of the network's efforts, in collaboration with DOE, EPA, and other federal and state agencies, was the development of national protocols for lead-safe weatherization. The Montana Asbestos Safe Weatherization Demonstration Program project partners hope that asbestos-safe weatherization protocols and training materials will develop from the groundwork established through this research and demonstration project.

Project Objectives and Approach

The primary goal of the Montana Asbestos Safe Weatherization Demonstration Project was to develop and test procedures that would allow for the safe and effective weatherization of low-income homes with asbestos. After the presence of asbestos insulation was confirmed by testing bulk sampling of the suspect material, the homes were tested for the presence of asbestos fibers in the living spaces. The houses were cleaned if asbestos contamination exceeded project background levels. Finally, the participating homes were fully weatherized. In doing so, the project accomplished two important goals: 1) to provide much-needed weatherization in low-income homes with asbestos; and 2) to develop, test, and refine protocols for safely weatherizing homes with asbestos based on extensive asbestos testing and monitoring. Montana Tech of the University of Montana's Safety Health and Industrial Hygiene Department developed the testing and monitoring protocols and conducted the testing and monitoring.

The draft protocols resulting from this project include procedures that protect the health and safety of both weatherization workers and residents by preventing asbestos exposure during the asbestos identification and monitoring processes and during each step of the weatherization process. The project was carried out in two phases: Phase I (pre-implementation) and Phase II (implementation).

The pre-implementation phase of the project consisted of developing project procedures and resolving issues posed by weatherizing homes with asbestos. The popular assumption is that some weatherization activities may lead to disturbance of the ACM and cause it to become airborne.

Originally, Phase I was to involve weatherization of up to ten unoccupied homes with asbestos. Unfortunately, the project team was unable to find unoccupied homes suitable for this project. Consequently, five occupied homes were used for Phase I. Experience with these Phase I homes allowed development of refined procedures that were applied in Phase II of the project. Initially, 11 homes were identified for Phase I participation, but six of these homes were disqualified after baseline testing due to updated LIEAP ineligibility information.

During Phase II, 32 homes were weatherized, for a project total of 37. The project had originally anticipated weatherizing twice that many homes. The most significant factor influencing the lower number of homes weatherized was the number of homes that needed asbestos contamination cleaning either prior to or following weatherization. This added significantly to the average cost to weatherize a house.

The original project work plan called for eliminating all homes from the project that were contaminated above acceptable background levels as determined by baseline testing. However, due to difficulty in finding participant homes, a licensed asbestos abatement contractor was hired to clean asbestos from homes in order to allow the homes to continue in the project. Of the 37 homes weatherized, 22 required pre-weatherization asbestos decontamination. Costs for this asbestos cleaning ranged from $2,000 to $4,675 per house. The average cost was $3,400 per house. This added cost for cleaning reduced funds available for weatherizing additional houses.

Originally, the project planned to hire an independent asbestos contractor through a competitive request for proposal process to provide weatherization services for the project. This approach was necessitated by an initial reluctance on the part of the participating weatherization agencies to perform asbestos-related work. After a weak response to an asbestos weatherization work Request for Proposals, District XII HRDC in Butte volunteered to have its staff trained to perform asbestos work. Five of the HRDC's staff received a week of asbestos training by a state-certified trainer and are now certified as Asbestos Contractor/Supervisors.

Phase II of the project was a broader implementation of the procedures developed from Phase I. Following are the primary questions that were addressed by the project:

- What are the baseline surface and air asbestos concentrations in selected homes?
- To what extent will weatherization activities such as blower door tests and addition of insulation disturb the asbestos?
- What is the potential for and amount of worker exposure to asbestos during weatherization activities (blower door tests, insulation replacement)?
- What is the correlation, if any, between the percentage of asbestos in vermiculite insulation and airborne asbestos?
- What remedial activities can safely be undertaken to abate airborne and surface asbestos that has been disturbed through weatherization?
- What measures should be taken to protect weatherization workers and residents from asbestos exposure before, during and after weatherization?
- What training is required for weatherization workers to participate in specific phases of the weatherization work?

Initial lists of potential participants were provided by partner weatherization agencies (Butte, Missoula, and Kalispell) and the Montana Department of Health and Human Services. The number of participant homes is included in the following table.

Participating Homes

	Homes
Butte	**9**
Missoula	**3**
Kalispell	**0**
Helena	**3**
Billings	**3**
Great Falls	**15**
Bozeman	**4**
Total	**37**

Few of the initial lists were useful in identifying participants because the occupant information was no longer accurate. Many of the listed potential participants had moved since the lists were compiled. Being displaced from their homes for up to three weeks while weatherization and asbestos testing took place was a major barrier for some potential participants. As word of the project spread among weatherization agencies and the agencies realized that homes with asbestos could be weatherized through the project, more homes were identified. Maintaining current lists of homes with asbestos is an important step toward dealing with these homes in the future.

Funding Asbestos-Related Testing and Cleaning

The asbestos testing and contamination cleaning performed during this project were funded by the Montana Asbestos Safe Weatherization Demonstration Project grant. Typically, weatherization agencies will not have funding for these activities.

Department of Energy Weatherization Program Notice 02-5 (Effective Date July 12, 2002) provides health and safety guidance to weatherization agencies. This notice can be found on the Weatherization Assistance Program Technical Assistance Center website at http://www.waptac.org/sp.asp?id=6914. The notice states that “the primary goal of the Weatherization Program is energy efficiency.” However, the notice allows some minor expenditures for health and safety:

> “Energy-related health and safety concerns need to be remedied before, or because of, the installation of weatherization materials. Therefore, energy-related health and safety hazards associated with weatherization activities may be remedied or prevented with DOE funds. Measures and their costs must be reasonable and must not seriously impair the primary energy conservation purpose of the program.”
>
> *“Asbestos -* ***General asbestos removal is not approved as a health and safety weatherization cost*** (emphasis added). Major asbestos problems should be referred to the appropriate state agency and/or the Environmental Protection Agency (EPA). Where local agencies work on large heating and distribution systems, including related piping, asbestos removal may be necessary. Removal is allowed to the extent that energy savings resulting from the measure will provide a cost-effective savings-to-investment ratio. This would normally be true with work done on large, multifamily heating systems. Where permitted by code or EPA regulations, less costly measures that fall short of asbestos removal, such as encapsulation, may be used. Removal and replacement of asbestos siding for purposes of wall cavity insulation is permissible if allowed by state and local codes.”

While not forbidding states and weatherization agencies to deal with asbestos in homes, there is a general understanding that expenditures for asbestos-related activities must be very limited. Unfortunately, the protocols recommended in this study call for testing and cleaning that in most cases will exceed these program guidelines.

Over the course of this project, several homes were identified with asbestos but did not continue in the project. In these cases, the project team attempted to identify funding sources that would provide testing and clean-up funds. None were identified. The project results conclude that all homes with either vermiculite or thermal systems insulation with asbestos require testing and that over half of these require cleaning by a licensed asbestos contractor. Again, no potential funding sources for these activities were identified.

Asbestos Background Information

The word *asbestos* refers to a group of fibrous silicate minerals capable of forming thin fibers. The two primary families of asbestos minerals include serpentine and amphibole. Chrysotile is the only asbestos in the serpentine family and it is the asbestos most commonly used for industrial purposes including thermal system insulation. The amphibole group is represented by amosite, crocidolite, tremolite, actinolite, and anthophyllite. Although numerous forms of asbestos minerals exist, chrysotile, along with these five amphiboles, is regulated by EPA and OSHA. Unregulated asbestos minerals also may be present in various ores.

Chrysotile is characterized by long, flexible crystalline fibers, while amphibole minerals are typically more brittle and rod- or needle shaped (DHHS/ATSDR, 2000). Chrysotile comprises 95 percent of asbestos used in commercial products. Amphibole fibers such as amosite and crocidolite also have been used for commercial applications. The remaining regulated amphiboles, anthophyllite, tremolite, and actinolite were not commonly mined for commercial applications, but are found as asbestos contaminants within ore bodies, including chrysotile.

Table 1: Asbestos Minerals

Family	EPA Regulated Mineral Forms *	Remarks
Serpentine	Chrysotile	Found in products such as thermal systems insulation, siding, flooring, fireproofing, and other industrial products.
Amphibole	Amosite	Mined for limited commercial applications.
	Crocidolite	Mined for limited commercial applications.
	Tremolite	Found as asbestos contaminant in some ore bodies, notably in vermiculite mined near Libby, Montana.
	Actinolite	Found as asbestos contaminant in some ore bodies.
	Anthophillite	Found as asbestos contaminant in some ore bodies.

** - Other forms of asbestos that are not regulated by EPA are suspected of causing asbestos-related diseases.*

Asbestos resists thermal degradation, does not conduct electricity, and is chemically resistant. In addition, asbestos has tensile strength and flexibility. These properties make it attractive for use in the auto-parts industry, agriculture, horticulture and construction. Examples of building products that contain asbestos include insulation, fireproofing materials, textiles, paper and cement products, roofing shingles, floor tiles, packing material, soil conditioner, fertilizers and pesticides. According to EPA, automobile industry products such as brakes, clutch, and transmission often contain asbestos. Asbestos has been found to be present in 3,000-4,000 commercial products (Dodson and Hammer, 2006).

Libby Vermiculite

Vermiculite is the mineralogical name given to the group of hydrated silicate minerals that resemble mica in appearance. When subjected to heat, vermiculite expands into worm-like, accordion-shaped pieces. The expansion process is called exfoliation. This characteristic of exfoliation, the basis for commercial use of the mineral, is the result of mechanical separation of the layers by the rapid conversion of contained water to steam. This property makes it an excellent choice for many applications in the construction and industrial markets. Vermiculite that originated from the mine near Libby, Montana (called Zonolite Mountain), was sold under the commercial name Zonolite. The Zonolite brand and the mine were acquired by the W.R. Grace Company in 1963. Vermiculite from Zonolite Mountain was contaminated with amphibole asbestos containing a combination of winchite (84 percent), richterite (11 percent) and tremolite (6 percent) (Meeker, 2003). The mineralogy of Libby amphibole asbestos is very unique both chemically and structurally.

For 70 years, according to EPA, Zonolite Mountain supplied nearly 80 percent of the world's vermiculite. While the Libby vermiculite had useful insulating and soil-conditioning properties, ore from the mine (in operation from the 1920s-1990) was contaminated with amphiboles in veins throughout the deposit.

Zonolite was installed in an estimated 35 million homes in the United States, including thousands of homes in Montana. It should be noted that not all vermiculite contains asbestos, as is the case with Zonolite. Today, vermiculite is mined at three U.S. facilities and in other countries that have low levels of asbestos contamination in the final product.

Figure 1
Example of asbestos-containing vermiculite attic insulation.

Health Effects of Asbestos

Asbestos is composed of microscopic bundles of fibers that can become airborne when the material containing asbestos is damaged. Once fibers are airborne, they can enter the lungs and become embedded, causing adverse health effects.

Chronic exposure to asbestos can result in asbestosis, lung cancer, mesothelioma, or stomach and bowel cancers. Changes in the lining of the lungs such as, pleural plaques, pleural thickening, and pleural effusions are also the result from exposure to asbestos (Lippmann, 2000; Mossman et al., 1990).

Asbestosis, or scarring of the lungs, is characterized by a diffuse increase in collagen in the alveolar walls (fibrosis) and the presence of asbestos fibers, referred to as asbestos bodies (Casarett & Doull, 2007). This increase in collagen interferes with alveolar gas-exchange, impairs breathing and ultimately leads to death (Mossman et al., 1990). Asbestosis has a latency period of 25 to 40 years after the initial exposure (EPA, 2004).

Lincoln County, Montana, has the highest age-adjusted mortality rate from asbestosis in the nation (DHHS/ATSDR CERCLIS No. MT0009083840, December 2000). A medical screening conducted in 2000 of 6,200 Libby residents who lived there before 1990 found that 14 percent of all participants had radiographic changes consistent with asbestos-related abnormalities (Whitehouse, 2004). Cross-sectional x-ray screening conducted in Libby for the ATSDR revealed that 6.7 percent of the residents with no occupational or family exposure to asbestos have radiographic evidence of asbestos-related disease and an enhanced risk of radiographically detectable lung scarring associated with common childhood activities around Libby area (Peipins, 2003).

Lung cancer resulting from asbestos exposure occurs in the epithelial linings of the airway or in the terminal bronchioles. Lung cancer usually results 15 to 30 years after initial exposure. Cigarette smoking combined with asbestos exposure greatly increases the chance of developing lung cancer according to EPA.

Mesothelioma is characterized by malignant tumor on the linings of the lungs and the adjacent wall and is caused primarily by chronic asbestos exposure (EPA,a 2004). Mesothelioma commonly occurs 35 to 45 years following exposure and can occur up to 60 years after exposure. Various studies have found that amphiboles are twice as likely to cause mesothelioma as serpentine fibers; however, there is some discrepancy between observations in humans and in animal studies (EPA, 2004a; Hodgson and Darnton, 2000; Mossman et al., 1990, Casarett & Doull, 2007). Fiber length may also contribute to the likelihood of developing mesothelioma. Longer fibers (> 8 µm) are more difficult to remove from the pleural and peritoneal spaces because their large size prohibits removal by the lymphatic channels (Mossman, et al., 1990; Lippmann, 2000).

The type of asbestos fiber, the concentration of asbestos, and fiber size are important factors in determining toxicity (DHHS/ATSDR, 2008). Generally, the longer the fiber length and smaller fiber diameter, the greater will be the carcinogenic potential of an asbestos fiber (Besson et al.,1999). While there is evidence that longer fibers may increase toxicity, the toxicity of short fibers (< 5 um) is still being debated. Short fibers are suspected of being toxic for both cancer and non-cancer diseases (DHHS/ATSDR, 2008).

Asbestos exposure does not always lead to health problems; however, frequent and intense exposure over an extended period of time is associated with a higher risk of asbestos-related disease. Other significant factors that lead to an increased risk are a history of smoking, a history of lung disease, and heredity (DHHS/ATSDR, 2001).

SECTION 2: Recommended Asbestos Safe Weatherization Protocols

Preliminary protocols were developed in Phase 1. Following Phase 1, the protocols were modified prior to implementation of Phase 2. The lessons learned from implementation of both phases of the project were incorporated into the final recommended protocols described here.

The objective of these protocols is to provide guidance for weatherization agencies in regard to performing weatherization work practices in homes that contain vermiculite insulation (which contains any amount of asbestos) and/or non-vermiculite asbestos containing material (ACM) that contains over one percent asbestos. The basis for these protocols was research data collected over a two-year period during which weatherization work was performed in 37 homes that contained asbestos. These data revealed that performing weatherization measures in these homes has the potential to disturb asbestos-containing materials and disperse asbestos fibers into the air. This presents a risk to weatherization workers and home occupants of inhaling asbestos. The majority (79 percent and 67 percent, respectively) of high-volume air and personal breathing zone air samples from this study did not reveal detectable airborne concentrations of asbestos. However, enough test samples did reveal detectable concentrations that careful consideration should be given when performing weatherization work in homes with asbestos. Significantly, airborne asbestos was detected during numerous weatherization measures, suggesting that weatherization practices as a whole, not single weatherization measures, may contribute to the disturbance and dispersal of asbestos fibers into the air.

There is considerable pressure on weatherization agencies to weatherize as many homes as possible as efficiently as possible to minimize costs. This creates an ongoing struggle between maximizing productivity and maximizing safe work practices. The following practices may appear overly cautious to some in the weatherization community. However, the project team chose to error on the side of caution. If lead-safe weatherization practices are any indication, health-related procedures tend to become more cautious over time. The health effects related to asbestos exposure are well established; therefore, it is crucial to take all precautions available to minimize potential exposures.

Work in the field is never as neat and organized as written procedures may suggest. There will always be circumstances when the individuals performing work in actual homes will make decisions that weigh saving time against how strictly to follow suggested best practices such as those described below.

Even within Montana, weatherization agencies differ in their approach to using in-house staff to accomplish weatherization activities versus contracting for those activities. If funds become available for the added costs of asbestos testing and cleaning suggested in these protocols, then it is likely some agencies will choose to train their own workers to perform many of these tasks. Other agencies will likely choose to contract for these activities.

The protocols are organized in a series of eight steps.

Asbestos Safe Weatherization Protocols

Step 1	**Weatherization Crew Training**
Step 2	**House Screening and Bulk Sampling**
	 **Weatherization Agencies should perform no activities in homes with vermiculite insulation or non-vermiculite ACM unless non-Weatherization Assistance Program funding for asbestos testing and cleaning is secured.**
Step 3	**Baseline Assessment for Potential Living Space Contamination**
Step 4	**Living Space Asbestos Cleaning** (if necessary)
Step 5	**Energy Audit**
Step 6	**Weatherization Measure Implementation Protocols including Final Blower Door**
Step 7	**Living Space Asbestos Cleaning** (if necessary)
Step 8	**Post Weatherization Occupant Meeting and Presentation of Asbestos Notice**

Step 1 - Weatherization Crew Training

In order to accurately screen the home for asbestos, the weatherization worker who conducts the initial site inspection should complete OSHA-approved Asbestos Inspector training. In order to manage the weatherization process in a home with asbestos, the weatherization crew supervisor or other responsible person (referred throughout this document as weatherization inspector) should complete both the OSHA-approved Asbestos Inspector training and Asbestos Project Contractor/Supervisor Training (Montana Department of Environmental Quality, http://deq.mt.gov/Asbestos/acpOverview.mcpx). The crew supervisor should receive both the Inspector and Supervisor Training since asbestos may be uncovered during the process of implementing other weatherization measures. OSHA-approved Asbestos Worker Training should be mandatory for all weatherization workers who take part in weatherization activities that could disturb materials with asbestos. The training must include criteria for:

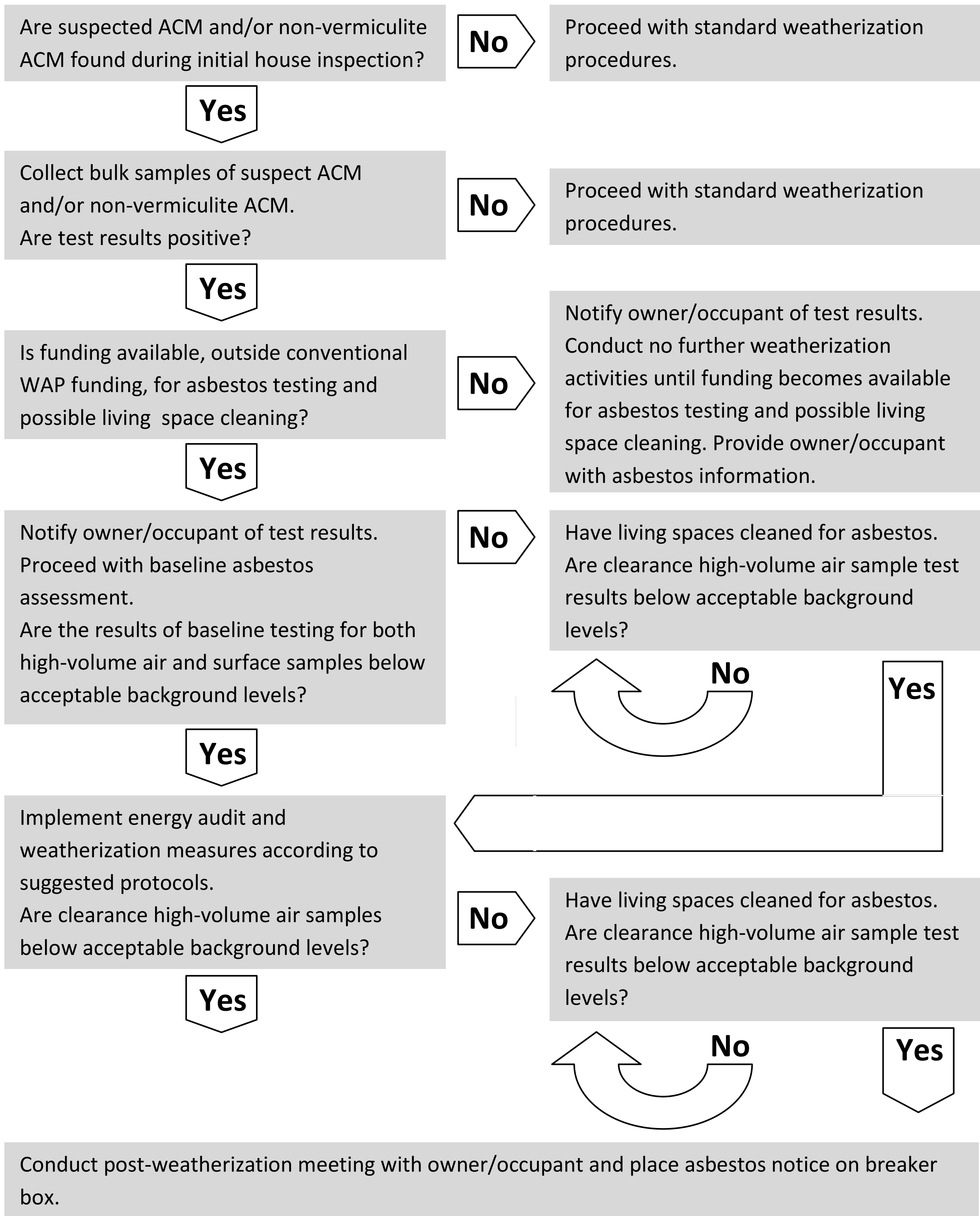
- Recognizing asbestos routes of exposure and potential health impacts
- Recognizing common sources of asbestos in homes
- Identifying suspect non-vermiculite ACM and/or vermiculite insulation
- Collecting material (bulk) samples of suspect non-vermiculite ACM and/or vermiculite insulation
- Employing containment and other practices to minimize dispersion of non-vermiculite ACM and/or vermiculite insulation during bulk sample collection and weatherization measures
- Employing personal protective equipment practices to minimize potential asbestos exposure during the asbestos screening and weatherization measures
- Understanding medical evaluation and fit-test requirements for wearing respiratory protection
- Understanding the limitations of respiratory protection
- Understanding how to care for and clean respiratory protection

All weatherization workers assigned to work in homes with non-vermiculite ACM and/or vermiculite insulation, regardless of activities performed, should pass an asbestos worker training course. Appropriate training is crucial for the health and safety of not only weatherization workers, but for home occupants as well. This training must include criteria for:

- Recognizing asbestos routes of exposure and potential health impacts
- Recognizing common sources of asbestos in homes
- Identifying suspect non-vermiculite ACM and/or vermiculite insulation
- Employing containment and other practices to minimize the dispersion of non-vermiculite ACM and/or vermiculite insulation during weatherization measures
- Employing personal protective equipment practices to minimize potential asbestos exposure during weatherization measures
- Understanding medical evaluation and fit-test requirements for wearing respiratory protection

- Understanding the limitations of respiratory protection
- Understanding how to care for and clean respiratory protection

Asbestos Safe Weatherization Project Protocol Decision Tree



Step 2. House Screening and Bulk Sampling

The initial site visit by the weatherization staff includes an overall house inspection, which includes a thorough review of potential materials with asbestos. If suspect materials are identified, then the weatherization inspector should collect bulk samples of the suspect material for laboratory testing. It is important that the weatherization inspector note any house characteristics that would complicate performing weatherization on the home, such as cracks or openings into structural cavities that include asbestos materials or a significant number of personal belongings stored in spaces where asbestos materials are located. This initial screening visit also provides an opportunity to visit with the client about the weatherization process, including the special challenges presented by asbestos in the home.

Where is asbestos most likely to be found?

The most common residential materials containing asbestos include thermal system insulation on ductwork associated with furnaces, hot water heaters, etc.; tile and linoleum flooring; exterior siding; electrical wiring insulation; popcorn ceiling; roofing shingles and adhesive materials; and gaskets. Homes constructed from the 1930s through the 1970s are most likely to contain these materials.

Another source of asbestos in homes may be vermiculite insulation. A mine near Libby, Montana, supplied up to 80 percent of the world's vermiculite from the 1920s to 1990. Unfortunately, vermiculite from this mine was contaminated with amphibole asbestos, commonly referred to as Libby amphibole. While not all vermiculite contains asbestos, there is a high likelihood that vermiculite, especially in Montana homes, was mined in Libby.

Visual Asbestos Inspection

When performing the initial site assessment, the weatherization inspector should create an inventory of potential asbestos containing materials, as follows:

- *Document Suspect Non-Vermiculite ACM.* Document the location of suspect non-vermiculite ACM with detailed notes and photos. Document the approximate quantity and condition of suspect non-vermiculite ACM.
- *Occupant Interview.* Conduct an informal interview with the occupant to obtain the home's construction history. For example, was the home re-sided or was thermal system insulation removed with a furnace replacement? It may be necessary to contact the owner for information about the home's history.
- *Attic Inspection.* Visually observe and document attic insulation materials.
    - *Protection When Entering Attic*. If this visual observation will require the weatherization inspector to partially enter the attic for this inspection (observing by sticking head in attic hatch) a half-mask air purifying respirator equipped with N, P, or R 100 filters should be donned prior to this assessment. In addition, if the visual inspection will require the

weatherization inspector to partially enter the attic, a Tyvek suit and nitrile gloves should be worn.

  - *Respirator Fitting.* All personnel wearing assigned respiratory protection must have passed a quantitative or qualitative fit test and must have obtained medical approval to wear air-purifying respiratory protection. This information must be on file as a component of the HRC's Respiratory Protection Program.
  - *Interior Attic Hatch Containment.* It is preferable to access the attic from the exterior of the building to minimize the risk of bringing asbestos from the attic into the living space. If the visual observation must be conducted from inside the home's living space (attic hatch in a closet or within some other living space), a 6-mil plastic containment should be constructed and used to minimize the potential of dispersing asbestos from vermiculite insulation into the living space. The cleanup of after this activity should include vacuuming with HEPA filters.
- *Identify and Document Any Attic Bypasses*. Identify and document air pathways between living space and construction cavities with asbestos containing materials. For example, are there holes in the ceiling, gaps in the ceiling associated with light fixtures, or electrical/plumbing penetrations?

Bulk Sampling Procedures

Suspect Non-Vermiculite ACM Samples. Bulk samples of suspect non-vermiculite ACM should be collected. Following are guidelines for collecting bulk suspect non-vermiculite ACM samples.

- Construct a 6-mil plastic containment around the area where the bulk sample will be collected, leaving a small access port for the hand and sample equipment (tweezers) to enter.
- Don a pair of nitrile gloves.
- Reach into the containment to remove a full-depth sample with coring or boring tools, fixed blade knife, or tweezers that is ¼- to 1-inch long. Care must be taken with this method not to disperse material.
- Place the sample in a labeled sample bag and seal the bag.
- Wipe the sample equipment and nitrile gloves with wet wipes immediately after each sample collection.
- Remove the plastic containment by rolling it up, keeping the external side only exposed.
- Place the plastic containment, wet wipes, and nitrile gloves in a double plastic bag and seal. Waste materials generated from the bulk sampling procedures described above will most likely contain less than one percent asbestos and can be discarded as solid waste in landfills.
- Cleanup after this activity should include vacuuming with HEPA filters.

Vermiculite Insulation Samples. Following are guidelines for collecting bulk vermiculite insulation samples (EPA, 2004b). It is recommended that an additional person (with equivalent training) assist the supervisor/inspector with bulk vermiculite insulation sample collection.

Vermiculite Attic Insulation Sampling

- Construct a 6-mil plastic containment structure around the attic hatch or vent access port.
- Place the ladder within the plastic containment.
- Wear a half-mask air purifying respirator with N, P, or R 100 filters, hooded Tyvek coveralls, nitrile gloves. Refer to the caution under the "Visual Asbestos Inspection" section above regarding respirator fitting and medical clearance.
- Use a clean, large garden soil scooper (preferably metal) to collect approximately a one-gallon sample of the vermiculite insulation. Collect this sample from three separate areas within the attic. Avoid sampling at the top of the loose-fill insulation. Asbestos is most likely found in the finer vermiculite particles or dust, which tends to settle over time. Samples also should be taken from the lower sections in the attic and from the bottom layer of the insulation.
- Place the sample in a labeled, one-gallon plastic sample bag and seal the bag.
- Wipe this sample bag with wet wipes and place this bag within a secondary, one-gallon sample bag.
- Wipe down the sample scooper with wet wipes.
- Descend from the attic and wipe down the ladder with wet wipes.
- Wipe down all personal protective equipment with wet wipes while within the plastic containment.
- Remove the Tyvek suit first by rolling it inside out from the head down.
- Step out of the plastic containment and remove the nitrile gloves, followed by the respirator. Wipe down the respirator once again with wet wipes.
- Remove the plastic containment by rolling it up, keeping only the external side exposed.
- Place the plastic containment, wet wipes, Tyvek suit, and nitrile gloves in a double plastic bag and seal. Waste materials generated from the bulk sampling procedures described above will most likely contain less than one percent asbestos and can be discarded as solid waste in landfills.

Vermiculite Wall Insulation Sampling

While vermiculite insulation is most commonly located in attics, it also may be used as insulation material within wall cavities. Vermiculite insulation sampling within the wall cavity presents some unique challenges. If the attic and walls both contain vermiculite insulation, it is advised that a composite sample be collected from the attic only. If only the wall cavity(s) contains vermiculite insulation, the following procedures should be used for sample collection.

- Place a minimum 3-foot-wide, 6-mil plastic sheet on the floor, extending 3 feet from the wall and secure 6 inches up the wall from the floor.
- Wear a half-mask air purifying respirator with N, P, or R 100 filters, hooded Tyvek coveralls, nitrile gloves
- Drill a 1- to 2-inch diameter hole in the wall immediately above the plastic containment.

- Use a clean, small metal ladle to collect the vermiculite sample, placing each ladle sample into a one-gallon bag. Continue collecting the sample until reaching the sill plate and then scrape the sill plate with the ladle. Collect similar samples from two additional areas within the wall cavity(s), employing identical containment measures and sample-collection methods. Although a one-gallon sample of vermiculite insulation is recommended for laboratory analysis, it may be difficult to achieve this minimum volume with wall cavity samples.
- Seal and label the one-gallon plastic sample bag.
- Wipe this sample bag with wet wipes and place the bag within a secondary, one-gallon sample bag.
- Wipe down the wall surface near the sample access hole, ladle and drill with wet wipes.
- Seal all sample access holes.
- Wipe down all personal protective equipment with wet wipes
- Remove the plastic containment by rolling it up, keeping the external side only exposed.
- Place the plastic containment, wet wipes, and nitrile gloves in a double plastic bag and seal. Waste materials generated from the bulk sampling procedures described above most likely will contain less than one percent asbestos and can be discarded as solid waste in landfills.

Bulk Sample Laboratory Analysis

All suspect non-vermiculite ACM and vermiculite insulation samples should be analyzed by an accredited laboratory. Laboratory accreditations include the American Industrial Hygiene Association (AIHA) and the National Voluntary Laboratory Accreditation Program (NVLAP). Polarized Light Microscopy (PLM) methods are most commonly used for bulk samples of ACM (NIOSH Method 9002 [NIOSH, 1994] and OSHA method ID-191 [OSHA, 1994]). A modified PLM method also is commonly used for determining the presence of asbestos in vermiculite insulation (EPA, 2004). Contact the laboratory prior to collecting bulk non-vermiculite ACM and vermiculite insulation samples and follow the laboratory's chain-of-custody procedures for sample shipment.

The U.S. EPA and OSHA define an asbestos-containing material (ACM) as any material containing more than one percent asbestos. However, EPA and NIOSH have determined that any disturbance of vermiculite insulation (i.e., even with less than one percent asbestos) has the potential to release asbestos fibers into the air. Therefore, bulk samples of suspect non-vermiculite ACM containing more than one percent asbestos should be considered as non-vermiculite ACMs, while the simple presence of asbestos in vermiculite should be considered as vermiculite insulation containing asbestos and disturbance should be minimized.

If the results of the bulk sample analysis confirm the presence of asbestos, then the next step is to test for asbestos contamination in the living space of the house.

Weatherization Agencies should perform no activities in homes with vermiculite insulation or non-vermiculite ACM unless non-Weatherization Assistance Program funding for asbestos testing and cleaning are secured.

Client Notification
If bulk sampling results confirm the presence of non-vermiculite ACM and/or vermiculite insulation in the house, the next step toward weatherization is to determine if asbestos contamination is present in the living spaces. At this point the occupant and owner should be informed of the bulk sample test results and the impact this will have on the weatherization process. In addition, a summary of asbestos-safe weatherization practices should be discussed with the client. This information should include:

- Bulk sample collection and analysis results.
- Baseline living space sample collection and analysis procedures.
- Consequences of performing weatherization in homes with asbestos.
    - Necessary to vacate the home once the audit has begun until the home has been cleared by air sampling results, and notification given to occupant.
    - Potential for weatherization activities to disperse asbestos fibers into living spaces, requiring cleaning by a licensed asbestos abatement contractor and clearing by air sample results prior to re-occupying the home.

The client should also be informed of his/her right to decline participation in the asbestos-safe weatherization project. Written permission should be obtained from the client before proceeding.

Step 3. Baseline Assessment for Potential Living Space Contamination

If bulk samples of suspect non-vermiculite ACM and/or vermiculite insulation do not reveal the presence of asbestos and there are no other potential sources of asbestos identified in the home, then the home may be weatherized following non-asbestos-based weatherization practices.

If the presence of non-vermiculite ACM and/or vermiculite insulation containing asbestos has been confirmed in the home via bulk sampling, an evaluation of potential living space contamination via high-volume air and surface baseline sampling should be made. The objective of this sampling is to determine if asbestos has been dispersed from the bulk sources into living spaces. Asbestos fibers dispersed into living spaces may be re-entrained during weatherization measures; therefore, homes with baseline sample results above established criteria should not be weatherized unless conditions are mitigated by a licensed asbestos abatement contractor. The established criteria used in this project are discussed elsewhere in the report.

Baseline sampling should include high-volume air sampling and surface sampling conducted in a minimum of five locations throughout the primary living spaces of the home. If the home is constructed of multiple stories, the high-volume air samples should be collected within living spaces, representing multiple stories, e.g., main floor, basement (if used as a living space as a bedroom, family room, etc.), and upper-level living spaces). In addition to primary living spaces, wipe sampling should be conducted in mechanical rooms, e.g., top of water heater. This sampling should be conducted by a certified industrial hygienist or a competent individual with specific training in asbestos air and wipe sampling procedures. Sampling methods are summarized below.

Baseline and Weatherization Work High-Volume Air Sampling Methods
High-volume air sampling should be based on Montana standards for clearing a structure in which asbestos abatement has occurred (*Montana Asbestos Work Practices and Procedures Manual*, 2005). A minimum of five high-volume air pumps should be used simultaneously and positioned throughout the living spaces of each home. Pumps should be calibrated prior to sampling at a maximum flow rate of 10 liters per minute (L/min). Each high-volume air sampler should be positioned to encounter normal air circulation. Sampling cassettes fitted with 0.8-µm, 25-mm mixed cellulose ester membrane (MCE) filters should be placed at breathing zone height (5 to 6 feet above the ground) at a 45-degree downward angle. The minimum sample volume for this method is 1200 liters. If multiple samples are to be collected, high-volume sampling cassettes may be replaced with new cassettes after the required 1200 liter sample volume is achieved. Alternatively, a larger air sample volume may be collected over a longer time period in a work day, providing that the sample cassettes do not become overloaded.

All high-volume air samples should be analyzed for asbestos per NIOSH 7400, Asbestos and Other Fibers by PCM (NIOSH, 1994[B]). Because of the limitation associated with PCM analysis (i.e., cannot distinguish between asbestos and non-asbestos fibers), further analysis by TEM should be performed for any samples that reveal PCM concentrations greater than 0.01 fiber per cubic centimeter (f/cc). According to EPA's Asbestos Hazard Emergency Response ActAirborne Asbestos by TEM is the recommended TEM method (EPA, 1987). All baseline high-volume air samples should be analyzed by an AIHA, NVLAP accredited laboratory.

Baseline Surface Sampling Methods
Surface wipe samples may be obtained by wet wipe and/or micro-vacuum techniques. Surface wet wipe samples should be collected from smooth, non-porous surfaces such as laminate floors, interior window sills, ductwork, or unmovable furniture and appliances. Micro-vacuum sample techniques should be applied with surfaces not

suitable for surface wipes (carpets and porous furniture). A minimum of five surface samples should be collected from the home during baseline sampling.

Surface wipes should be collected using the American Society for Testing and Materials (ASTM) D 6480-05 procedures, Wipe Sampling for Settled Asbestos (ASTM, 2006). A disposable, 10x10-centimeter, manila template should be placed in the desired sample location and a SKC Ghost Wipe pre-moistened with deionized water used to collect the sample. The wipe is then placed in a labeled plastic bag and sealed.

Micro-vacuum samples should be collected using ASTM method D5755-02 (ASTM, 2007). A disposable 10x10-centimeter disposable manila template should be placed on the surface and a sample probe is moved over this surface for two minutes. The sample probe consists of a ¾-inch long section of Tygon tubing attached to a 25-mm asbestos sampling cassette. The sample cassette is fitted with a 25-mm, 0.8-µm MCE filter. The cassette is attached to an SKC Aircheck sampling pump. The sampling pump should be calibrated pre- and post-sampling at 2 liters per minute (L/min) with a primary flow calibrator. At the conclusion of sampling, micro-vacuum samples should be capped and submitted for analysis.

All wet wipe and micro-vacuum surface samples should be analyzed by an AIHA, NVLAP accredited laboratory by TEM. Ten percent field blanks should also be submitted for the high-volume air, surface wipes, and micro-vacuum samples.

Interpreting Baseline High-Volume Air and Surface Sample Results

Montana standards for clearing a structure in which asbestos abatement has occurred require that five high-volume samples must be collected to verify that the airborne contamination level within the home is not greater than 0.01 fibers per cubic centimeter (0.01 f/cc) as determined by the NIOSH 7400 method or an equivalent method, or not greater than 70 structures per square millimeter (70 s/mm^2) as determined by the EPA TEM (*Montana Asbestos Work Practices and Procedures Manual*, 2005). This value of 0.01 f/cc or 70 s/mm^2 is the recommended "clearance" concentration for high-volume air baseline sampling.

In terms of surface concentration, a review of available literature indicates that a surface may be considered "clean" when the asbestos concentration is below 1000 structures per square centimeter (s/cm^2). A surface would be considered contaminated when the asbestos concentration is greater than 100,000 s/cm^2 (Millette and Hays, 1994).

Little scientific research has been performed to quantify "background" surface levels typically seen in homes. Based on existing scientific literature, 10,000 structures per square centimeter (s/cm^2) was the project's adopted background concentration and is recommended for this protocol for surface baseline sampling.

If any of the high-volume air or surface samples reveal asbestos concentrations greater than the clearance or background concentrations, respectively, then the home should not be scheduled for weatherization unless evaluated, cleaned, and cleared by a licensed asbestos abatement contractor. Sampling results should be discussed with occupants and owners. Occupants and owners should be informed of the need to have the home assessed for cleaning and possibly mitigation before it can be considered for weatherization.

Cleaning and mitigation techniques used by licensed asbestos abatement contractors should include HEPA vacuuming and wet surface cleaning of select rooms within the home and repair or mitigation of potential asbestos pathways (e.g., holes in the ceiling exposing vermiculite, damage to thermal system insulation) if necessary. All mitigation and cleaning should include air clearance sampling as per *Montana Asbestos Work Practices and Procedures Manual*, 2005.

Step 4. Living Space Asbestos Cleaning

If the baseline high-volume air or surface sampling identifies asbestos in the living spaces above the acceptable background levels, then the house should be cleaned by a licensed asbestos abatement contractor. This cleaning may be limited to only those rooms where sampling identified the presence of asbestos above background levels.

In most cases, the cleaning will include wet wiping of porous surfaces and HEPA vacuuming of non-porous surfaces. The licensed asbestos abatement contractor may need to encapsulate deteriorating asbestos insulation surfaces and repair openings that have allowed asbestos fibers to move from a construction cavity into the living space.

When the work is complete, five clearance high-volume air samples should be conducted. The procedures for clearance high-volume air sampling are the same as described for baseline high-volume air sampling. If any of the five clearance samples are greater than 0.01 f/cc)(via PCM analysis) or 70 s/mm^2 (via TEM analysis), then the house must be re-cleaned and re-tested and the high-volume air sampling repeated until the results are less than 0.01 fibers per cubic centimeter (0.01 f/cc).

Step 5. Energy Audit

Criteria for Proceeding with Weatherization in Homes with Non-Vermiculite ACM and/or Vermiculite Insulation

A home containing non-vermiculite ACM and/or vermiculite insulation should only be considered for weatherization work after the following criteria have been met:

- Criteria #1. There are no other unmitigated safety and/or structural concerns identified in the home that prevent stabilizing the asbestos material in place.
- Criteria #2. Baseline high-volume air and surface concentrations in the home are below the clearance and background concentrations described above, or the home has been cleaned and mitigated by a licensed asbestos abatement contractor and air clearance concentrations are below the clearance concentrations described above.
- Criteria #3. Home occupants have agreed to vacate the home for the entire weatherization duration and until weatherization high-volume air

concentrations are obtained and are below the clearance concentrations described above, or until the home has been cleaned by a licensed asbestos abatement contractor and air clearance concentrations are obtained and are below the clearance concentrations described above.

Auditing procedures for homes containing non-vermiculite ACM and/or vermiculite insulation require special considerations. It is not the purpose of this report to describe typical audit procedures. Rather, this section of the report will address procedures that are unique to homes with asbestos.

Work Area Preparation

*Restrict Access - Physical Barrier***.** Although, as discussed in Criteria 3 above, the home occupants have agreed to vacate the home during the entire weatherization period, a physical barrier should be placed at the home entrances during all weatherization measures as a warning to the general public. The barrier should consist of yellow caution tape placed across the doorways (or front gate if single-family dwelling). In addition to the caution tape, signs stating: 1) DANGER ASBESTOS; 2) NO UNAUTHORIZED ENTRY; and 3) NO EATING DRINKING OR SMOKING should be posted.

Remove Belongings from Storage Areas with Asbestos. It is not unusual to find attic spaces, knee-wall spaces, and crawlspaces being used to store various personal belongings. When these areas also include friable asbestos, they are often contaminated with asbestos fibers. The following procedures should be followed:

- Items should be placed in double, 6-mil plastic bags. The inner bag must be labeled to indicate that the contents are likely contaminated with asbestos fibers.
- Bagged items should be removed from the house through a containment that prevents contamination of the living space.
- The outer bag should be thoroughly wiped with wet wipes before storage.

The now single-bagged items will be placed in a garage or under other roof cover. The occupants are to be notified that the material in the bags is likely contaminated with asbestos fibers and that they have two options. One option is to pay a licensed asbestos abatement contractor to clean the items. The second option is to have the items disposed of as if they were contaminated with asbestos. If possible, the agency should offer to dispose of the items at no cost to the owner.

Personal Protective Equipment. The following minimum personal protective equipment should be used when performing weatherization measures in homes with non-vermiculite ACM and/or vermiculite insulation:

- Hooded Tyvek® disposable coveralls worn over standard work clothes
- Disposable Tyvek® booties
- Nitrile or neoprene gloves

    - It is recommended that duct tape be applied at the wrist and ankles to secure the suit to the gloves and booties. A pull-tab should be used with the duct tape for ease in suit removal.
    - Suits should be removed (doffed) and placed in 6-mil plastic bags as workers complete weatherization measures, take lunch breaks, enter vehicle cabs, etc. It is important to minimize the potential of cross-contamination. Protective suits should never be worn home or carried home. Prior to doffing, protective suits should be wiped with wet wipes.
    - Workers should remember to wash their hands and faces periodically during the day, and especially before eating, drinking or smoking.
    - Workers should be aware that working in protective suits, especially in hot weather, may increase the potential for heat-related illnesses including heat exhaustion and heat stroke. Therefore, workers should be provided with adequate breaks and constant availability of re-hydrating fluids.
- The minimum respiratory protection recommended for the majority of weatherization measures includes half-mask air purifying respirator with N, P, or R 100 filters. The minimum respiratory protection recommended for attic insulation blow in includes a full-face air purifying respirator with N, P, or R 100 filters. Periodic personal breathing zone sampling should be conducted in order to continually evaluate the adequacy of the respiratory protection prescribed.
    - Note: All personnel wearing assigned respiratory protection must have passed a quantitative or qualitative fit test and must have obtained medical approval to wear air purifying respiratory protection. This information must be on file as a component of the HRC's Respiratory Protection Program

Energy Audit Procedures
Exterior Inspection. Perform inspection of house exterior, taking special note of locations for possible attic hatch. Wall insulation in homes with asbestos exterior siding must be assessed from the interior.

Interior Inspection. Perform an inspection of house interior, taking special note of suspect non-vermiculite ACM. If it is necessary to enter the attic or basement where suspect non-asbestos ACM and/or vermiculite insulation is located, then the inspector should be in a full Tyvek suit and have a half-mask air purifying respirator. It is common for this inspection to include obtaining a sample of wall insulation. This should be done within a small containment to prevent asbestos fibers from entering the living space.

Seal Attic Bypasses. In homes with vermiculite in the attic, seal accessible air bypasses from the living space. Bypasses include plumbing penetrations in wall top plates, electrical penetrations at wall top plates, ceiling-mounted fixtures, and other openings.

Seal and Relocate Interior Attic Access Hatches. If the house contains vermiculite attic insulation, then the interior attic hatch should be permanently sealed and a new attic hatch installed in the garage or at an exterior gable prior to the blower door test being performed. Eliminating the interior attic hatch prevents future direct contamination of the living space from the interior attic hatch.

Positive-Pressure Blower Door Test. Only positive-pressure blower door tests should be conducted. Creating a significant negative pressure within the home could draw asbestos fibers from the structural cavities into the living space.

Heating System and Hot Water Heater Assessment. The interior inspection should determine if suspect ACM has been found associated with the heating and cooling systems. Anywhere that flues penetrate the floor or ceiling are areas where vermiculite can enter the mechanical room or basement from the building cavities.

Combustion Appliance Zone Test. A combustion appliance zone test is occasionally performed in existing homes to asses the potential for backdrafting combustion appliances. This test should not be conducted in a home with asbestos. The procedure includes turning on all appliances that exhaust air from the house (exhaust fans, clothes dryer, etc.) to measure the negative pressure of the combustion zone relative to the outside. This procedure could draw asbestos fibers from the building cavities into the living space in the same way a negative-pressure blower door could result in living space contamination.

Weatherization Work High-Volume Air Sampling

This research has demonstrated that the majority of weatherization activities may be performed without contributing to the disturbance and dispersal of asbestos fibers into the air. But, it is extremely difficult to predict when dispersal may occur and to anticipate what weatherization measure(s) will most likely cause dispersal. For that reason, immediately following the conclusion of weatherization work in the home, clearance high-volume sampling should be conducted. This sampling should be conducted following the same practices as detailed in Step 3, Baseline High-Volume Air Sampling.

Personal Weatherization Worker Personal Breathing Zone Sampling

When weatherization workers perform activities that may disturb vermiculite insulation and/or non-vermiculite ACM, personal breathing zone sampling should be conducted. This would include whenever the worker enters an attic with vermiculite insulation, enters a basement or crawlspace with other non-vermiculite ACM, or when insulation is being blown into wall cavities.

Personal breathing zone samples should be collected with conductive three-piece asbestos sampling cassettes positioned in the breathing zone of each worker. The carbon-filled polypropylene cassettes should contain 25-mm, 0.8 µm pore-size MCE membrane filters. Personal sampling pumps should be pre- and post-calibrated with a primary flow meter at 3.0 Liter per min (L/min).

Personal breathing zone samples (including 10 percent field blanks) should be analyzed for fibers per National Institute for Occupational Safety and Health's *Manual of Analytical Method (NMAM) 7400*. Samples that reveal PCM concentrations greater than 0.1 f/cc (OSHA's 8-hour time weighted average Permissible Exposure Limit) should be further analyzed by EPA's Asbestos Hazard Emergency Response Act (AHERA), Airborne Asbestos by TEM (EPA, 1987). All personal breathing zone samples should be analyzed by an NVLAP, AIHA accredited laboratory.

Personal breathing zone sample results should be regularly evaluated to ensure that weatherization workers are adequately protected with the personal protective equipment selected. If personal breathing zone air concentrations exceed the maximum concentration for respiratory protection, then a higher level (full-face respirator or powered air-purifying respirator) should be prescribed.

Step 6. Weatherization Measure Implementation Protocols

Prior to performing any weatherization work, including the energy audit, in homes that contain non-vermiculite ACM and/or vermiculite insulation, the planned measures should be discussed between the HRC manager and all weatherization workers. This discussion should include containment practices for minimizing the dispersal of asbestos fibers into living spaces and practices for minimizing potential exposure to weatherization workers.

In addition to standard health and safety protocols developed for the Montana Weatherization Assistance Program for safe weatherization, and in addition to the general asbestos safe weatherization practices described above, below are specific weatherization measure activity recommendations for minimizing the potential for asbestos dispersal into living spaces.

Attic Insulation

- Identify all potential pathways of potential exposure from non-vermiculite ACM and/or vermiculite insulation to living spaces within the home.
  - Isolate potential pathways by sealing all attic penetrations (light fixtures, electrical conduit, vent systems, etc.)
- In homes containing vermiculite insulation with interior attic entry ways, permanently seal the interior attic entrance(s) and provide an exterior attic entrance(s).
  - For attics that must be entered from an interior entrance, extraordinary care must be taken to isolate the attic space from the living space. Construct and operate a clean area outside of the attic entrance so that it will be the last room traversed by any individual exiting the work area, and provide facilities in the clean room for removing or donning personal protective equipment and appropriate respiratory protection.
- An effort should be made to avoid cross-contamination from homes with vermiculite insulation to homes without vermiculite insulation. To minimize the potential for cross-contamination, the following practices are recommended:
  - The entire length of hose that enters the attic during an attic blow-in should be covered with a minimum 6-mil plastic sleeve. At the conclusion of attic blow-in, the sleeve should be wiped with wet wipes and discarded

in a 6-mil waste bag and both ends of the hose should be capped with duct tape; or
    - Attic blow-in of homes containing vermiculite insulation should be performed with a separate hose from the hose used for attic blow-in of homes without vermiculite insulation. It is recommended that in order to minimize cross-contamination, the vermiculite insulation hose should be painted a bright color. At the conclusion of attic blow-in, the hose should be HEPA vacuumed and stored in a large, 6-mil plastic bag in a separate location from the non-vermiculite insulation hose.

Adding Batting Insulation – Attic

- In homes containing vermiculite insulation with interior attic entryways, permanently seal the interior attic entrance(s) and provide an exterior attic entrance(s).
    - For attics that must be entered from an interior entrance, extraordinary care must be taken to isolate the attic space from the living space. Construct and operate a clean area outside of the attic entrance so that it will be the last room traversed by any individual exiting the work area, and provide facilities in the clean room for removing or donning personal protective equipment and appropriate respiratory protection.

Blower Door Assessments

- All (initial and final) blower door assessments conducted in homes with vermiculite insulation and/or non-vermiculite ACM should be performed under positive pressure only, in order to minimize the potential of pulling asbestos fibers into living spaces.
- Blower door assessments should be performed only after potential pathways of exposure from vermiculite insulation and/or non-vermiculite ACM have been identified and sealed.
- Initial blower door assessments should not be conducted until criteria for proceeding with weatherization in homes with vermiculite insulation and/or non-vermiculite ACM summarized in Step 5 have been met.
- At the conclusion of all blower door assessments conducted in homes with vermiculite insulation and/or non-vermiculite ACM, all equipment (fan, temporary door structure and frame) should be wiped with wet wipes to minimize the possibility of cross-contamination.

Exterior Wall Drilling and Insulation Blow-In

- No drilling or exterior insulation blow-in should be conducted on homes with asbestos siding. If the home contains multiple layers of siding, all layers should be evaluated prior to proceeding with exterior wall drilling and exterior insulation blow-in.
- Prior to conducting an exterior wall blow-in, the condition of the interior walls should be evaluated to ensure that they will be able to withstand the positive pressure created in the wall cavity. Interior walls with signs of decay, mold growth, or wetness may burst with the additional positive pressure. Exterior wall

drilling and insulation blow-in should not be performed when interior walls are in this condition.
- Prior to conducting an exterior wall blow-in, all gaps or holes in the interior walls should be repaired.

Interior Wall Drilling and Insulation Blow-In

- Prior to drilling the walls for an interior wall blow-in, the condition of the interior walls should be evaluated to ensure that they will be able to withstand the positive pressure created in the wall cavity. Interior walls with signs of decay, mold growth, or wetness may burst with the additional positive pressure. Interior wall drilling and insulation blow-in should not be performed on walls in this condition.
- Prior to conducting an interior wall blow-in, all gaps or holes in the interior walls should be repaired.
- Isolate all forced-air heating ducts near the area of the wall blow-in with two layers of 6-mil plastic.
- Move all furniture and any other materials out from the wall surface a minimum distance of 3 feet. Cover any immovable appliances with 6-mil plastic.
- Lay 6-mil plastic on the floor, 12 inches up the wall and 3 feet out from the wall surface along the entire length of the wall.
- Construct a 6-mil plastic containment from the floor to the ceiling at least 3 feet out from the wall surface. Securely affix the plastic sheeting to ensure that it will remain in position throughout the length of the wall drilling and insulation blow in project. Two overlapping layers of 6-mil plastic are recommended in order to provide an access door.
- Construct and operate a clean area outside of the wall containment area so that it will be the last room traversed by any individual exiting the work area, and provide facilities in the clean room for removing or donning personal protective equipment and appropriate respiratory protection.
- Sill-plate wall sample results have demonstrated that homes with asbestos siding may have asbestos fibers within the wall cavity. It is hypothesized that this may be associated with puncturing the siding when nailed. An effort should be made to avoid cross-contamination from house to house or room to room associated with wall blow-in. To minimize the potential for cross-contamination, the portion of the hose that was inserted into the wall cavity should be thoroughly wiped with wet wipes and the end of the hose should be capped with duct tape at the conclusion of the wall blow-in.
- At the conclusion of wall drilling and wall blow-in, the plastic containment may be removed by rolling it from the outside in starting from the ceiling and working to the floor. All discarded plastic, wipes, etc. should be placed in 6-mil plastic bags. Weatherization workers should continue to wear personal protective equipment (described in previous section) during the containment removal.

Adding Batting Insulation – Basement

- The addition of batting insulation in basements may need to be performed near thermal system insulation (duct pipe wrap) non-vermiculite ACM.

- Construct and operate a clean area outside of the basement batting area so that it will be the last room traversed by any individual exiting the work area, and provide facilities in the clean room for removing or donning personal protective equipment and appropriate respiratory protection.

Installing/Repairing Bathroom Fans

- Prior to installing or repairing bathroom fans, electrical safety lockout tagout procedures for de-energizing power sources must be performed. All weatherization workers must receive training in lockout tagout procedures. If wiring repairs or new wiring installations must be performed in association with a bathroom fan installation, these must be performed by a crew member specifically trained to perform this task or by a licensed electrician with asbestos awareness training.
- Bathroom fan installation and/or repair in homes with vermiculite insulation warrant careful consideration.
    - Construct a 6-mil plastic containment structure around the fan or proposed fan location.
    - Construct and operate a clean area outside of the bathroom fan area so that it will be the last room traversed by any individual exiting the work area, and provide facilities in the clean room for removing or donning personal protective equipment and appropriate respiratory protection.
    - If a ladder will be used to access the fan, ensure that the ladder is in good condition and is used per the manufacturer's recommendations.
    - Place the ladder within the plastic containment.
    - If a ventilation access hole must be cut into the ceiling (new fan installation) and the attic space above the proposed ventilation hole can be safely accessed (preferably from external access ways) :
        - Remove the vermiculite insulation away from the proposed ventilation hole by scraping the vermiculite insulation to the side for an area approximately 1 foot in diameter. After the bulk vermiculite insulation has been removed from the proposed ventilation access, wipe the area with wet wipes.
        - Carefully cut the ventilation access port and wipe down the area with wet wipes.
        - Ensure that the bathroom fan ventilation pipe exits out of the attic space.
    - If the bathroom fan is in need of repair or replacement (where a ventilation access port is in place), carefully dislodge the fan and wipe with wet wipes. Place the discarded fan in a 6-mil plastic bag.
    - At the conclusion of work, descend from the attic and wipe down the ladder with wet wipes.

Final Blower Door

Cleanup/Decontamination

- At the conclusion of all weatherization tasks conducted inside the living space (interior drilling and wall blow-in, bathroom fan installation/maintenance, door/window repair, etc.), the work area should be thoroughly cleaned. Recommended cleaning methods include:
  - HEPA vacuum all flooring materials within the work areas. Crews performing weatherization in homes with vermiculite insulation and/or non-vermiculite ACM should be equipped with a large, canister-based HEPA vacuum. A scheduled maintenance program should be developed for the HEPA system to ensure that it will remain in proper working condition.
  - Wet wipe other horizontal surfaces within the work area such as top of shelves, appliances, etc.
- In addition, all tools and equipment should be HEPA vacuumed and wet-wiped prior to being placed back in the weatherization trailer.
- All discarded waste (e.g., plastic containment, wet wipes, HEPA vacuum filters) should be placed in 6-mil plastic bags.

At the conclusion of all weatherization work, and providing that the post-weatherization high-volume sampling (from sampling discussed in Step 5) results are below the clearance concentration, home occupants can be notified that they may re-occupy the home. If any of the five clearance samples are greater than 0.01 f/cc (via PCM analysis) or 70 s/mm^2 (via TEM analysis), then the house must be evaluated, cleaned and cleared by a licensed asbestos abatement contractor. All mitigation and cleaning should include air clearance sampling as per *Montana Asbestos Work Practices and Procedures Manual*, 2005. If the post-cleaning air clearance sample results are below the clearance concentration, then the home occupants should be notified that they may re-occupy the home.

Step 7. Living Space Asbestos Cleaning and Retesting

If the clearance high-volume air sampling identifies asbestos in the living spaces above acceptable background levels, then the house should be assessed and cleaned by a licensed asbestos abatement contractor. It is possible that a weatherization agency will have someone on staff who has been certified to perform the assessment and cleaning. This cleaning may be limited to only those rooms where sampling identified the presence of asbestos above background levels based on the judgment of the licensed asbestos abatement contractor. In most cases, the cleaning will include wet wiping of porous surfaces and HEPA vacuuming of non-porous surfaces.

When the work is complete, clearance high-volume air sampling should be conducted. The procedures for clearance high-volume air sampling are the same as described for baseline high-volume air sampling. If any of the five clearance samples are greater than 0.01 f/cc (via PCM analysis) or 70 s/mm^2 (via TEM analysis), the house must be re-cleaned and the high-volume air sampling repeated until air concentrations are below the clearance concentrations.

Step 8. Post-Weatherization Occupant Meeting and Presentation of Asbestos Notice

After the weatherization project is complete, a member of the weatherization agency staff should meet with the occupant to:

- Describe the weatherization work performed in the house
- Discuss how those weatherization measures affect the asbestos that remains in the house
- Discuss the potential danger from disturbing the asbestos that remains in the house
- Describe the potential health risks associated with asbestos
- Discuss the Asbestos Notice and why is has been placed on the house electrical breaker panel
- Place the Asbestos Notice on the house electrical breaker panel

Discussion: The Importance of Baseline Testing and Cleaning

Currently there are very limited funds available, at least under current Department of Energy Weatherization Assistance Program guidelines, that may be used to perform asbestos testing and cleaning. Yet the protocols developed by this project call for surface and air sampling prior to any weatherization work.

Isn't there some other option that would allow at least some minor weatherization work to be performed without the expense of baseline testing? The project team wrestled with this question. Measures such as installing water heater wraps, furnace tune-ups, and lamp replacements have little potential to add asbestos fibers to the living space. However, OSHA regulations require an employer to evaluate the hazards of the work place. In the opinion of the project team, this requires testing before sending workers into an environment with a significant likelihood of asbestos contamination. The OSHA code of federal regulations (1910.134(iii)) states that:

> "The employer shall identify and evaluate the respiratory hazard(s) in the workplace: this evaluation shall include a reasonable estimate of employee exposures to respiratory hazard(s) and an identification of the contaminants' chemical state and physical form. Where the employer cannot identify or reasonably estimate the employee exposure, the employer shall consider the atmosphere to be IDLH."

IDLH is the abbreviation for "immediately dangerous to life or health." Under the IDLH assumption, very extensive measures are required to protect the worker. Such measures would likely be more expensive than the testing recommended in the protocols.

Under the current regulations, baseline testing should be considered mandatory for homes with ACM. Unless funding can be found for testing, weatherization agencies have no choice but to walk away from homes with asbestos. Cleaning of the living spaces also may be required based on testing results. Without a source of funds for cleaning, it would be imprudent for a weatherization agency to proceed with weatherization activities even if tests show no contamination of living spaces.

Unfortunately, this project identified no alternative funding sources to assist either weatherization agencies or home owners and occupants with the costs of asbestos testing and cleaning.

SECTION 3: ASBESTOS TESTING METHODOLOGY

Asbestos Sampling/Detection Methods

The Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH) have defined airborne asbestos fibers as those particles that, when examined using phase contrast microscopy, have: (1) an aspect ratio of 3:1 or greater and a length greater than 5 micrometer (μm); and (2) the mineralogic characteristics (i.e., the crystal structure and elemental composition) of the asbestos minerals (chrysotile, crocidolite, amosite, anthophyllite asbestos, tremolite asbestos, and actinolite asbestos) or their nonasbestiform analogs (the serpentine minerals antigorite and lizardite, and the amphibole minerals contained in the cummingtonite-grunerite mineral series, the tremolite-ferroactinolite mineral series, and the glaucophane-riebeckite mineral series).

Having accurate techniques for measuring asbestos levels is critical in determining the extent of asbestos contamination and the health risks for humans. There are a number of microscopy techniques for asbestos detection that have been developed. The most important and widely used microscopy techniques are phase contrast microscopy (PCM), transmission electron microscopy (TEM), and polarized light microscopy (PLM).

Table 2: Asbestos Sampling Analytical Methods and Project Study Contamination Standards

	Analytical Method	Project Contamination Standard	Sampling Techniques	Advantages	Disadvantages
PCM	Phase Contrast Microscopy	0.01 f/cc	NIOSH 7400 (Air Sampling)	Inexpensive (~$25); can be performed on site; used widely in past studies.	Cannot distinguish between asbestos and non-asbestos fibers; Lower resolution - can't identify smaller fibers
TEM	Transmission Electronic Microscopy	70 s/mm^2 0.01 s/cc 10,000 s/cm^2	NIOSH 7402 and EPA AHERA (Air Sampling) NIOSH 7402 and EPA AHERA (Air Sampling) ASTM (Surface)	Can distinguish between asbestc and non-asbesto fibers; identifies type of asbestos fibers; higher resolution than PCM.	Expensive (~$125); 2-4 days required for lab processing
PLM	Polarized Light Microscopy	Not Applicable	NIOSH 9002) and OSHA ID-191 (Bulk Sampling non-Vermiculite ACM) Modified EPA/600/R-04/004, Chatfield Method (bulk vermiculite insulation sampling)	Inexpensive (~$30)	

f/cc = fibers per cubic centimeter
s/mm2 = structures per square millimeter
s/cm2 = structures per square centimeter

Phase Contrast Microscopy (PCM)

Phase contrast microscopy (PCM) is an optical microscopy analytical technique used to measure asbestos levels in air. Regulations issued by OSHA require the use of PCM to determine indoor asbestos air levels for occupational settings to ensure a safe working environment. PCM uses a compound light microscope to illuminate the fibers with a hollow cone of light. The lens induces a phase shift of a wavelength of light that causes minute variations of the refractive index of the specimen. The magnification is 400 times. The change in the phase contrast allows fibers as thin as 0.25 μm in diameter to become visible but prevents fiber identification. Therefore, PCM is used to identify fibers but cannot distinguish between asbestos fibers and non-asbestos fibers. Only fibers that are greater than 5 μm in length and have an aspect ratio of 3:1 or greater are counted in this method (Dodson and Hammar, 2006). Air sample analytical techniques that utilize PCM methods include NIOSH 7400, asbestos by PCM where samples are mounted on a slide, immersed in acetone and counted to yield total fiber counts per sample (NIOSH, 1994[B]).

The advantages of the PCM method for determining asbestos in air is that it is inexpensive and analysis can be performed on-site (DeMalo, 2004), which makes it a convenient technique for monitoring asbestos exposure in the workplace. Also, PCM has been used in historical epidemiological studies (OSHA, 1997), so the results from a PCM analysis can be compared to health studies used to estimate the risk of acquiring an asbestos-related disease (Chesson et al., 1990; Verma and Clark, 1995). This makes the results from a PCM analysis more applicable in assessing risk than TEM analysis.

The main disadvantage with PCM is that it cannot distinguish between asbestos and non-asbestos fibers, which causes great uncertainty about the actual asbestos fiber concentration for a given area. Another disadvantage of PCM, compared to TEM, is its lower resolution. PCM analysis misses many smaller fibers during fiber counting that can be caught using other techniques (OSHA, 1997; NIOSH, 1994a; Mossman et al., 1990; Verma and Clark, 1995; Karaffa et al., 1987; GETF, 2003). Using PCM, the smallest fibers that are visible have diameters of about 0.20 to 0.25 μm (OSHA, 1997; NIOSH, 1994a; Harper and Bartolucci, 2003; Karaffa et al., 1987) or 0.3 μm (Verma and Clark, 1995), while the finest asbestos fibers may have diameters as small as 0.02 μm (OSHA, 1997; NIOSH, 1994a). Because of its poor resolution, PCM can result in a significant underestimation of the asbestos fiber concentration in air.

Transmission Electron Microscopy (TEM)
Transmission electron microscopy (TEM) is used as an analytical technique for air and surface samples when specific identification of individual asbestos fibers is required. This technique relies on electron microscopy rather than optical microscopy. TEM uses electromagnetic coils as lenses to form magnified images from an electron beam to form images. TEM allows for magnification of about 100,000 with a resolution greater than 10 nm. Fibers as small as 0.02 μm in diameter can be identified. TEM classifies fibers as non-asbestos or asbestos, identifies fiber morphology (type of asbestos), and reports the concentration of structures (Dodson and Hammar, 2006). Air sample analytical techniques that utilize TEM methods include NIOSH 7402, asbestos by TEM and EPA AHERA (NIOSH, 1994[C]). Surface sample analytical techniques that utilize TEM analysis include ASTM D 6480-05 (ASTM, 2006) and ASTM D 5755-03 (ASTM, 2007).

TEM is considered a superior technique to PCM for several reasons. First, transmission electron microscopes have greater resolution and thus can better detect smaller fibers (Mossman, et al., 1990; Kauffer et al., 1996; Karaffa et al., 1987; GETF, 2003) and better examine a particulate's morphology. Secondly, TEM methods for analyzing airborne asbestos use energy dispersive X-ray analysis (EDXA) to determine the elemental makeup of a fiber, which enables this technique to determine if a fiber possesses a chemical composition characteristic of asbestos or not (DeMalo, 2004) (EPA, 1987).

Polarized Light Microscopy (PLM)
Bulk samples of suspect ACM are commonly analyzed by polarized light microscopy (PLM). PLM utilizes a compound light microscope containing a polarized material in the light path below the sample and another in the light path above the sample to identify the fibers among the binders and fillers. Bulk analysis of asbestos using PLM methods involve identifying the type of asbestos present based on optical properties and then estimating the relative amount of asbestos in relation to the rest of the sample PLM identification of asbestos fibers is limited to fibers approximately1 μm in diameter (Dodson and Hammar, 2006).

Polarized light microscopy is frequently used for determining the asbestos content of bulk samples of insulation or other building materials (NIOSH Method 9002 [NIOSH, 1989] and OSHA method ID-191 [OSHA, 1994]). This method also enables qualitative identification of asbestos types using morphology, color, and refractive index. A modified EPA/600/R-04/004, Chatfield Method, is used for determining the presence of asbestos in vermiculite insulation.

Bulk/Baseline Sampling Methods

Prior to scheduling each home for weatherization work, researchers from Montana Tech conducted a Bulk/Baseline assessment. The objective of this segment of the project was to verify the presence of vermiculite insulation and/or non-vermiculite ACM in the home and to determine whether living spaces were contaminated with asbestos. The presence of vermiculite insulation and/or non-vermiculite ACM in the homes was verified via the collection and analysis of bulk samples, while potential contamination in living spaces was assessed via high-volume air and surface sampling.

Bulk Sampling Methods

Prior to entry into the attic, a 6-mil plastic containment was constructed (Figure 2). One researcher then donned level C personal protective equipment and entered the attic while the remaining two or three researchers secured the ladder within the containment and handed necessary equipment (camera, plastic bags, etc.) to the individual within the containment as needed. If the attic revealed vermiculite via visual observation (Figure 3), a one-gallon sample of vermiculite insulation was collected. Several attics revealed a vermiculite base along with cellulose or fiberglass on the top layer. The one-gallon sample of vermiculite insulation was collected with a large plastic garden scooper and placed in a plastic freezer bag. The scooper was used to ensure that the bottom layer of vermiculite insulation was included in the sample, as directed by the analytical laboratory. The sample bag was then sealed, wet-wiped, and labeled. This bag was then placed within an additional containment bag outside of the enclosure. Vermiculite insulation samples were sent to DataChem Laboratories, Cincinnati, OH, for analysis by PLM for asbestos using a modified EPA/600/R-04/004, Chatfield Method, for determining the presence of asbestos in vermiculite insulation. DataChem Laboratory is accredited by the American Industrial Hygiene Association (AIHA), the National

Voluntary Laboratory Accreditation Program (NVLAP), and the New York State Department of Health Environmental Laboratory Approval Program.

Figure 2
Example of containment constructed around attic hatch.

Figure 3
Vermiculite attic insulation

After gathering a sample of vermiculite insulation and collecting pictures to assist with a visual observation of the attic, the researcher came out of the attic, wiped down equipment and personal protective equipment with wet wipes and ,finally, removed the plastic containment for disposal.

Locations throughout the home were observed for other non-vermiculite ACM. If suspect non-vermiculite ACM was found, a bulk sample was typically collected. Suspect non-vermiculite ACM bulk samples were commonly collected from thermal system insulation (TSI) sources (Figure 4). There were some instances where collecting a bulk sample of suspect non-vermiculite ACM would have resulted in a negative impact to the home (removing a piece of external siding or flooring). In those instances, the presence of suspect non-vermiculite ACM was recorded in field notes.

Figure 4
Example of thermal system insulation (TSI) in mechanical room.

The area where a bulk sample was collected was contained with 6-mil plastic. A researcher then donned nitrile gloves and reached into the containment to remove a full-depth sample with tweezers that is ¼- to 1-inch long. The sample was then placed in a plastic bag and the bag was sealed, labeled, and wet-wiped. The tweezers were then wiped with a wet wipe, along with the nitrile gloves, prior to disposal. Bulk samples were sent to DataChem Laboratoriesfor analysis via PLM for asbestos and other fibrous constituents using EPA-600/R-93/116.

Baseline Sampling Methods

After positive identification of asbestos in vermiculite insulation and/or other non-vermiculite ACM samples, high- volume air, and surface wipe samples were collected from each home. The high-volume air samples were collected using Gast Model 1532 High Flow Vacuum Pumps. A minimum of five high-volume air pumps were used simultaneously and positioned throughout the living spaces of each home. Pumps were calibrated pre- and post-sampling at 9.5 – 9.9 liters per minute (L/min) with a Bios Defender 510 dry cal primary flow calibrator. Each high-volume air sampler was placed so that it encountered normal air circulation. Sampling cassettes fitted with 0.8-µm, 25-MCE filters were positioned 5 to 6 feet above the ground at a 45-degree downward angle (Figure 5). The mean sample duration was two hours. At the conclusion of sampling, the cassettes were removed, capped and sent to DataChem Labs. The air samples were analyzed for asbestos per NIOSH 7400, Asbestos and Other Fibers by PCM (NIOSH, 1994[B]). Samples that revealed PCM concentrations greater than 0.01 fiber per cubic centimeter (f/cc) were further analyzed by EPA's Asbestos Hazard Emergency Response Act (AHERA), Airborne Asbestos by TEM (EPA, 1987). In the event that none of the samples revealed PCM concentrations greater than 0.01 f/cc, the two highest PCM samples from each home were selected for TEM analysis.

Figure 5
Example of high-volume air sampling placement in a home.

Surface samples were collected from numerous locations in various rooms via wet wipe and micro-vacuum techniques. Wipe samples were collected from floors, interior window sills, ductwork, or unmovable furniture and appliances. The wipes were collected using the American Society for Testing and Materials (ASTM) D 6480-05 procedures, Wipe Sampling for Settled Asbestos (ASTM, 2006) and analyzed by TEM by Data Chem Laboratories. A disposable 10x10-centimeter disposable manila template was placed in the desired location and a SKC Ghost Wipe pre-moistened with deionized water was used to collect the sample (Figure 6.).

Micro-vacuum samples also were taken throughout homes on surfaces not suitable for surface wipes (carpets, porous furniture) using ASTM method D5755-02 (ASTM, 2007). A disposable, 10x10-centimeter manila template was placed on a surface and a sample probe was moved over this surface for two minutes (Figure 7.) The sample probe consisted of a ¾-inch long section of Tygon tubing attached to a 25-mm asbestos sampling cassette. The sample cassette was fitted with a 25-mm, 0.8 µm MCE filter. The cassette was attached to an SKC Aircheck sampling pump. The sampling pump was calibrated pre- and post-sampling at 2 liters per minute (L/min) with a Bios Defender 510 dry cal primary flow calibrator. Micro-vacuum samples were typically composites from two to four surfaces. Micro-vacuum samples were capped and sent to the Data Chem Laboratories for analysis by TEM. Ten-percent field blanks were submitted for the high-volume air, surface wipes, and micro-vacuum samples.

Figure 6
Example of surface wipe sample collection on non-porous flooring.

Figure 7
Example of micro-vacuum sample collection from porous carpet.

Weatherization Sampling Methods

Researchers from Montana Tech were informed when each home was scheduled for weatherization. Researchers met the weatherization crews at each home and began preparing for sampling. At this time, the weatherization crew leader met with the home occupant(s) and explained the weatherization process. The home occupant(s) were instructed to remain out of the home until the home was cleared via sample results. A stipend check was issued to the home occupant(s) to minimize the economic hardship associated with this requirement.

The objective of the sampling in this segment of the project was to evaluate the impact of weatherization on the interior living spaces of the home and to evaluate potential occupational exposures to asbestos associated with weatherizing homes with vermiculite insulation or other non-vermiculite ACM. These objectives were evaluated via high-volume air sampling, surface sampling and personal breathing zone sampling.

High-Volume Air Sampling

High-volume air sampling was conducted in homes during each weatherization measure. The methods for the high-volume sampling mimicked the methods used for the baseline sampling (described earlier in this section). In order to achieve the minimum sample volume of 1200 liters, the average duration of the high-volume sample was 2.5 hours. It was not unusual for this sampling period to include activities associated with more than one weatherization task.

Surface Sampling

On the first day of weatherization, prior to any weatherization measures in homes selected for the second segment of this research, a 20x20-cm piece of 0.3-ml plastic was secured to a minimum of five horizontal surfaces (interior window sills, dressers, table tops, etc.) in each home with duct tape or painters tape (Figure 6). A disposable, 10x10-cm manila template was then secured onto each plastic base. These plastic templates were placed in approximately the same area as the baseline samples were placed prior to weatherization.

At the conclusion of all weatherization tasks, including clean-up of debris and dust, and removal of protective barriers, surface wipes were collected from these template locations employing the wet surface sampling methods described earlier in this section.

Personal Breathing Zone Sampling

The potential occupational asbestos exposure to weatherization workers associated with weatherization measures in the homes was assessed by personal breathing zone sampling. A minimum of two workers performed weatherization measures in each home during each sample period. Personal breathing zone samples were collected with conductive, three-piece asbestos sampling cassettes positioned in the breathing zone of each worker. The carbon-filled polypropylene cassettes contained 25-mm, 0.8 µm, pore-size MCE membrane filters. SKC Aircheck 224 sampling pumps were calibrated before and after each sample period with a Bios Defender 520 primary flow meter at an average flow rate of 3.0 liters per minute (L/min).

Personal breathing zone samples (including 10-percent field blanks) were analyzed by DataChem Laboratory for fibers per National Institute for Occupational Safety and Health's Manual of Analytical Method (NMAM) 7400. Samples that revealed PCM concentrations greater than 0.1 f/cc (OSHA's 8-hour time weighted average Permissible Exposure Limit) were further analyzed by EPA's Asbestos Hazard Emergency Response Act (AHERA), Airborne Asbestos by TEM (EPA, 1987).

Baseline and Clearance Concentrations Adopted for This Project

Montana standards for cleaning a structure in which asbestos is present require that five high-volume samples must be collected to verify that the airborne contamination level within the home is not greater than 0.01 fibers per cubic centimeter (0.01 f/cc) as determined by the NIOSH 7400 method or an equivalent method or not greater than 70 structures per square millimeter (70 s/mm^2) as determined by the EPA TEM (*Montana Asbestos Work Practices and Procedures Manual*, 2005). This value of 0.01 f/cc or 70 s/mm^2 was adopted as the high-volume air clearance concentration for this project.

In terms of surface concentration, a review of available literature indicates that a surface may be considered "clean" when the asbestos concentration is below 1,000 structures per square centimeter (s/cm^2). A surface would be considered contaminated when the asbestos concentration is greater than 100,000 s/cm^2 (Millette and Hays, 1994).

Based on existing scientific literature, an acceptable background level for surface samples of 10,000 structures per square centimeter (s/cm^2) was adopted for this research. While the 10,000 s/cm^2 surface contamination level was adopted for this project, it is not our intent to suggest that this be adopted as a national standard. More research and analysis is warranted on this question.

According to EPA (2003), "establishing action levels based upon indoor dust levels is not straightforward. There are two primary reasons for this. First, unlike air samples, there are no established regulatory or health-based standards to guide the determination of acceptable concentrations of asbestos in indoor dust.

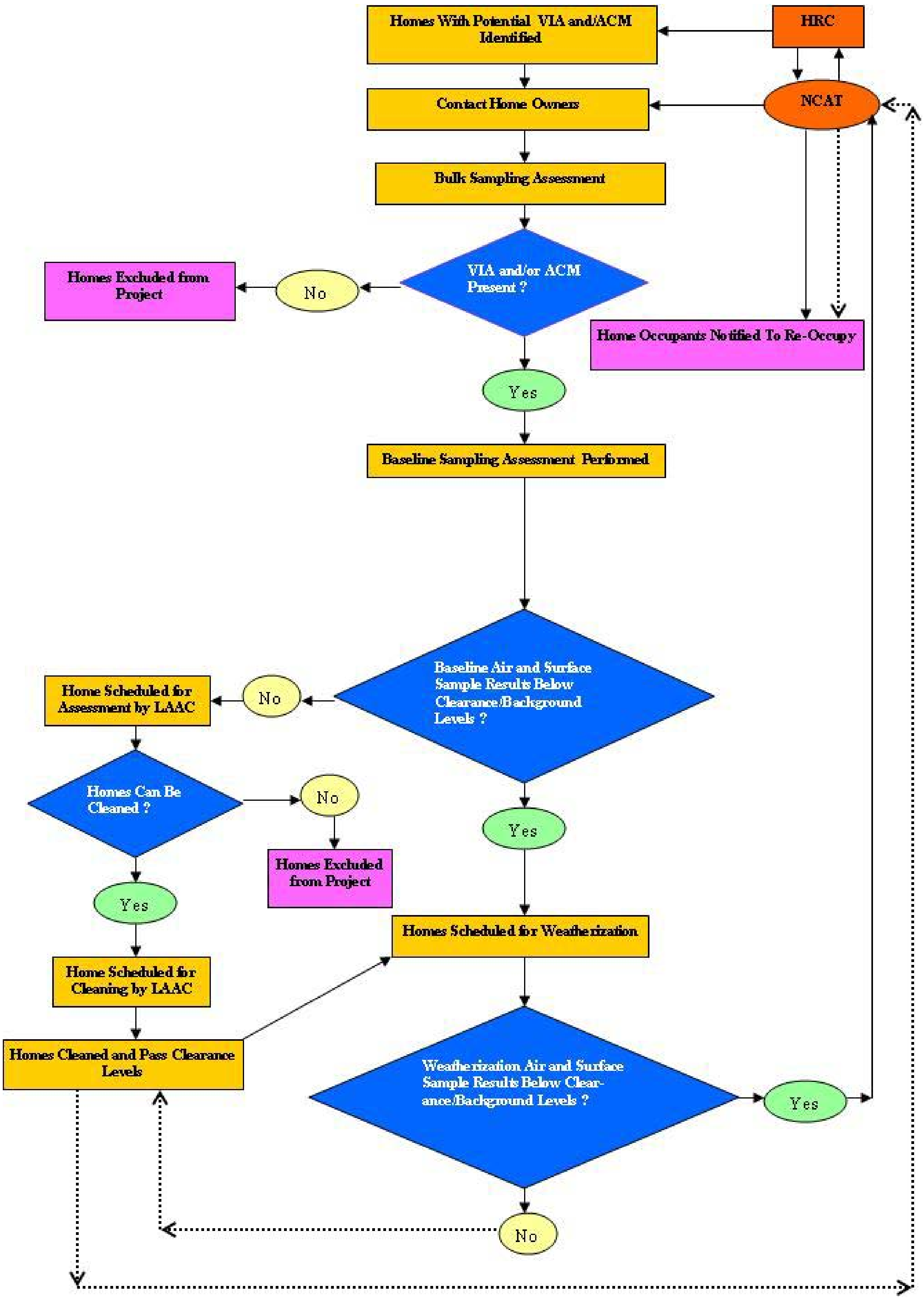
Second, the relationship between the concentration of asbestos in dust and the resultant concentration in air (the medium that actually determines human exposure and risk) is highly variable. This is because the relationship depends on a long list of different factors, most important of which is the nature and frequency of dust disturbance. This means that it is difficult to calculate a value in dust that corresponds to an acceptable level in air, and it is even harder to try to select a level in dust based on site-specific measurements."

Homes that tested positive for vermiculite insulation and/or or non-vermiculite ACM and did not reveal baseline sampling asbestos contamination in living spaces above the background or clearance concentrations adopted for this project were then scheduled for weatherization (providing that the home owner or renter met economic criteria). Homeowners or renters also were sent a letter describing the sampling results (a sample letter is provided in Appendix A).

Homes that tested positive for vermiculite insulation and/or or non-vermiculite ACM and also contained baseline sampling asbestos contamination in living spaces above the background or clearance concentrations adopted for this project were evaluated by a licensed asbestos abatement contractor. Homeowners or renters were sent a letter describing the sampling results and informing the occupants of the need to have the home assessed for cleaning before it could be considered for weatherization. If the home could feasibly be cleaned, the cleaning was then scheduled. If the home could not be feasibly cleaned, then the home owner was advised of the situation and the home was not scheduled for weatherization. High-volume air clearance sampling was conducted by the licensed asbestos abatement contractor in all homes that were cleaned prior to weatherization. A copy of this clearance sampling results and a description of work performed was provided by the licensed asbestos abatement contractor.

At the conclusion of weatherization work, homes that did not reveal asbestos contamination through weatherization sampling in living spaces above the clearance or background concentrations adopted for this project were cleared for the occupant(s) to move back into the home. Homes that revealed weatherization high-volume air or surface wipe concentrations greater than the clearance or background concentrations adopted for this project were cleaned by a licensed asbestos abatement contractor. High-volume air clearance sampling was conducted by the licensed asbestos abatement contractor in all homes that were cleaned. Once the home was cleared for occupancy, based on the asbestos contractor’s clearance samples, the home occupants were notified (Figure 8).

Figure 8: Process Overview



SECTION 4: ASBESTOS TESTING – RESULTS AND CONCLUSIONS

Bulk and Baseline Sampling Results

Bulk/baseline sampling was conducted in 46 homes. Of these homes, 16 were weatherized without the need for prior cleaning and 21 were cleaned and cleared by air sampling prior to weatherization. Nine of the homes included in the bulk/baseline assessments were not weatherized for the following reasons: five of the homeowners or renters did not meet economic qualifications, one home could not be feasibly cleaned prior to weatherization, two homeowners requested to be dropped from the study, and one homeowner passed away prior to scheduling weatherization.

Bulk sampling results for the 37 homes that were weatherized are presented in Table 3. Vermiculite insulation was present in 33 of the 37 homes. Vermiculite insulation was most commonly found in the attic; one home contained vermiculite insulation in two walls. All bulk samples of vermiculite insulation analyzed contained asbestos. Twenty-six samples of bulk non-vermiculite ACM were collected in these homes. Seventeen of these samples contained greater than one percent asbestos. The majority of positive bulk non-vermiculite ACM samples were collected in basement areas and were chrysotile-based thermal system insulation (TSI) materials. Seven homes contained both vermiculite insulation and other non-vermiculite ACM, while four homes contained only non-vermiculite ACM.

Baseline high-volume air sampling results are presented in Table 4. One hundred ninety-nine high-volume air samples (excluding field blanks) were collected in the 37 homes prior to weatherization. All of the air samples were initially analyzed by PCM (column 4). The mean PCM concentration for these samples was 0.016 f/cc, standard deviation (SD) = 0.014 (not shown in Table 4). Samples with PCM concentrations greater than the clearance concentration of 0.01 f/cc were further analyzed by TEM (column 5). If none of the samples from an individual home sample set exceeded this value, then the two highest PCM samples were selected for TEM analysis.

One hundred thirty three (67%) of the PCM samples were analyzed by TEM. Of these, 12 (9%) samples revealed detectable levels of asbestos. These 12 samples were collected in eight separate homes. None of the samples analyzed by TEM exceeded the clearance concentration of 0.01 s/cc (or 70 s/mm^2).

Table 3: Bulk Sampling Results – Vermiculite Insulation and Other Non-Vermiculite Asbestos Containing Materials (ACM)

Home	Vermiculite attic insulation (present)	Asbestos present in Vermiculite Insulation	Non-Vermiculite Asbestos Containing Material (ACM		
			Number of bulk non-vermiculite ACM samples collected	Number of bulk non vermiculite ACM samples containing asbestos	Location & Analytical Results (%) from non-vermiculite ACM analyzed by PLM
IN-0102	PRESENT	PRESENT	0	0	N/A[1]
IN-0101	PRESENT	PRESENT	0	0	N/A
NS-7400	NO	N/A	5	3	Basement TSI: 30-40% Chrysotile Boiler Room: 50-60% Chrysotile Basement TSI: 30-40% Chrysotile
NS-7280	NO	N/A	3	3	Basement TSI: 40-50% Chrysotile Basement TSI: 60-70% Chrysotile Outside Siding: 10-20% Chrysotile
NS-7368	PRESENT	PRESENT	1	0	N/D[2]
ND-7968	PRESENT	PRESENT	3	1	Basement TSI: 31-40% Chrysotile
ND-7967	PRESENT	PRESENT	3	2	Basement TSI: 40-50% Chrysotile Basement Furnace: 40-50% Chrysotile
NS-7969	PRESENT	PRESENT	0	0	N/A
ASB-8093	NO[3]	N/A	0	0	N/A
ASB-8092	PRESENT	PRESENT	0	0	N/A
ASB-8091	PRESENT	PRESENT	2	0	ND
ASB-8846	PRESENT	PRESENT	0	0	N/A
ASB-8848	PRESENT	PRESENT	0	0	N/A
ASB-8863	PRESENT	PRESENT	1	0	ND
ASB-9196	NO	N/A	1	1	Basement TSI: 30-40% Chrysotile
ASB-9193	PRESENT	PRESENT	0	0	N/A
ASB-9194	NO	N/A	1	1	Basement TSI: 60-70% Chrysotile

Table 3: Bulk Sampling Results – Vermiculite Attic Insulation and Other non- Vermiculite Asbestos Containing Materials (ACM)(continued)					
Home	**Vermiculite attic insulation (present)**	**Asbestos present in Vermiculite Insulation**	**Number of bulk non-vermiculite ACM samples collected**	**Number of bulk non vermiculite ACM samples containing asbestos**	**Location & Analytical Results (%) from non vermiculite ACM analyzed by PLM**
ASB-9195	PRESENT	PRESENT	0	0	N/A
ASB-9637	PRESENT	PRESENT	0	0	N/A
ASB-9638	PRESENT	PRESENT	0	0	N/A
ASB-9636	PRESENT	PRESENT	0	0	N/A
ASB-9639	PRESENT	PRESENT	0	0	N/A
NS-6867	PRESENT	PRESENT	0	0	N/A
ASB-10165	PRESENT	PRESENT	2	2	Outside Siding: 10-20% Chrysotile Basement TSI: 40-50% Chrysotile
ASB-10168	PRESENT	PRESENT	0	0	N/A
ASB-10167	PRESENT	PRESENT	0	0	N/A
ASB-10372	PRESENT	PRESENT	1	1	Basement TSI: 60-70% Chrysotile
ASB-9283	PRESENT	PRESENT	1	1	Basement TSI: 60-70% Chrysotile
ASB-10586	PRESENT	PRESENT	0	0	N/A
ASB-10369	PRESENT	PRESENT	0	0	N/A
ASB-9056	PRESENT	PRESENT	1	1	Basement TSI: 60-70% Chrysotile
ASB-10651	PRESENT	PRESENT	0	0	N/A
ASB-10648	PRESENT	PRESENT	0	0	N/A
ASB-10399	PRESENT	PRESENT	0	0	N/A
ASB-10649	PRESENT	PRESENT	0	0	N/A
ASB-10587	PRESENT	PRESENT	1	1	Basement TSI: 40-50% Chrysotile
ASB-10585	PRESENT	PRESENT	0	0	N/A

[1]N/A= no samples analyzed; [2]ND= none detected; [3] vermiculite attic insulation was not present; however, vermiculite was identified in the walls.

Table 4: Baseline High-Volume Air Sample Results Analyzed by PCM and TEM

Home Identifier	Number of Air Samples Collected	Location of Samples	PCM Concentration (f/cc)	TEM Concentration (s/mm^2), (s/cc)
IN-0102	5	Kitchen	0.061	<AS
		N. Bedroom	0.015	
		Living Room	0.052	
		S. Bedroom	0.067	<AS
		Upstairs Bedroom	0.040	
IN-0101	6	S. Bedroom	0.012	<AS
		Upstairs E. Bedroom	0.011	<AS
		Upstairs W. Bedroom	0.009	
		Kitchen	0.008	
		Living Room	0.006	
		Computer Room	0.009	
NS-7400	6	Living Room	0.013	
		Kitchen	0.017	
		Bedroom	0.016	
		Upstairs	0.029	<AS
		E. Living Room	0.022	<AS
		Basement	0.004	
NS-7280	5	Laundry Room	0.025	<AS
		Entry	0.013	
		Living Room	0.020	
		Kitchen	0.020	<AS
		Basement	0.018	
NS-7368	5	Kitchen	0.009	<AS
		W. Bedroom	0.007	<AS
		Living Room	0.005	
		E. Bedroom	0.006	
		Bathroom	0.003	
ND-7968	5	Kitchen	0.007	
		Living Room	0.009	<AS
		N. Bedroom	0.003	
		W. Bedroom	0.01	<AS
		Crawl Space	0.004	
ND-7967	6	W. Bedroom	0.013	<AS
		Kitchen	0.013	<AS
		SE Bedroom	0.011	20.00, 0.0044
		S. Bedroom	0.009	
		Living Room	0.014	
		Basement	0.010	

Table 4: Baseline High-Volume Air Sample Results Analyzed by PCM and TEM (continued)

Home Identifier	Number of Air Samples Collected	Location of Samples	PCM Concentration (f/cc)	TEM Concentration (s/mm^2), (s/cc)
NS-7969	6	Bedroom off Living Room	0.009	
		N Living Room	0.012	<AS
		Bedroom of Kitchen	0.011	<AS
		Kitchen	0.006	
		New S Living Room	0.007	
		Bedroom off S Living Room	0.009	
[2]ASB-8093	5	NE Bedroom	0.017	<AS
		Living Room	0.019	<AS
		NW Bedroom	0.018	<AS
		Kitchen	0.021	<AS
		Upstairs Bedroom	0.017	<AS
ASB-8092	5	Kitchen	0.013	<AS
		Living Room	0.016	<AS
		Bedroom	0.018	<AS
		Bathroom	0.011	<AS
		Glass Workroom	0.015	<AS
ASB-8091	5	Living Room	0.007	<AS
		Kitchen	0.007	<AS
		Adult Bedroom Upstairs	0.006	
		SE bedroom Upstairs	0.005	
		NE bedroom Upstairs	0.006	
ASB-8846	5	Storage Room	0.011	<AS
		Bathroom	0.007	
		N. Bedroom	0.007	
		Living Room	0.009	<AS
		Kitchen	0.005	
ASB-8848	6	NE Bedroom	0.013	<AS
		SW Bedroom	0.007	
		Kitchen	0.012	<AS
		Living Room	0.010	<AS
		SE Bedroom	0.011	<AS
		S Bedroom	0.008	
ASB-8863	5	N Bedroom	0.033	<AS
		Kitchen	0.025	<AS
		S Bedroom	0.025	<AS
		Living Room	0.018	<AS
		Basement	0.016	<AS

Table 4: Baseline High-Volume Air Sample Results Analyzed by PCM and TEM (continued)

Home Identifier	Number of Air Samples Collected	Location of Samples	PCM Concentration (f/cc)	TEM Concentration (s/mm^2), (s/cc)
ASB-9196	6	Basement Bedroom	0.007	<AS
		Living Room	0.004	
		Kitchen	0.004	
		Basement Near Water Heater	0.007	<AS
		Main floor child’s bedroom	0.003	
		Main adult bedroom	0.004	
ASB-9193	6	Kitchen	0.005	
		Basement Living Room	0.008	<AS
		Main Floor Computer Room	0.002	
		Main Floor Living Room	0.006	
		Main Floor Bedroom	0.002	
		Basement Laundry Room	0.008	<AS
ASB-9194	5	Main Floor Bedroom	0.008	<AS
		Living Room	0.005	
		Basement Bedroom	0.006	<AS
		Basement Radio Room	0.005	
		Kitchen	0.005	
ASB-9195	5	Basement	0.003	
		Main floor back Bedroom	0.006	31.75, 0.0096
		Living Room	0.004	
		Kitchen	0.004	
		Main Floor Front Bedroom	0.008	31.75, 0.0096
ASB-9637	6	Downstairs Storage Room	0.014	<AS
		Kitchen	0.009	
		Upstairs Living Room	0.015	<AS
		S E Bedroom	0.019	<AS
		Downstairs Living Area	0.015	<AS
		Upstairs Hallway	0.016	<AS
ASB-9638	5	Living Room	0.014	<AS
		Kitchen	0.013	<AS
		Extra Bedroom	0.013	<AS
		Bedroom	0.014	<AS
		Basement	0.008	

Table 4: Baseline High-Volume Air Sample Results Analyzed by PCM and TEM (continued)

Home Identifier	Number of Air Samples Collected	Location of Samples	PCM Concentration (f/cc)	TEM Concentration (s/mm^2), (s/cc)
ASB-9636	5	Entrance/Utility Room	0.012	<AS
		Basement	0.019	31.75, 0.0096
		W Bedroom	0.015	<AS
		S Bedroom	0.016	<AS
		Kitchen	0.014	<AS
ASB-9639	5	Laundry Room	0.012	<AS
		Living Room	0.012	<AS
		Kitchen	0.011	<AS
		Sun Room	0.008	
		Bedroom	0.007	
NS-6867	6	Living Room	0.027	<AS
		Kitchen	0.022	15.87, 0.0046
		Downstairs Laundry	0.017	<AS
		Bedroom	0.021	<AS
		Upstairs S Bedroom	0.022	<AS
		Upstairs N Bedroom	0.020	<AS
ASB-10168	6	Kitchen	0.049	<AS
		E Bedroom	0.033	31.75, 0.0096
		Main Floor Living Room	0.055	<AS
		E Basement	0.019	15.87, 0.0047
		W Basement	0.014	31.75, 0.0094
		Upstairs	0.046	15.87, 0.0047
ASB-10167	4	Pantry	0.016	<AS
		Kitchen	0.011	<AS
		Living Room	0.012	<AS
		Bedroom	0.005	
ASB-10372	6	Upstairs	0.009	<AS
		Living Room	0.006	
		Downstairs	0.003	
		Front Bedroom	0.005	
		Kitchen	0.006	<AS
		Back Bedroom	0.006	

Table 4: Baseline High-Volume Air Sample Results Analyzed by PCM and TEM (continued)				
Home Identifier	**Number of Air Samples Collected**	**Location of Samples**	**PCM Concentration (f/cc)**	**TEM Concentration (s/mm^2), (s/cc)**
ASB-9283	6	Bedroom	0.008	
		Upstairs Bedroom	0.010	<AS
		Sewing Room	0.006	
		Kitchen	0.006	
		Apartment	0.002	
		Living Room	0.010	<AS
ASB-10586	6	Living Room	0.072	<AS
		Parents Bedroom	0.084	<AS
		Childs Bedroom	0.075	<AS
		Downstairs by washer	0.040	<AS
		Kitchen	0.023	<AS
		Downstairs Bedroom	0.034	15.87, 0.0047
ASB-10369	5	Garage	0.012	<AS
		Bedroom	0.035	<AS
		Living Room	0.044	<AS
		Basement	0.013	<AS
		Kitchen	0.042	<AS
ASB-9056	6	Bedroom next to bath	0.048	<AS
		Girl's Bedroom	0.015	<AS
		Bedroom off living room	0.020	<AS
		Living Room	0.013	<AS
		Parents Bedroom	0.026	<AS
		Kitchen	0.019	<AS
ASB-9056	5	Childs Bedroom	0.017	<AS
		Basement	0.006	
		Kitchen	0.018	<AS
		Living Room	0.023	<AS
		Parents Bedroom	0.015	<AS
ASB-10651	5	Childs Bedroom	0.016	<AS
		Mother's Bedroom	0.014	<AS
		Basement	0.011	<AS
		Living Room	0.016	13.61, 0.0043
		Kitchen	0.013	<AS
ASB-10648	5	Parents Bedroom	0.036	<AS
		Kitchen	0.036	<AS
		Basement	0.012	<AS
		Living Room	0.075	<AS
		Basement	0.014	<AS

Table 4: Baseline High-Volume Air Sample Results Analyzed by PCM and TEM (continued)				
Home Identifier	**Number of Air Samples Collected**	**Location of Samples**	**PCM Concentration (f/cc)**	**TEM Concentration (s/mm^2), (s/cc)**
ASB-10399	6	Basement Living Area	0.036	<AS
		Basement Bedroom	0.022	<AS
		Bedroom by front door	0.019	<AS
		Living Room	0.033	<AS
		Bedroom by kitchen	0.022	<AS
		Kitchen	0.027	<AS
ASB-10649	4	Kitchen	0.008	
		Living Room	0.006	
		Main Bedroom	0.010	<AS
		Child's Bedroom	0.008	<AS
ASB-10587	6	Downstairs Living Area	0.026	<AS
		Downstairs bedroom	0.018	<AS
		Office Upstairs	0.024	<AS
		Kitchen	0.034	19.05, 0.0049
		Upstairs Bedroom	0.030	<AS
		Living Room	0.019	<AS
ASB-10585	5	Spare Bedroom	0.014	<AS
		Kitchen	0.012	<AS
		Basement	0.007	
		Living Room	0.026	<AS
		Main Bedroom	0.011	<AS

*<AS- below analytical sensitivity of one asbestos structure in total area analyzed

One hundred eleven baseline micro-vacuum samples were collected in the 37 homes on porous surfaces not suitable for surface wipe sampling. Baseline micro-vacuum sample results are presented in Table 5. Of the 111 samples, 14 (12.6%) revealed detectable asbestos concentrations. Three samples (3%) revealed asbestos concentrations greater than the background surface concentration of 10,000 s/cm^2 adopted for this project. These three samples were collected in three separate homes.

Baseline surface wipe sample results are presented in Table 6. Asbestos was detected in surface dust in all 37 homes. Excluding field blanks, 155 surface wipe samples were collected in the 37 homes prior to weatherization and analyzed by TEM. One hundred two (52%) of these samples revealed detectable levels of asbestos (column 3), while 27 (14%) of the total wipe samples collected revealed asbestos concentrations greater than the background surface concentration of 10,000 s/cm^2 adopted for this project (column 7). The wipe samples with concentrations above the background concentration were collected in 20 separate homes. These 20 homes were cleaned by a licensed asbestos abatement contractor and cleared by air sample results prior to weatherization. In terms of individual asbestos structure counts reported by the laboratory, 585 structures were chrysotile and 14 asbestos structures were amphiboles (column 7).

Table 5: Baseline Micro-Vacuum Sample Results from TEM Analysis in Structures/cm^2 for Asbestos Concentrations <5 µm and >5 µm in Length

Home	Samples Collected (n=)	Samples with Detectable Asbestos Structures (n=)	Sample Location	Total Asbestos <5 um s/cm²	Total Asbestos ≥5 um s/cm²	Total Asbestos (s/cm²)
IN-0102	3	0	All samples <LOD[1]			
IN-0101	2	1	Main Floor dining room, TV room floor, bottom of stairway, computer room floor	224 [2]C=1	<LOD	224
NS-7400	2	1	Main Floor in front of basement door, E. side & center of living room floor	3,763 C=14	<LOD (269) C=1	4,031
NS-7280	2	1	Living Room chair, entry room floor & couch, living room floor, NE bedroom floor & chair	448 C=3	149 C=1	597
NS-7368	4	0	All samples <LOD			
ND-7968	1	1	Main Floor carpet, living room couch, W. bedroom carpet	597 C=2	<LOD	597
ND-7967	2	1	Dining Room carpet, living room recliner, hallway carpet	<LOD C=1	<LOD	299
NS-7969	4	1	Floor in bedroom off kitchen	1024 C=2	<LOD	1024
ASB-8093	2	0	All samples <LOD			
ASB-8092	3	0	All samples <LOD			
ASB-8091	2	0	All samples <LOD			
ASB-8846	4	1	Carpets in kitchen & storage room	3,128 C=11	<LOD (285) C=1	3,413
ASB-8848	5	1	Upstairs Bedroom carpet	2,133 C=5	<LOD (427 x 2) C=2	2,986
ASB-8863	3	0	All samples <LOD			
ASB-9196	4	1	Top of laundry room shelf in basement	<LOD (213 x 2) C=2	<LOD	427

Table 5: Baseline Micro-Vacuum Sample Results from TEM Analysis in Structures/cm^2 for Asbestos Concentrations <5 µm and >5 µm in Length (continued)

Home	Samples Collected (n=)	Samples with Detectable Asbestos Structures (n=)	Sample Location	Total Asbestos <5 s/cm²	Total Asbestos ≥5 s/cm²	Total Asbestos (s/cm²)
ASB-9193	4	0	All samples <LOD			
ASB-9194	4	0	All samples <LOD			
ASB-9195	1	0	All samples <LOD			
ASB-9637	4	1	SE. bedroom under attic access & at base of bed	2,133 C=5	<LOD	2,133
ASB-9638	3	0	All samples <LOD			
ASB-9636	4	1	Basement by furnace door & in living area under light fixture	21,500 C=21	5,119 C=5	26,619
ASB-9639	2	0	All samples <LOD			
NS-6867	4	0	All samples <LOD			
ASB-10165	4	1	Carpets in basement	30,714 C=6	<LOD (5119) C=1	35,833
ASB-10168	2	0	All samples <LOD			
ASB-10167	3	0	All samples <LOD			
ASB-10372	5	0	All samples <LOD			
ASB-9283	4	0	All samples <LOD			
ASB-10586	1	0	All samples <LOD			
ASB-10369	3	0	All samples <LOD			
ASB-9056	3	0	All samples <LOD			
ASB-10651	3	1	Basement stair & on basement carpet under light fixture	52,693 C=10	<LOD	52,693
ASB-10648	3	0	All samples <LOD			
ASB-10399	4	1	Basement stair & in living area under light fixture	4,216 C=4	<LOD	4,216
ASB-10649	2	0	All samples <LOD			
ASB-10587	2	0	All samples <LOD			
ASB-10585	3	0	All samples <LOD			

[1]<LOD- 4 structures/Filter Area Analyzed; [2]Chrysotile asbestos fiber counts

Table 6: Baseline Surface Wipe Sample Results Reported by Home, Location of Samples, Asbestos Structures, Type of Asbestos Detected, and Concentration <5 µm and >5 µm in s/cm² by TEM Analysis

Home	Total Samples Collected (n=)	Total Samples with Detectable Asbestos Structures (n=)	Sample Location	Asbestos Concentration <5µm (s/cm²)	Asbestos Concentration ≥5µm (s/cm²)	Total Asbestos Concentrations (s/cm²) Asbestos Structure Counts (n=) Asbestos Structure Morphology (AT[1], LA[2],C[3])
IN-0102	4	2	Main Floor Bedroom Upstairs Bedrooms	<AS[4] 689	448 <AS	448;1-AT 689;1-AT
IN-0101	3	1	Kitchen/S Bedroom	448	<AS	448;1-C
NS-7400	5	3	Kitchen Upstairs Water Heater	<AS 1,706 34,400	448 853 11,825	448;1-LA 2,560;2-C;1-LA 46,225;31-C;11-C
NS-7280	5	4	E Bedroom Kitchen/Bath Laundry/S Bed Water Heater	448 896 1,194 122,000	<AS 448 <AS 35,833	448;1-C 1,344;2-C;1-C 1,194;1-C 207,833;48-C;10-C
NS-7368	5	2	W Bedroom Bathroom	640 427	<AS <AS	640;1-C 427;1-C
ND-7968	4	4	Kitchen N Bedroom W Bedroom Crawl Space	6,202 448 689 1,737,917	2,067 448 <AS 394,167	8,269;9-C;3-C 896;1-C;1-C 689;1-C 2,132,083;97-C;22-C
ND-7967	4	2	Kitchen Basement	448 64,500	<AS 10,750	448;1-C 75,250;24-C;4-C
NS-7969	5	1	Bedrooms	427	<AS	427;1-C
[2]ASB-8093	4	1	Bathroom/Upstairs	8,063	<AS	8,063;3-C
ASB-8092	5	2	Living Room Bathroom	7,525 1,075	2,150 2,150	9,675;5-C;2-AT, 3,225;1-C;2-C
ASB-8091	5	1	Bedrooms	1,280	<AS	1,280;2-C
ASB-8846	5	3	N Bedroom Kitchen Laundry Room	427 853 1,861	<AS 427 931	427;1-AT 1,280;2-AT;1-AT 2,792;2-C;1-C
ASB-8848	8	4	S Bedroom Living Room Laundry Room Upstairs Shelving	2,560 1,706 1,706 853	640 <AS <AS <AS	3,199;4-C;1-C 1,706;1-C 1,706;4-C 853;1-C;1-AT

Table 6: Baseline Surface Wipe Sample Results Reported by Home, Location of Samples, Asbestos Structures, Type of Asbestos Detected, and Concentration <5 µm and >5 µm in s/cm^2 by TEM analysis (continued)

Home	Total Samples Collected (n=)	Total Samples with Detectable Asbestos Structures (n=)	Sample Location	Asbestos Concentration <5µm (s/cm^2)	Asbestos Concentration ≥5µm (s/cm^2)	Total Asbestos Concentrations (s/cm²) Asbestos Structure Counts (n=) Asbestos Structure Morphology (AT, LA,C)
ASB-8863	8	4	N Bedroom Living Room Basement Water Heater	<AS 427 44,792 20,476	853 <AS 19,196 40,952	853;2-C 427;1-AT 61,429;7-C;3-C 61,429;1-C;2-C
ASB-9196	5	3	Bedrooms Basement Basement Room	1,024 47,095 8,532	<AS 3,071 5,119	1,024;1-C 51,167;45-C;1-A;3-C 13,651;5-C;3-C
ASB-9193	6	3	Attic Stairs Living Roo Main floor computer and bedroom	5,119 512 1706	<AS <AS <AS	5,119;1-C 512;1-C 1,706: 4-C
ASB-9194	5	2	Bedrooms Downstairs	2,925 2,560	<AS 7,679	2,925;5-C;1-AT 10,238;1-C;3-C
ASB-9195	6	3	Living Room Water Heater Basement	853 552,860 3,839	<AS 22,524 1,706	853;2-C 77,810;27-C;11-C 5,546;9-C;4-C
ASB-9637	7	5	Bedroom Bedrooms Downstairs Downstairs Water Heater	1,024 5,119 4,607 10,238 5,119	1,024 <AS 1,024 10,238 5,119	2,048;1-C;1-C 5,119;1-C 5,631;9-C;2-C 20,476;2-C;2-C 10,238;1-C;1-C
ASB-9638	5	2	Water Heater Basement	853 3,413	<AS 3,413	853;1-C 6,825;4-C;4-C
ASB-9636	6	1	Basement	2,986	427	3,413;7-C;1-C
ASB-9639	4	1	Kitchen	1,024	<AS	1,024;1-C
NS-6867	5	2	Kitchen Water Heater	14,077 4,095	1,280 2,048	15,357; 33-C, 3 C 6,143;4-C;2-C

Table 6: Baseline Surface Wipe Sample Results Reported by Home, Location of Samples, Asbestos Structures, Type of Asbestos Detected, and Concentration <5 µm and >5 µm in s/cm^2 by TEM analysis (continued)

Home	Total Samples Collected (n=)	Total Samples with Detectable Asbestos Structures (n=)	Sample Location	Asbestos Concentration <5µm (s/cm^2)	Asbestos Concentration ≥5µm (s/cm^2)	Total Asbestos Concentrations (s/cm²) Asbestos Structure Counts (n=) Asbestos Structure Morphology (AT, LA,C)
ASB-10165	7	6	Kitchen	1,706	853	2,560;2-C;1-C
			Bathroom	30,714	15,357	46,071;12-C;6-C
			Bedroom	6,825	1,706	8,832;4-C;1-C
			Water Heater	61,429	20,476	81,905;6-C;2-C
			Basement	17,063	23,889	40,952;4-C;1-AT
			W Bedroom	1,706	<AS	1,706;1-C;1-AT
ASB-10168	4	1	Bedroom	8,532	<AS	8,532;1-C
ASB-10167	6	5	Living Room	853	<AS	853;2-C
			Kitchen	1,280	<AS	1,280;2-C
			Bedrooms	640	640	1,280;1-C;1-C
			Downstairs	143,335	5,119	148,452;26-C;1-C
			Water Heater	2,560	<AS	2,560;3-C
ASB-10372	6	3	Sewing Room	2,560	<AS	2,560;4-C
			Kitchen	2,560	<AS	2,560;4-C
			Bathroom	1,024	<AS	1,024;1-C
ASB-9283	7	7	Kitchen	10.238	<AS	10,238;10-C
			Bedroom	1,024	<AS	1,024;2-C
			Parents Bedroom	5,119	<AS	5,119;5-C
			Living Room	4,266	<AS	4,266,5-C
			Water Heater	<AS	51,190	51,190;1-C
			Basement	26,619	2,048	26,667;13-C;1-C
			Basement Room	2,048	1,024	3,071;2-C;1-C
ASB-10586	5	1	Water Heater	4,095	2,048	6,143;4-C;2-C
ASB-10369	5	2	Living Room	2,560	<AS	2,560;3-C
			Water Heater	18,429	6,143	24,571;9-C;3-C
ASB-9056	6	5	Living Room	1,706	<AS	1,706;2-C
			Parents Room	4,875	975	5,850;5-C;1-C
			Kitchen	8,190	<AS	8,190;4-C
			Water Heater	71,667	51,190	122,857;7-C;5-C
			Basement	1,706	853	2,560;2-C;1-C

Table 6: Baseline Surface Wipe Sample Results Reported by Home, Location of Samples, Asbestos Structures, Type of Asbestos Detected, and Concentration <5 µm and >5 µm in s/cm^2 by TEM analysis (continued)

Home	Total Samples Collected (n=)	Total Samples with Detectable Asbestos Structures (n=)	Sample Location	Asbestos Concentration <5µm (s/cm^2)	Asbestos Concentration ≥5µm (s/cm^2)	Total Asbestos Concentrations (s/cm²) Asbestos Structure Counts (n=); Asbestos Structure Morphology (AT, LA,C)
ASB-10651	5	1	Water Heater	69,037	4,931	73,968;14-C;1-C
ASB-10648	5	4	Bedrooms Kitchen Water Heater Basement	1,644 881 7,890 4,931	<AS <AS 3,945 <AS	1,644;2-C 881;1-C 11,835;4-C;2-C 4,931;3-C
-ASB-10399	6	4	Living Room Bedrooms Water Heater Basement	1,233 1,233 12,328 1,233	1,233 <AS 2,466 <AS	2,466;1-C;1-C 1,233;1-C 14,794;5-C;1-C 1,233;1-C
ASB-10649	5	3	Living Room Kitchen Bathroom	8,532 10,238 51,190	<AS <AS <AS	8,532;1-C 10,238;1-C 51,190;-1-C
ASB-10587	4	2	Living Room Water Heater	2,560 696,190	<AS 143,333	2,560;1-C 839,524;34-C;7-C
ASB-10585	5	3	Living Room Bedrooms Water Heater	914 5,119 2,844	<AS <AS <AS	914;1-C 5,119;1-C 2,844;3-C

AT[1] =Actinolite-Tremolite; LA[2] = Libby Amphibole; C[3] = Chrysotile; [4]<AS=- below analytical sensitivity of one asbestos structure in total area analyzed;

Weatherization Measure Sampling Results

Weatherization High-Volume Air Sampling Results

The weatherization measures performed during this project can be categorized into six main categories: home auditing/initial blower door, sealing penetrations into attic, adding attic/kneewall insulation, adding wall insulation, final blower door and miscellaneous activities (window/door replacement, adding bathroom fan, installing basement batting, adding attic vents and cleanup). During the performance of the weatherization measures by the HRC crew, detailed field notes of the work were kept by the researchers. Based on the field notes, the six categories of weatherization measures were further divided into 16 different activities: audit, initial blower door, sealing penetrations in attic, attic blow-in, drilling holes in exterior walls, drilling holes in interior walls, exterior wall blow-in, interior wall blow-in, final blower door, HEPA vacuuming, basement batting installation, attic batting installation, door work, window work, and miscellaneous activities which included adding bathroom fan, adding attic vents or mudding access holes.

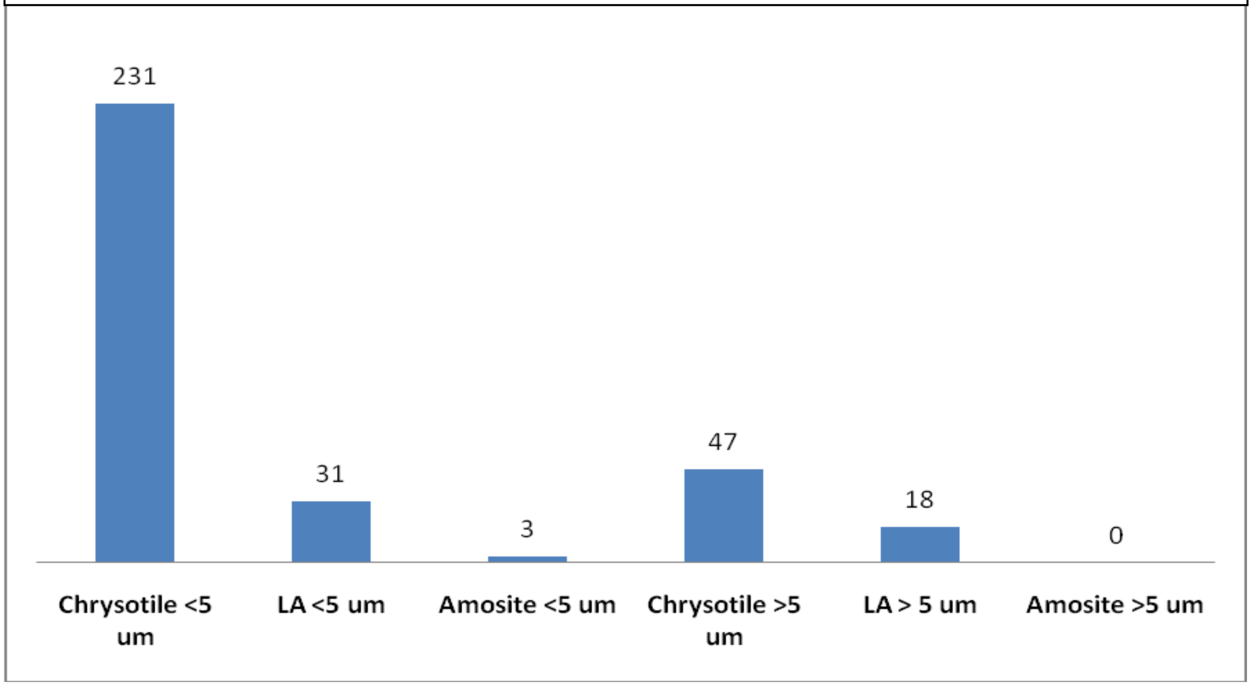
Due to the need to run the high-volume pumps for at least two hours to meet the minimum required air volume sample (1200 liters), several weatherization activities often were performed during the collection of individual high-volume air samples. Therefore, the results from the high-volume samples may be influenced by more than one weatherization activity. Based on a review of high-volume air sampling results and field notes, the weatherization activities that were most likely to generate airborne asbestos fibers were attic blow-in, sealing penetrations in attics, drilling holes in interior walls, interior wall blow-in, and basement batting installation.

Table 7: Airborne Asbestos Detected During Weatherization

	Number of Homes	%
Homes Weatherized	37	100%
Homes with Detectable Concentrations of Asbestos	28	76%
Chrysotile Detected	26	70%
Libby Amphibole Detected	14	38%
Libby Amphibole & Chrysotile Detected	11	30%

Airborne asbestos was detected in high-volume samples in 28 of the 37 homes weatherized. Of these, chrysotile asbestos was detected in the air in 26 homes, and Libby amphibole (including actinolite-tremolite), was detected in 14 homes. Eleven homes had both Libby amphibole (LA) asbestos and chrysotile detected in the air during weatherization activities. LA was detected alone, without the presence of chrysotile, in air samples in three homes. Amosite asbestos, probably associated with TSI, was detected in three air samples from two different homes. Figure 9 below shows the asbestos fiber counts by type and fiber length of asbestos detected in high-volume air samples during weatherization activities. The most common type of asbestos detected in high-volume air samples was chrysotile, and the majority of fibers detected were less than 5 um in length.

Figure 9. Asbestos Fiber Counts by Type and Length of Asbestos Detected in High-Volume Air Samples



Summary statistics for the high-volume air sample results are shown below in Table 8. The 688 high-volume air samples (excluding field blanks) collected in the 37 homes during weatherization measures were analyzed by PCM. The mean PCM concentration for these samples was 0.053 f/cc, with a standard deviation (SD) of 0.0157 and a maximum concentration of 10.22 f/cc. Samples with PCM concentrations greater than the clearance concentration of 0.01 f/cc, were further analyzed by TEM. If none of the samples from a single-day sample set exceeded this value, then the two highest PCM samples were selected for TEM analysis.

Five hundred ninety nine (74%) of the PCM samples were analyzed by TEM. Of these, 107 (21%) samples revealed detectable levels of asbestos. The mean TEM concentration for asbestos fibers < 5 um was 0.0048 structures/ cubic centimeter (s/cc) and the mean TEM concentration for asbestos fibers ≥ 5 um was 0.0011 s/cc. The mean TEM concentration for total asbestos structures (< 5 um and ≥ 5 um) was 0.0059. In direct comparison with the high-volume air clearance concentration of ≥ 0.01 s/cc adopted for this project, 14 (2.8% of total) high-volume air samples for asbestos fibers ≥ 5 um long exceeded this clearance concentration. Considering both short (< 5 um) and long (≥ 5 um) asbestos fibers, 69 (13.6%) of the total high-volume air samples exceeded this clearance concentration of ≥ 0.01 s/cc.

Table 8. Weatherization High-Volume Air Sample Summary Statistics

Sample Type	Number of Samples	Mean (s/cc)	SD[1]	Maximum
PCM f/ cc	688	0.0533	0.0157	10.22
TEM s/cc < 5 um	509	0.0048	0.0265	0.4480
TEM s/cc ≥ 5 um	509	0.0011	0.0003	0.1119
TEM Total s/cc	509	0.0059	0.0014	0.5600

[1]Standard Deviation

High-volume air samples were collected and analyzed by TEM for airborne asbestos concentrations during weatherization activities in 37 homes. Table 9 below provides a comparison of mean asbestos concentrations by home, with the homes in column 1, followed by the number of samples per home (N), the mean asbestos concentration in s/cc, standard deviation, and the individual 95% confidence intervals (CI) for the mean based on the pooled standard deviation (0.03097). It is clear from Table 9 that homes ASB-10372 and ASB-10649 had higher mean (statistically significant) asbestos air concentrations (means of 0.04437 and 0.04532 s/cc respectively) than the remaining 35 homes.

Baseline testing in home ASB-10372 found asbestos in the vermiculite insulation and TSI in the basement containing 60-70% chrysotile asbestos, and asbestos was detected in surface dust in three samples below the clearance level of 10,000 s/cm^2 adopted for this research. Baseline high-volume air sampling results were less than the analytical sensitivity for the method. Although home ASB-10372 did not show contamination levels above the clearance level during the baseline testing, an old boiler with associated ACM was dismantled and removed from this home by the home occupants shortly before the weatherization work began. Post-weatherization testing showed asbestos levels beyond established background levels throughout the house. A licensed asbestos abatement contractor cleaned this home by thoroughly HEPA vacuuming and wet-wiping all surfaces in laundry room, back living room, upstairs, kitchen, and bedroom 1. Additionally, the homeowner had removed several boxes of financial records from the attic where vermiculite is present, and brought them into the living space. The asbestos contractor cleaned this documentation by removing contents from boxes under negative pressure, cleaning and wiping the boxes, and HEPA vacuuming the documents. These boxes were then put into a sealed bag. Samples collected after cleaning were found to be within established background levels and the homeowner was allowed to reoccupy the residence.

Table 9. Mean Asbestos Concentrations (s/cc) by Home and Individual 95% Confidence Intervals (CI) for the Mean Based on the Pooled Standard deviation

Home	N[1]	Mean	StDev[2]	Individual 95% CIs For Mean Based on Pooled StDev
				---+---------+---------+---------+------
IN-0102	23	0.00099	0.00233	(----*----)
IN-0101	25	0.00035	0.00122	(----*----)
NS-7400	17	0.00036	0.00148	(-----*-----)
NS-7280	23	0.00138	0.00534	(-----*----)
NS-7368	4	0.00620	0.00481	(-----------*------------)
ND-7968	10	0.00033	0.00104	(-------*-------)
ND-7967	14	0.00000	0.00000	(------*------)
NS-7969	16	0.01068	0.03043	(-----*-----)
ASB-8093	9	0.00000	0.00000	(-------*-------)
ASB-8092	9	0.00164	0.00353	(-------*-------)
ASB-8091	2	0.01135	0.01605	(-----------------*----------------)
ASB-8846	15	0.00272	0.00320	(-----*-----)
ASB-8848	20	0.00000	0.00000	(----*----)
ASB-8863	11	0.00000	0.00000	(------*------)
ASB-9196	24	0.00553	0.00864	(----*----)
ASB-9193	10	0.00040	0.00126	(-------*-------)
ASB-9194	12	0.00113	0.00215	(------*------)
ASB-9195	24	0.00245	0.00521	(----*----)
ASB-9637	17	0.00053	0.00149	(-----*-----)
ASB-9638	12	0.00076	0.00177	(------*------)
ASB-9636	9	0.00090	0.00270	(-------*-------)
ASB-9639	7	0.00163	0.00152	(---------*--------)
NS-6867	12	0.00000	0.00000	(------*------)
ASB-10165	20	0.01084	0.03339	(----*-----)
ASB-10168	11	0.00111	0.00197	(------*-------)
ASB-10167	17	0.00046	0.00135	(-----*-----)
ASB-10372	23	0.04437	0.06944	(----*----)
ASB-9283	5	0.00110	0.00151	(---------*----------)
ASB-10586	4	0.00000	0.00000	(-----------*-----------)
ASB-10369	12	0.00062	0.00145	(------*------)
ASB-9056	14	0.00139	0.00330	(------*-----)
ASB-10651	6	0.00000	0.00000	(---------*---------)
ASB-10648	12	0.00036	0.00124	(------*------)
ASB-10399	12	0.00000	0.00000	(------*------)
ASB-10649	24	0.04532	0.11560	(----*----)
ASB-10587	17	0.00069	0.00163	(-----*-----)
ASB-10585	7	0.00000	0.00000	(--------*--------)
				---+---------+---------+---------+------
				-0.025 0.000 0.025 0.050

[1]Number of samples; [2]Standard Deviation.

Baseline testing in home ASB-10649 found asbestos in the vermiculite insulation but no other non-vermiculite ACM was identified. Baseline high-volume air sampling results were less than the analytical sensitivity for the method. Surface samples from this home found asbestos levels beyond the established background level of 10,000 s/cm^2 on top of a refrigerator in the kitchen and on a shelf in the bedroom. A licensed abatement control contractor cleaned these areas by thoroughly HEPA vacuuming and wet wiping surfaces. Samples collected after cleaning were found to be within established background levels and weatherization crews proceeded with weatherization. Part of the weatherization activities in this home involved tearing out a wall in the front bedroom and installing sheetrock after insulation was installed. This home also contained exterior asbestos siding, and it is likely that the wall cavities were contaminated with surface dust containing asbestos. Post-weatherization testing showed asbestos levels beyond established background levels throughout the home. The licensed asbestos abatement contractor re-cleaned this home by thoroughly HEPA vacuuming and wet-wiping all surfaces in kitchen, living room, bathroom, front and back bedrooms. Extra attention was paid to the front bedroom, where contamination levels were highest. Samples collected after cleaning were found to be within established background levels and the homeowner was allowed to reoccupy the residence.

Other homes with elevated mean airborne concentrations of asbestos detected during weatherization activities include NS-7969, ASB-8091, and ASB-10165, with mean asbestos concentrations of 0.01068, 0.01135 and 0.01084 s/cc, respectively. Baseline testing in home NS-7969 found asbestos in the vermiculite insulation but no other non-vermiculite ACM was identified. Asbestos was detected in surface dust in two samples below the clearance level of 10,000 s/cm^2 adopted for this research, and baseline high-volume air sampling detected airborne asbestos below the clearance level of 0.01 s/cc (70 s/mm^2) in two samples. During weatherization activities in this home, vermiculite insulation was observed penetrating an interior wall when insulation was being blown into the wall from the exterior of the home. Post-weatherization testing showed asbestos levels beyond established background levels throughout the home. A licensed asbestos abatement contractor cleaned this home by thoroughly HEPA vacuuming and wet-wiping all surfaces in bedroom, den, office, kitchen, and living room. Samples collected after cleaning were found to be within established background levels and the homeowner was allowed to reoccupy the residence.

Home ASB-8091 contained asbestos in the vermiculite insulation but no other non-vermiculite ACM was identified. Baseline testing in this home found asbestos in surface dust in one sample below the clearance level of 10,000 s/cm^2 adopted for this project, and baseline high-volume air sampling results were less than the analytical sensitivity for the method. During weatherization activities in this home, small holes were drilled into interior knee wall ceiling to determine if insulation was present. This drilling is suspected to have contributed to one high-volume air sample result (0.0227 s/cc, 228.57 s/mm^2) greater than the clearance level of 0.01 s/cc (70 s/mm^2). It should be noted that the mean asbestos concentration of 0.01135 s/cc is from only two high-volume air samples, one of which was less than the analytical sensitivity for the method and the other (0.0227 s/cc) being above clearance levels. A licensed asbestos abatement contractor cleaned this home by thoroughly HEPA vacuuming and wet -wiping all surfaces in the entire house. This home was very dirty and very cluttered throughout, which made cleaning particularly challenging. Samples collected after cleaning were found to be within established background levels and the homeowner was allowed to reoccupy the residence.

Baseline testing in home ASB-10165 found asbestos in the vermiculite insulation and TSI in the basement containing 10-50% chrysotile asbestos. Asbestos was detected in surface dust in four samples above the clearance level of 10,000 s/cm^2 adopted for this research, and baseline high-volume air sampling detected airborne asbestos below the clearance level of 0.01 s/cc (70 s/mm2) in four samples. Prior to weatherization, a licensed asbestos abatement contractor cleaned the entire basement, the entire upstairs, and the east bedroom on main floor by thoroughly HEPA vacuuming and wet wiping surfaces. Samples collected after cleaning were found to be within established background levels and weatherization crews proceeded with weatherization. Post-weatherization testing showed asbestos levels beyond established background levels throughout the home. The licensed asbestos abatement contractor re-cleaned this home by thoroughly HEPA vacuuming and wet-wiping all surfaces upstairs and on main floor. The licensed asbestos abatement contractor also encapsulated ACM pipe wrap in basement. Samples collected after cleaning were found to be within established background levels and the homeowner was allowed to reoccupy the residence.

Weatherization Personal Breathing Zone Air Sampling Results
Personal breathing zone samples were collected to evaluate the potential asbestos inhalation hazard to weatherization workers associated with this research and to ensure that the appropriate personal protective equipment was selected. Summary statistics for the personal breathing zone sampling results are presented in Table 10 below. Personal breathing zone sampling was conducted for the work periods and was not task-specific.

During the work performed on the 37 homes, a total of 250 samples were collected from the personal breathing zone of four different weatherization crew members. Personal breathing zone samples were collected from the crew leader, the crew leader assistant, the furnace technician and supervisors. The crew leader and his assistant took turns performing the primary weatherization activities; therefore, the majority of samples were collected from these employees. Activities performed by the furnace technician included measuring furnace efficiency, furnace maintenance and new furnace installation when needed. The supervisors performed auditing measures and assisted crew members occasionally.

Personal breathing zone samples collected during the weatherization activities were analyzed for asbestos by PCM and samples with concentrations greater than 0.1 f/ml were analyzed by AHERA TEM. Fibers were observed on most samples analyzed by PCM, excluding field blanks. The NIOSH PCM method cannot identify fiber types (Dodson and Hammar, 2006). A total of 213 personal breathing zone samples were analyzed by TEM. Of the 213 samples analyzed by TEM, 71 samples (33%) showed detectable asbestos concentrations. Of the 71 samples with detectable asbestos concentrations, 38 samples (54%) contained asbestos structures > 5 um in length. Four of the 71 personal breathing zone samples revealed abnormally high asbestos concentrations: 21.5, 20.6, 6.4, and 6.2 asbestos structures per cubic centimeter (s/cc). The personal breathing zone sample with 21.5 s/cc was collected on a worker installing batting in the basement in which a coal furnace was removed a short time before the weatherization work was begun. It is probable that the worker dispersed asbestos fibers that were present in the basement after the removal of the furnace. The personal breathing zone samples with 20.6 and 6.2 s/cc were collected on two different workers performing weatherization activities in the same home. The former personal breathing zone sample (20.6 s/cc) was collected on a worker installing batting in the attic. The latter personal breathing zone sample (6.2 s/cc) was collected on a worker blowing insulation in the attic knee walls and interior walls. The personal breathing zone sample with 6.38 s/cc was collected on a worker blowing attic insulation. Table 11 below shows the summary statistics for the personal breathing zone sample TEM results after removing the four high samples described above.

Table 10. Personal Breathing Zone Sample Summary Statistics – Sample Weighted Mean Concentrations

Sample Type	Number of Samples	Mean (s/cc)	SD1	Maximum (s/cc)
PCM (f/ cc)	250	1.149	2.60	19.95
TEM s/cc < 5 um	213	0.293	0.120	18.60
TEM s/cc $\geq$ 5 um	213	0.0787	0.032	5.37
TEM Total s/cc	213	0.372	0.146	21.50

[1]Standard Deviation

Table 11. Personal Breathing Zone Sample Summary Statistics after Removing Four High Samples – Sample Weighted Mean Concentrations

Sample Type	Number of Samples	Mean (s/cc)	SD1	Maximum (s/cc)
TEM s/cc < 5 um	209	0.0916	0.338	3.70
TEM s/cc $\geq$ 5 um	209	0.0262	0.099	0.79
TEM Total s/cc	209	0.1175	0.378	3.70

[1]Standard Deviation

Weatherization Surface Wipe Sampling Results

A total of 216 surface wipe samples were collected at the conclusion of the weatherization activities in the 37 homes. Asbestos structures were detected in 14.0%, or in 30 of the 216 surface wipe samples. Summary statistics for the surface wipes samples are shown in Table 12 below.

Table 12. Surface Wipe Sample Summary Statistics

Sample Type	Number of Samples	Mean (s/cm2)	SD1	Maximum (s/ cm2)
TEM s/cm^2 < 5 um	216	471	2624	34,127
TEM TEM s/cm^2 $\geq$ 5 um	216	78.8	385.1	3,413
TEM Total TEM s/cm^2	216	534	2911	37,540

[1]Standard Deviation

Surface wipe samples were also collected on sill plates within walls in four homes where wall insulation was being installed from the interior of the home. After wall holes were drilled and before the work crew began blowing the wall insulation, a wipe samples was collected from the sill plate inside the wall cavity. A total of nine sill plate surface samples were collected. All but one sample was positive for asbestos. Of the nine positive samples, chrysotile asbestos was detected in seven samples, and amphibole asbestos (LA and/or amosite) was detected in four samples. The summary statistics for the sill plate surface wipe samples are shown in Table 13. It is clear from the sill plate surface sample results that high levels of asbestos can be present in the wall cavities.

Table 13. Sill Plate Surface Wipe Sample Summary Statistics

Sample Type	Number of Samples	Mean (s/cm2)	SD1	Maximum (s/ cm2)
TEM s/cm^2 < 5 um	9	118,369	137,641	368,571
TEM TEM s/cm^2 $\geq$ 5 um	9	27,693	34,106	97,727
TEM Total TEM s/cm^2	9	146,064	168,142	430,000

[1]Standard Deviation

Conclusions and Discussion

Data collected from the bulk, baseline and weatherization measure sampling on the 37 homes participating in this study are important in terms of planning future weatherization activities in homes with vermiculite insulation and/or other non-vermiculite ACM. The protocols developed for future weatherization activities, presented in Section 2, are based on these research data. Following are conclusions derived from this research.

Vermiculite Insulation is very likely to contain asbestos, especially in Montana.
Thirty-three of the 37 homes participating in this study contained vermiculite insulation. In most cases, this insulation was present in the attic, while one home contained the insulation in two walls. Another home that was dropped from the study also contained vermiculite in walls. Bulk sampling and PLM analysis of the 33 vermiculite insulation samples revealed the presence of asbestos in all samples. Since Zonolite Mountain produced nearly 80% of the world's vermiculite supply from the 1920s to 1990, there is

a high likelihood that vermiculite, in Montana homes especially, was derived from Zonolite Mountain. The presence of asbestos in project vermiculite bulk samples strengthens this hypothesis.

Bulk sampling of vermiculite insulation and non-vermiculite ACM should be performed in homes with suspect asbestos materials. Bulk sampling of non-vermiculite ACM was most commonly obtained from thermal system insulation sources, with asbestos concentrations ranging from 30% to 70%. There were several instances where chrysotile asbestos was detected in the living space of a home despite non-vermiculite ACM sources not being identified. This is most likely associated with historic asbestos sources in the home that may have been replaced in remodeling projects (furnaces and ductwork with TSI, flooring materials, etc).

Air and surface sampling methods are recommended as baseline indices to assess potential living space contamination prior to initiating future weatherization measures in homes with vermiculite insulation and/or non-vermiculite ACM. Baseline air sampling conducted in the 37 homes revealed detectable concentrations of asbestos in eight homes; however, none of the baseline air sample concentrations exceeded the clearance concentration of 0.01 s/cc. Baseline surface wipe samples revealed detectable levels of asbestos in all 37 homes. Twenty homes revealed baseline surface wipe concentrations above the background concentration of 10,000 s/cm^2 adopted for this project. Baseline surface microvac sampling revealed consistently lower concentrations of asbestos than the surface wipe samples with three homes revealing baseline surface microvac concentrations above the background concentration of 10,000 s/cm^2. The 21 homes that were cleaned by a licensed asbestos abatement contractor prior to weatherization all required cleaning because of surface baseline concentrations, not high-volume air concentrations.

Efforts should be made to identify and seal pathways that would allow fibers from vermiculite and non-vermiculite ACM sources into the living space prior to weatherization activities. While 33 of the 37 homes contained vermiculite insulation, detectable concentrations of amphiboles (the family of asbestos found in Libby vermiculite) were revealed in baseline surface wipe samples from only nine homes. Of the baseline surface wipe samples revealing asbestos concentrations above the adopted background concentration of 10,000 s/cm^2, this surface contamination was due to chrysotile asbestos (asbestos commonly associated with commercial material sources) in 19 of the 20 homes. These data demonstrate that pathways to living spaces from vermiculite insulation and non-vermiculite ACM exist in homes.

Clearance high-volume air sampling is recommended for weatherization measure work performed in homes with vermiculite insulation and/or non-vermiculite ACM. No high-volume baseline air samples revealed asbestos concentrations above the clearance concentration of 0.01 s/cc. However, during some weatherization measure high-volume air sampling, concentrations above this value were recorded. In direct comparison with the high-volume air clearance concentration of $\geq$ 0.01 s/cc adopted for this project, 14 (2.8% of total) high-volume air samples for asbestos fibers $\geq$ 5 um long exceeded this clearance concentration. Considering both short (< 5 um) and long (≥ 5 um) asbestos fibers, 69 (13.6%) of the total high-volume air samples exceeded this clearance concentration of ≥ 0.01 s/cc. This implies that weatherization measures have the ability to disperse asbestos fibers into living spaces in concentrations above the clearance standard adopted for this project.

The weatherization activities that were most likely to generate airborne asbestos fibers were attic blow-in, sealing penetrations in attics, drilling holes in interior walls, interior wall blow-in, and basement batting installation. While the majority (82%) of high-volume weatherization samples did not reveal the presence of asbestos, detectable concentrations of asbestos were identified in high-volume weatherization measure samples from 28 of the 37 homes. One objective of this research was to identify weatherization measures that are most likely to generate airborne asbestos fibers. Statistical analysis evaluating the impact of each weatherization measure was problematic for several reasons including: 1) the variability of asbestos sources from home to home; 2) variability in home construction; 3) the fact that several weatherization measures may have been performed during a high-volume sample duration; and 4) not all weatherization measures were performed in each home or performed for the same duration, etc. It should be noted that window replacements were not performed in houses participating in this project.

Sill plate samples in walls with exterior asbestos siding found with asbestos fibers. Midway through the project, sill plate wipe samples were collected in homes prior to interior wall insulation blow-in. It is important to note that interior wall blow-ins are typically performed when the exterior siding is not conducive to this process, e.g., the home contains asbestos-based exterior siding. It was hypothesized that asbestos may be dispersed into the wall cavity when the siding is applied (typically nailed) or asbestos fibers from vermiculite insulation may migrate into the wall cavity through gravitational forces. A total of nine sill plate surface samples were collected. All but one sample was positive for asbestos. Of the nine positive samples, chrysotile asbestos was detected in seven samples, and amphibole asbestos (Libby Amphibole and/or amosite) was detected in four samples. These data may be useful in explaining the higher asbestos air concentrations associated with wall insulation blow-in measures.

High-volume air sampling, not surface sampling, is recommended for clearance sampling when weatherization work is complete. Surface wipe sampling was an important tool for identifying living space contamination during baseline sampling. All of the homes requiring cleaning by a licensed asbestos abatement contractor prior to weatherization were identified by surface samples. In contrast, the surface samples used to assess the impact of weatherization measures on living spaces revealed detectable concentrations in 30 of 216 samples (14%). Weatherization surface samples revealed a lower percentage of detectable asbestos concentrations than the weatherization high-volume air samples. It is hypothesized that this may be due to the settling durations of dispersed asbestos fibers. Based on these data, high-volume air clearance sampling, not surface sampling, is recommended as clearance indices post-weatherization.

A larger fraction of chrysotile vs. amphibole fibers was found for weatherization air samples. In terms of raw asbestos fiber counts recorded for all weatherization air samples, 84% of the fibers were chrysotile and 16% were amphibole asbestos. As with the baseline sample results, this implies that pathways into living spaces are present from asbestos sources. The larger fraction of chrysotile vs. amphibole fibers is difficult to explain. This may be simply due to the abundance of chrysotile-based residential materials used during the majority of the 20th century.

Personal protective equipment is justified by personal breathing zone sampling. The mean total asbestos sample weighted personal breathing zone concentration reported for weatherization workers during this research was 0.3725 s/cc. For comparison with occupational exposure limits, the mean sample weighted personal breathing zone concentration for asbestos structures greater than 5 microns long was 0.08 s/cc. The personal protective equipment prescribed for this research—half-mask, air-purifying respirator, Tyvek suit, nitrile gloves—was adequate for these conditions. Similar personal protective equipment measures should be prescribed for future weatherization work in homes with vermiculite insulation and/or non-vermiculite ACM. It should also be noted that the highest personal breathing zone concentrations were recorded during attic insulation blow-in and attic insulation installation. Therefore, the respiratory protection prescribed for attic weatherization measure activities was revised midway through the project to a full-face respirator. Similar personal protective recommendations are presented in section 2.

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APPENDIX A: Project Implementation and Participation Information

Appendix A1
Introduction to the Weatherization Assistance Program

The DPHHS administers the Montana Weatherization Assistance Program. Funding for the program is provided by the U.S. Department of Energy Weatherization Assistance Program, the Low Income Heating Energy Assistance Program, and some local utilities. Funds are directed from the Montana Department of Health and Human Services to the local Human Resource Development Councils who implement the weatherization improvements in qualifying homes. According to Kane Quenemoen, the weatherization program administrator with the Montana Department of Health and Human Services, the non-DOE funds are administered by the Human Resource Development Councils in accordance with DOE regulations.

DOE establishes regulations for use of WAP and LIHEAP funds for weatherization. Following is a brief description of the MTWAP.

Montana Weatherization Assistance Program

The Montana Weatherization Assistance Program (WAP) is designed to help low-income residents save fuel and money, while increasing the comfort of their homes. Its mission is to insulate the dwellings of low-income persons, particularly the elderly, persons with disabilities, families with children, high residential energy users, and households with a high energy burden, in order to conserve needed energy and to aid those persons least able to afford higher utility costs.

In order to qualify for this benefit program, residents must be a resident of Montana and meet the following annual income guidelines before taxes:

Persons in Household	Before Tax Annual Income Must Not Exceed
1	$18,200
2	$24,500
3	$30,800
4	$37,100
5	$43,400
6	$49,700
7	$56,000
	$62,300

For larger households, add $5,610 for each additional person in the home.

DOE Weatherization Assistance Program

WAP was created by congress in 1976 to assist low-income families who lacked resources to invest in energy efficiency. WAP is operated in all 50 states, the District of Columbia, Native American tribes, and U.S. Territories. Funds are used to improve the energy efficiency of low-income homes using the most advanced technologies and testing protocols available in the housing industry. The energy conservation resulting from the efforts of state and local agencies helps our country reduce its dependence on foreign oil and decrease the cost of energy for families in need while improving the health and safety of their homes.

WAP is governed by various federal regulations designed to help manage and account for the resources provided by DOE. WAP funding is derived from annual appropriations from Congress. Each year, the Senate and House Interior Appropriations committees decide how much funding to allocate to the Program.

DOE provides funding to states, U.S. overseas territories, and Indian tribal governments, which manage the day-to-day details of the program. These governments, in turn, fund a network of local community action agencies, nonprofit organizations, and local governments that provide these weatherization services in every state, the District of Columbia, U.S. territories, and among Native American tribes.

DOE Weatherization Assistance Program Mission Statement

To reduce energy costs for low-income families, particularly for the elderly, people with disabilities, and children, by improving the energy efficiency of their homes while ensuring their health and safety.

Montana Weatherization Assistance Program Guidelines
The primary goal of the Montana Weatherization Assistance Program is to increase the affordability of residential energy for low-income families by reducing the energy demand for home space heating, appliances, lighting and water heating. It is the intent of the program to accomplish this goal while also assuring that all weatherized houses:

- do not jeopardize human comfort
- provide a safe living environment for family members
- provide a safe work environment for the weatherization crew

To determine which weatherization measure(s) are cost-effective and will be applied to all qualifying homes, a MTWAP Energy Audit is conducted using the following specific audit procedures. Montana's energy audit procedures consist of the following:

- Selection of dwelling units on the basis of actual annual energy consumption, household income and the elderly/handicapped status of occupants
- Thorough on-site inspection and documentation of each dwelling unit including pre- and post- blower door testing, electronic diagnosis of combustion heating devices and an assessment of health, safety and technical barriers that may exist
- Development of work specifications and labor and material cost estimates for candidate measures

• Application of the Montana Computerized Energy Audit as a means of selecting and prioritizing actual measures from the list of candidate measures. The State of Montana requires a site-specific computerized energy audit for each dwelling unit weatherized.

Weatherization providers are required to complete the audit to attain maximum energy efficiency at the lowest possible dollar expenditure. Only energy conservation measures demonstrating a savings-to-investment ratio (SIR) equal to or greater than 1.8 may be installed. Individual repair measures are not subject to the SIR requirement. However, the total cost of repair measures is included in an overall SIR calculation, which likewise must equal or exceed 1.8.

Weatherization Materials/Measures Considered by the Audit
The Montana Computerized Energy Audit, titled the CDS Audit, originated as a multi-sheet Lotus 123 spreadsheet. It was converted to computer software by Northrup Gruman. In general, it is considered simpler and easier to use than the National Energy Audit Tool. All materials and measures considered by the audit must conform to requirements of the federal program per the "Standards for Weatherization Materials" of 10 CFR Part 440. Measures considered by the audit include:

- Attic insulation
- Primary windows
- Storm windows
- Thermal curtains
- Primary doors
- Wall insulation
- Floor insulation
- Crawlspace/basement perimeter insulation
- Heating system replacements
- Health and safety measures
- Energy-related repairs (includes water heater, pipe and duct wraps)
- Infiltration

Heating system replacements, other than for health and safety reasons, must be paid for using non-DOE and non-Oil Overcharge funding sources. A separate fuel switching audit is utilized for efficiency-related furnace and water heater change-outs. Operation of the Montana Computerized Energy Audit requires entry of annual heating costs and an indication of fuel type and the efficiency rating of the heating system after it has been tuned or replaced.

Montana Computerized Energy Audit heat loss calculations are based on 30-year average heating degree data contained in *Climatography of the United States, Monthly Normalacy of Temperature, Precipitation, and Heating and Cooling Degree Days 1951-80*, *Montana*, NOAA, Environmental Data and Information Service, National Climatic Service (website: http://wrcc.sage.dri.edu /summary/climsmmt.html).

Health and Safety Hazards to be Abated
The Montana Computerized Energy Audit incorporates actual material, labor and on-site supervisory costs associated with the abatement of health and safety hazards, provided their elimination is necessary before, or because of, installation of weatherization materials.

Health and safety abatement costs are excluded from individual and overall SIR calculations contained in the Audit. They are, however, included in overall job costs displayed in the summary screen of the Audit.

Labor, material and on-site supervisory costs associated with health and safety hazard abatement are limited to an average of 15 percent of all labor, material, and on-site supervisory costs. The Audit also displays the costs of health and safety abatement measures as a percent of the total job cost.

Treatment of the Dwelling Unit as a Whole System
In using blower door and heating system diagnostic data in the course of completing the Montana Computerized Energy Audit, auditors analyze interactions between the envelope, heating and air exchange systems and lifestyle of occupants of each dwelling unit. SIR calculations and the priority of architectural and infiltration measures are dependant on dwelling-specific factors such as primary and secondary fuel type, heating system efficiencies, primary and secondary fuel usage, number of occupants, number of occupants who are smokers, buffer factors, wind exposure, health and safety hazards and the pre- and post-weatherization condition of each structure. The interaction of these factors is documented in the hard and electronic copy of the energy audit that sub-grantees are required to maintain for each dwelling weatherized.

MTWAP Weatherization Installation Standards
The MTWAP Weatherization Installation Standards includes several specific references that determine how asbestos is treated. These references include:

Specific Measure Installation Standards - Attic/Ceiling Insulation and Ventilation Standards for Framed Homes

- When non-approved materials are present, approved insulation shall not be installed (example: asbestos-contaminated vermiculite).

Wall Insulation Standards for Framed Homes

- Do not insulate if wall access is through asbestos millboard siding or interior plaster walls are known to contain asbestos.
- Do not drill or remove asbestos siding of wall exterior for purposes of accessing wall cavity for insulation installation. Assess interior option for installing insulation (sic).
- If lath and plaster walls are drilled to access cavities, asbestos may be present in the plaster or lead may be present in the paint. Test to avoid hazardous situation.

The MTWAP Weatherization Installation Standards also address asbestos in the section specifically titled “Health and Safety.” The Installation Standards state that the most common applications that could involve interaction with weatherization staff include:

- Vermiculite Insulation (main concern)
- Siding shingles
- Furnace insulation
- Pipe insulation
- Duct insulation
- Furnace gaskets
- To a lesser degree, plaster, joint compound, roof shingles, floor tiles and other building products

To minimize exposure to asbestos containing materials (ACM), the Installation Standard instructions to weatherization workers include the following:

- Do not perform a blower door unless the ACM is found to be less than onepercent.
- Avoid disturbance of friable ACM
- Learn to recognize suspected ACM through proper sampling procedures, training, videos, and the EPA "Purple Book" (*Guidance for controlling Asbestos-Containing Materials in Buildings*, 1985 edition)
- To conduct asbestos sampling, it is recommended you successfully complete an OSHA-approved Asbestos Inspector Course dealing with all aspect of sampling asbestos, policies concerning asbestos, and procedures that need to be followed when handling ACM.
- If potential for limited exposure exists, such as to extract a sample from an attic, wear at least a half-face, fit-tested, HEPA respirator and OSHA recommended protective suit. Wet down suspected ACM to reduce levels-of airborne fibers.
- Provide written disclosure to client regarding the existence of suspected ACM and provide client education advising non-disturbance of such materials.

Significantly, the Installation Standards note that “Training and supervision for personnel intending to provide asbestos abatement services are beyond the scope of the State Weatherization Program. Weatherization personnel or appointed representatives shall not remove or dispose of asbestos without proper training and without prior authorization from the State Weatherization Office.”

Use of a blower door test to determine house tightness is considered a critical element in weatherization. The Installation Standards state that the presence of friable asbestos in the building is one of several criteria for omitting such a test. The Installation Standards specify that a blower door test may be performed by depressurizing or pressurizing the home to 50 Pascals. According to the Installation Standards a blower door shall be used to measure both pre-weatherization and post-weatherization air leakage.

Appendix A2
Summary of Applicable Asbestos Regulations

The current occupational 8-hour time weighted average (TWA) exposure limit for asbestos is 0.1 fiber per ml for fibers > 5 µm long, with an aspect ratio greater than or equal to 3:1, as determined by PCM (OSHA, ACGIH, 2001). The National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit for asbestos is identical except that it is based on a 10-hour TWA (NIOSH). In addition to the TWA permissible exposure limit, OSHA has defined an excursion limit of 1.0 fiber per ml averaged over a sampling period of 30 minutes.

Applicable State and Federal Asbestos Regulations

Asbestos and asbestos containing material (ACM) are regulated at the federal level by the Environmental Protection Agency (EPA) and the Occupational Safety and Health Administration (OSHA). The Department of Transportation (DOT) also regulates asbestos waste transportation and containment. ACM is be regulated in Montana by the Montana Department of Environmental Quality. The Environmental Protection Agency provides regulations to protect public employees performing asbestos abatement work in states that are not covered by OSHA asbestos standards or state regulations. DOE has addressed asbestos in the WAP with notices relating to health and safety.

Environmental Protection Agency Regulations

EPA defines asbestos-containing material as any material containing one percent asbestos by weight. This level is based on the technological constraints that make measuring asbestos levels below one percent difficult. This definition restricts the use of products and materials with detectable amounts of asbestos.

EPA developed asbestos air pollution regulations under the National Emission Standards for Hazardous Air Pollutants (NESHAP), which was developed under the Clean Air Act. The NESHAP regulation restricts the release of asbestos fibers during the processing and handling of ACM and prohibits or restricts the use of ACM in several industries.

The National Emission Standards for Hazardous Air Pollutants can be found in Title 40, Part 61, Subpart M of the *Code of Federal Regulations*. As defined in Subpart M, regulated asbestos-containing material (RACM) is:

a. Friable asbestos material;
b. Category I nonfriable ACM that has become friable;
c. Category I nonfriable ACM that will be or has been subjected to sanding, grinding, cutting, or abrading; or

d. Category II nonfriable ACM that has a high probability of becoming or has become crumbled, pulverized, or reduced to powder by the forces expected to act on the material in the course of demolition or renovation operations.

Category I nonfriable ACM includes asbestos-containing packing, gaskets, resilient floor covering, and asphalt roofing products containing more than 1 percent asbestos. Resilient floor covering is defined as asbestos-containing floor tile, including asphalt and vinyl floor tile, or sheet vinyl floor covering, containing more than 1 percent asbestos.

Subpart M also contains standards for demolition and renovation, insulating materials, and waste disposal. Appendix A to this subpart contains the interpretive rule governing roof-removal operations. These rules include threshold amounts of ACM roofing material, ACM shingle removal, removal methods for Category I ACM, notification requirements, emission control practices, waste collection, handling, transportation, disposal, and training.

EPA also is the regulating agency in Title 40, Part 763, Subpart G of the *Code of Federal Regulations*, which protects public employees performing asbestos abatement work in States not covered by the OSHA asbestos standards.

Occupational Safety and Health Administration (OSHA)

OSHA regulations can be found in 29 CFR 1910.1001, which contains worker protection measures, engineering controls, worker training, labeling, respiratory protection, bagging of waste, and permissible exposure levels. Additional regulations can be found in 29 CFR 1926.1101, which contains worker protection measures for all construction work involving asbestos, including demolition and renovation-work practices, worker training, bagging of waste, and permissible exposure levels. This regulation also includes exposure assessments, protective clothing, regulated areas, hygiene facilities, and medical surveillance.

The current occupational 8-hour TWA breathing zone exposure limit for asbestos is 0.1 fiber per ml for fibers > 5 µm in length, with an aspect ratio (length: width) greater than or equal to 3:1, as determined by PCM (OSHA, ACGIH, 2001). The National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit for asbestos is identical except that it is based on a 10-hour TWA (NIOSH). In addition to the TWA permissible exposure limit, OSHA has defined an excursion limit of 1.0 fiber per ml for a sampling period of 30 minutes.

A surface may be considered ‘clean’ when the asbestos concentration is below 1,000 structures per square centimeter (s/cm^2). A surface would be considered contaminated when the asbestos concentration is greater than 100,000 s/cm^2 (Millette and Hays, 1994).

Little scientific research has been performed to quantify the background surface levels typically seen in homes. Surface dust concentrations between the values of 1,000 and

100,000 require professional judgment to determine the risks involved (Millette and Hays, 1994).

Department of Transportation

The Department of Transportation (DOT) regulates the transportation of asbestos containing waste material under Title 49, Parts 171 and 172 of the *Code of Federal Regulations*. The Department also requires waste containment and shipping manifests under these regulations.

Montana Regulations

The Montana Department of Environmental Quality (MDEQ) administers the Asbestos Control Act, which governs asbestos permits, asbestos-related accreditations, asbestos training, asbestos abatement work practices, cleanup, inspection, penalties, and emergency actions. MDEQ also administers the National Emission Standards for Hazardous Air Pollutants (NESHAP), which regulates building renovation, demolition, asbestos disposal, and asbestos emission sources. This standard requires asbestos inspection prior to demolition or renovation activities. The *Montana Asbestos Work Practices and Procedures Manual* (adopted from ARM, title 17, Chapter 74, Subchapter 3) contains asbestos practices for the state of.

Montana standards for cleaning an asbestos-containing structure require the collection of five high-volume samples to verify that airborne contamination levels within the home are not greater than 0.01 fibers per cubic centimeter (0.01 f/cc), as determined by the NIOSH 7400 (or equivalent) method or not greater than 70 structures per square millimeter (70 s/mm^2), as determined by the EPA transmission electron microscopy method (TEM). TEM sample analysis must be done by laboratories that are accredited by the National Voluntary Laboratory Accreditation Program (*Montana Asbestos Work Practices and Procedures Manual*, 2005).

According to MDEQ, asbestos projects undertaken by homeowners, in their own homes, are not regulated. Such projects may include encapsulation, demolition, and removal. However, the transportation and disposal of the asbestos material associated with such projects are regulated by the MDEQ.

Department of Energy Weatherization Assistance Program

Over the years, a number of issues have been addressed to ensure that weatherization activities do not cause or exacerbate health and safety problems for workers and clients. These issues include, but are not limited to, wood stoves, knob-and-tube wiring, carbon monoxide and space heaters, lead paint, and asbestos. Health and safety is addressed in three sections of the program regulations: 1) minimum program requirements (Section 440.16); 2) allowable expenditures (Section 440.18); and 3) weatherization materials standards and energy audit procedures (Section 440.21).

Weatherization Program Notice 02-5 (Effective Date July 12, 2002) provides health and safety guidance. This notice can be found on the Weatherization Assistance Program Technical Assistance Center website at http://www.waptac.org/sp.asp?id=6914. The notice states that:

> "Energy-related health and safety concerns need to be remedied before, or because of, the installation of weatherization materials. Therefore, energy-related health and safety hazards associated with weatherization activities may be remedied or prevented with DOE funds. Measures and their costs must be reasonable and must not seriously impair the primary energy conservation purpose of the program.
>
> States are reminded that the primary goal of the Weatherization Program is energy efficiency. States should set health and safety expenditure limits for their subgrantees. These limits are often expressed as a percentage of the average cost per dwelling unit even though health and safety costs have been removed from the average cost calculation. Budgeting and financial reporting issues relating to health and safety are described in the application and reporting package in the annual file (Section II.2.2) and the master file (Section III.4)."

In accordance with federal regulations each state must develop a STATE HEALTH AND SAFETY PLAN. At minimum, state health and safety plans must include a section on "Potential Hazard Considerations." DOE reviews the hazards, remediation materials, and weatherization costs allowed under Section 440.18(c)(15). At a minimum, state health and safety plans should consider the hazards which include indoor air quality including asbestos. The plans should describe the approaches that agency crews and contractors will take to determine if the potential hazard should be remedied, referred to other agencies, result in partial weatherization services, or cause weatherization services not to be provided. The Health and Safety Guidance notice states that:

> *"Asbestos* - General asbestos removal is not approved as a health and safety weatherization cost. Major asbestos problems should be referred to the appropriate state agency and/or the Environmental Protection Agency (EPA). Where local agencies work on large heating and distribution systems, including related piping, asbestos removal may be necessary. Removal is allowed to the extent that energy savings resulting from the measure will provide a cost-effective savings-to-investment ratio. This would normally be true with work done on large, multifamily heating systems. Where permitted by code or EPA regulations, less costly measures that fall short of asbestos removal, such as encapsulation, may be used. Removal and replacement of asbestos siding for purposes of wall cavity insulation is permissible if allowed by state and local codes."

The Weatherization Assistance Program Technical Assistance Center website also addresses asbestos in a section titled "Technical Tools, Health and Safety, Asbestos." Refer to http://www.waptac.org/sp.asp?id=1653. This website suggests that major asbestos problems be referred to the appropriate state agency and/ EPA. This website reminds weatherization providers that general asbestos removal is not an approved health and safety weatherization cost but goes on to say that limited asbestos removal or remediation is allowed when implementing an energy-saving weatherization measure. When local agencies work on large heating and distribution systems (including piping), asbestos removal or encapsulation may be necessary:

- Removal is allowed when the measure will provide a cost-effective savings-to-investment ratio, normally true of large, multifamily heating systems.
- Removal and replacement of asbestos siding for purposes of wall cavity insulation is permissible if allowed by state and local codes.
- When permitted by code or EPA regulations, less costly measures that fall short of asbestos removal, such as encapsulation, may be used.

On May 21, 2003, the federal government launched a national consumer awareness campaign to provide homeowners with important information on vermiculite attic insulation, which may contain asbestos. This campaign, coordinated by EPA and the Agency for Toxic Substances and Disease Registry (ATSDR), instructs homeowners on how to identify vermiculite attic insulation and recommends that people make every effort to not disturb it.

Appendix A3
Project Weatherization Practices

Background

This section of the report will provide an overview of the specific weatherization practices followed during this project. The practices adopted for this project adhered to the state weatherization program guidelines unless asbestos considerations required modified procedures. Refer to Appendix A, Section A1 for a description of the typical practices established for the Montana weatherization program. Preliminary project protocols were developed in Phase 1 of the project. Following Phase 1, the protocols were modified prior to implementation of Phase 2. The lessons learned from implementation of both phases of the project were incorporated into the final recommended protocols described in Section 2 of this report.

As noted earlier in this report, weatherization agencies in Montana typically identify homes suspected as including friable asbestos. Some agencies proceed by taking a bulk samples for asbestos testing and sending that sample to a laboratory for analysis. Other agencies simply "walk away" from these homes based on WAP recommended practices. If a bulk sample tested less than one percent asbestos, then the house was normally audited and weatherized as if no asbestos was present. If the bulk sample tested greater than one percent asbestos, then the house was unable to continue in the MTWAP due to federal regulations. It is these houses with asbestos containing materials that are the subject of this project.

Worker Training

In this project, all weatherization activities in homes suspected of containing asbestos material were performed by certified and licensed asbestos abatement professionals. The energy audits and other weatherization work were performed by District XII Human Resources Council (HRC) staff who completed OSHA approved training and certification. The following topics were included in this training in order to ensure compliance with OSHA standards and to ensure the health and safety of crew members.

- Worker Training – a course meeting EPA requirements for training of local education agency maintenance and custodial staff (40 CFR 763.92(a)(2)
- Exposure Assessments as per 29 CFR 1926.1101 (f)
- Respiratory Protection as per 29 CFR 1910.134
- Protective Clothing as per 29 CFR 1926.1101(i)
- Regulated Areas/Hygiene Facilities as per 29 CFR 1926.1101 (j)
- Medical Surveillance as per 29 CFR 1926.1101(m) (NCAT, 2007)

This training occurred prior to Phase 1 of the project. Phase 1 allowed HRDC staff to refine their weatherization procedures in light of EPA and OSHA guidelines. Prior HRDC staff familiarization with lead safe weatherization practices facilitated their incorporating the asbestos mandated procedures.

Personal Protective Equipment

The personal protective equipment prescribed initially for weatherization crew workers performing measures in homes with asbestos was level C in the OSHA classification system. This consisted of hooded Tyvek® coveralls; half-mask, air-purifying respirators with P100 filters; and work boots. This personal protective equipment prescription was modified during year two of the project based on analysis of personal breathing zone sample results. Level C personal protective equipment was modified to include full-face, air-purifying respirators with P100 filters when crews performed work in attics (attic insulation blow-in).

Additional personnel (e.g., project supervisors, Montana Tech researchers, evaluation contractor) who entered containment areas for brief periods during weatherization measures wore half-mask, air-purifying respirators and hooded Tyvek® coveralls. Work crew members and the additional personnel described above passed quantitative fit tests and obtained medical clearance to wear negative-pressure respiratory protection per OSHA regulations.

Weatherization Procedures

Prior to the initial project weatherization activities, the project team determined that several procedures would be adopted that were atypical for the MTWAP. Those procedures included:

1. *Sealing Attic Bypasses*. In homes with vermiculite in the attic, weatherization workers attempted to seal accessible air bypasses from either the living space or from the attic. Bypasses included plumbing penetrations in wall top plates, electrical penetrations at wall top plates and ceiling-mounted fixtures, and other openings (Figures A1, A2, A3, A4, and A5).

Figure A1
Wrapping plastic around light fixture to prepare for sealing of potential attic bypass.

Figure A2
Example of hole at wall and ceiling intersection allowing vermiculite to enter living space.

Figure A3
Weatherization crew member HEPA vacuuming light fixture prior to sealing this potential attic bypass.

Figure A4
Crew member sealing light fixture, a potential attic bypass.

Figure A5
Crew member sealing potential attic bypass into living space.

2. *Sealing and Relocating Interior Attic Access Hatches.* If the house contained vermiculite attic insulation, the interior attic hatch was permanently sealed and a new attic hatch was installed in the garage or at an exterior gable (Figure A6) prior to the blower door test being performed. Eliminating the interior attic hatch prevents future direct contamination of the living space from the interior attic hatch.

Figure A6
Exterior attic access installed by weatherization crew member.

3. *Positive-Pressure Blower Door Tests*. Only positive-pressure blower door tests were conducted in houses included in the project. It was evident to the project team that creating a significant negative pressure within the home could draw asbestos fibers from the structural cavities into the living space.

<table>
<tr><th colspan="2">Table 14: House Activity Flow Chart</th></tr>
<tr><td colspan="2">House Identified as Containing Asbestos by Weatherization Agency</td></tr>
<tr><td colspan="2">Occupant LIEAP Qualification Check</td></tr>
<tr><td colspan="2">Occupant Release Forms Signed/Asbestos Education Information Provided</td></tr>
<tr><td colspan="2">Bulk Sample Collected and Analyzed</td></tr>
<tr><td colspan="2">Baseline Testing for Asbestos Contamination in Living Spaces</td></tr>
<tr><td>Asbestos Contamination Cleaning of Living Space – If Necessary</td><td rowspan="7">Occupants Absent from Home</td></tr>
<tr><td>Pre-weatherization Meeting with Occupant</td></tr>
<tr><td>Energy Audit Performed – With On-going Testing</td></tr>
<tr><td><u>Implementation of Weatherization Measures</u>
Measure 1 – With Asbestos Contamination Testing
Measure 2 – With Asbestos Contamination Testing
Measure 3 – With Asbestos Contamination Testing</td></tr>
<tr><td>Asbestos Contamination Cleaning of Living Space – If Necessary</td></tr>
<tr><td>Final Blower Door Test – Followed by Final Asbestos Clearance Test</td></tr>
<tr><td colspan="2">Occupant Exit Meeting for Energy and Health Education</td></tr>
</table>

Energy Audit Procedures

Pre-weatherization Meeting with Occupant. Prior to performing the audit, the weatherization staff met with the occupant to explain the weatherization process. Since the occupants were not allowed to remain in the home during the weatherization work period, this explanation and discussion was more important than during a standard weatherization project.

Pre-audit House Preparation. When the occupants were out of the house, the pre-audit activities began. The two primary pre-audit steps, which are not included in the typical weatherization project, were sealing attic bypasses and sealing and relocating the interior attic access hatch as described above.

Audit Activities. Prior to weatherization activities in each home, the work crew and supervisor performed an audit of the home. With the exceptions noted above the audit was typical of the MTWAP. Activities performed during the audit included the following:

Building Envelope Inventory. Digital photos and measurements of the house plan and elevations were recorded, including dimensions of outside, dimensions and locations of windows and doors, and a sketch of the house, which was performed by the crew auditor; most commonly, the crew supervisor. The energy-related information about the envelope components (i.e., insulation, window type, glazing characteristics, etc.) was recorded. Attic and crawl spaces were inspected to determine whether insulation could be added cost-effectively.

Heating System Inspection and Testing. The auditors identified the type and efficiency of the water- and space-heating systems. Testing was performed to determine efficiency. Safety testing included worst case combustion appliance zone to evaluate the possibility of back drafting. Proper draft was also evaluated.

Figure A7
Furnace technician checking furnace efficiency.

Blower Door Testing

The auditors conducted a positive-pressure blower door test to determine building tightness. The blower door (Figures A8, A9, and A10) is a diagnostic tool designed to measure the air-tightness of buildings and to help locate air leakage sites (Figure A11). A Model 4/230 V Minneapolis Blower Door™ system was used during weatherization measures

Figure A8
View of interior blower door setup.

Figure A9
View of blower door fan, fan speed controller and fan flow and pressure gauges.

Figure A10
View of blower door from exterior.

The blower door consists of a powerful calibrated fan that is temporarily sealed into an exterior doorway. The fan blows air into or out of the building to create a specific pressure difference between inside and outside. This pressure difference forces air through holes and penetrations in the exterior envelope. The measured air flow at the fan is equivalent to the air leaking out of the house.

Blower door tests are typically conducted with the building depressurized relative to the outdoors (i.e., the blower door fan exhausting air out of the building). However, under certain conditions (such as in this project), it is necessary to conduct a blower door test by pressurizing the building to avoid the possibility of pulling asbestos fibers from walls, attics or crawlspaces into the building during the test procedure. While the blower door fan was in operation, the weatherization crew located air leakage locations with a smoke stick.

Figure A11

Crew members performing blower door test.

Weatherization Measure Procedures

The information gathered during the audit was entered by the weatherization staff into the MTWAP CDS audit system. All cost-effective measures are identified. These measures, including any minor related repairs that are required, become the work scope for the weatherization project. Following are brief descriptions of the most common measures implemented in MASWDP houses.

Attic Insulation. Insulation was most commonly blown into the attic, including behind knee walls (Figure A12). Fiberglass was used for attic insulation for the following reasons: 1) fiberglass is a lighter product than cellulose; and 2) fiberglass is less absorbent than cellulose and is, therefore, more suitable in case of roof leakage. If an interior attic hatch was used to blow insulation into the attic spaces, then a polyethylene containment was erected to prevent contamination of the living space. After blowing insulation, the hose used for blowing insulation and contents of the attic were vacuumed using a HEPA vacuum as they were removed (Figure A13). If necessary, gable attic vents were installed.

Figure A12
View of hose blowing insulation into attic.

Figure A13
Crew member HEPA vacuuming hose after being removed from attic.

Wall Insulation. Wall insulation typically was added by drilling holes in the exterior wall finish (Figure A16). If the house had exterior asbestos siding, then holes were drilled on the interior of the house for blowing insulation (Figure A17). Prior to insulating, penetrations and openings on the interior of exterior walls were repaired. If the wall was to be blown from the interior, 6-mil polyethylene was used to build containments in order to control fibers that might be disturbed during weatherization activities (Figures A14 and A15). Access holes were drilled for the insertion of a 1.5-inch tube used for blowing insulation.

Materials used for attic and wall insulation include fiberglass and cellulose, respectively. Cellulose was used for the walls for the following three reasons: 1) cellulose is an efficient air-leakage tool, whereas air flows easily through fiberglass; 2) cellulose is easier to transport in the 1 ½-inch diameter tube than fiberglass; and 3) cellulose is easier to pack into the wall, therefore making it possible to achieve a higher R-value. The insulation blowing tube was inserted into the access hole in order to blow insulation (Figures A18 and A19). After blowing insulation, the access holes were sealed by gluing wood replacement caps into the port holes. These caps were later primered (painted walls) or covered with a wood trim (wood-paneled walls).

Figure A14:
Crew member building containment prior to wall blow-in.

Figure A15
Example of containment for wall blow-in.

Figure A16
Crew member drilling exterior holes for wall blow-in.

Figure A17
Crew member drilling interior holes for wall blow-in.

Figure A18
Crew member blowing insulation into exterior wall.

Figure A19
Crew member blowing insulation through interior wall.

Doors and Windows. Some exterior doors that were in poor condition were replaced. If appropriate, weatherstripping was replaced at existing doors. In addition, the thresholds were replaced on some exterior doors (Figure A20). Windows were weatherstripped, caulking (glazing) was applied, and broken glass was replaced as needed. No window replacements were performed during the project.

Figure A20
Crew member installing door weatherstripping.

Building Tightening. Building-tightening measures included sealing at window and door frames, sealing wall top plate penetrations, and adding foam gaskets at exterior wall electrical boxes. Tightening measures were performed while the blower door was set up so that the house was tightened to no less than 0.35 air changes natural.

Floors Over Unconditioned Space. Floors over unconditioned spaces were sealed to prevent air leakage. Urethane foam was used to seal smaller openings such as plumbing and electrical penetrations. Floor insulation was added if cost-effective.

Basement. Non-regulated amounts of asbestos pipe wrap that appeared potentially friable were sealed. ACM that is less than 3 linear feet in length or less than three square feet in area is not regulated by the State of Montana. Basement walls were insulated with fiberglass batts put in place prior to the application of insulation, which was applied through the exterior attic hatch.

Final Blower Door. At the conclusion of weatherization measure implementation, a final blower door was performed in the home. Final blower door values are compared to initial blower door results in order to evaluate the effectiveness of house measures designed to reduce the air leakage of the home.

Appendix A4
House Identification and Selection

Initial lists of potential participants were provided by partner weatherization agencies (Butte, Missoula, and Kalispell) and the Montana Department of Health and Human Services. The number of potential participant homes is in included in the following table. The table also indicates the number of homes that were ultimately weatherized.

Few of the names on the original lists were useful for the following reasons:

- Many phone numbers—perhaps as high as 30 percent—had been disconnected or reassigned, leaving the project team unable to contact those residents.
- Many phone numbers did not include voice mail, and despite several attempts we were unable to catch the residents at home. Many of those who did have voice mail did not return our call, despite leaving several messages.
- There were limited homes in the areas we were targeting.
- Some of the homes had since been weatherized.
- Some of the potential participants had since relocated to other homes.
- Current LIEAP eligibility is a requirement of participation, and many potential participants are no longer eligible due to a change in their economic circumstances.
- Some participants had asbestos removed from their homes (in the course of installing a new heating system, for example).
- A good number of potential participants were unable or unwilling to leave their homes for the necessary two to three weeks during weatherization.

In order to be accepted as a participant in the project, occupants had to meet several requirements, including:

1. Have asbestos present in their homes;
2. Be LIEAP-eligible, with a current application on file with the respective HRC;
3. Sign a Participant Release Form; and
4. Be willing to be displaced from their homes for up to three weeks while weatherization and asbestos testing took place.

While most of the participating homes were identified by weatherization agencies, NCAT also developed a newspaper advertisement to recruit participants for Phase I of the project. The advertisement was placed in *The Montana Standard* and *Anaconda Leader* newspapers during April 2007. This effort did result in 11 potential participants, although most who responded to the advertisement did not qualify, most often for economic reasons. Only one ultimately participated.

Maintaining current lists of homes with asbestos is an important step toward dealing with these homes in the future. However, as word of our project spread among weatherization agencies and the agencies realized that homes with asbestos could be weatherized through the project, more homes were identified.

NCAT reached out to other weatherization agencies across the state to explain the project and request lists of asbestos containing LIHEAP eligible homes. Most weatherization agencies did refer homes to NCAT as they were identified by weatherization crews.

Only one home was dropped from the project due to exceedingly high levels of asbestos contamination. The cost of cleaning this particular house was estimated between $10,000 and $20,000. The asbestos contractor who inspected the house was concerned with adequately cleaning the house without disposing of all the contents including carpet and draperies. Contamination in this home was largely the result of house remodel work being done workers without asbestos awareness or training. An interior wall that contained vermiculite insulation was exposed. The work performed caused the vermiculite insulation to leak out of the wall and pile up on the interior floor of the basement. In addition, the presence of chrysotile in surface samples throughout the home, suggests that there are most likely additional sources of contamination other than the exposed vermiculite insulation. The home owner and tenant were informed of the baseline sampling results and the tenant opted to relocate

APPENDIX B: PARTICIPATING HOMES SUMMARY INFORMATION