***Chapter 8***

***Abatement Techniques***

A NESHAP asbestos inspector should be familiar with the procedures the asbestos abatement industry implements to comply with federal and state regulations. This knowledge will result in a more complete inspection, especially in a pre-removal situation where actual abatement has not yet begun. By evaluating the set-up and proposed abatement plan, the inspector can determine if the project *may* be done in compliance with the asbestos NESHAP.

Although removal, encapsulation, enclosure and repair are all forms of asbestos abatement, NESHAP inspectors investigating demolition and renovation sites will most commonly encounter asbestos removal operations. For this reason, this chapter describes work area preparation, removal, and post-removal activities associated with common OSHA Class I and Class II abatement activities.

***Important Terms***

***Aggressive air sampling*** - Air sampling which takes place after final cleanup while the air is being physically agitated with leaf blowers and fans to produce a "worst case" situation.

***Amended water*** - Water to which surfactant (wetting agent) has been added to increase the ability of the liquid to penetrate ACM.

***Asbestos-containing material*** - Any material containing more than one percent asbestos.

***Asbestos-containing waste material*** – This term includes filters from control devices, friable asbestos waste material, and bags or other similar packaging contaminated with commercial asbestos. As applied to demolition and renovation operations, this term also includes regulated asbestos-containing material waste and materials contaminated with asbestos including disposal equipment and clothing.

***Class I asbestos work*** - Activities involving the removal of TSI and surfacing ACM and PACM.

***Class II asbestos work*** - Activities involving the removal of ACM that is not TSI or surfacing material. This includes, but is not limited to, the removal of asbestos-containing wallboard, floor tile and sheeting, roofing and siding shingles, and construction mastics.

***Clean room*** - An uncontaminated room having facilities for the storage of employees' street clothing and uncontaminated materials and equipment.

***Critical barrier*** - One or more layers of plastic sealed over all openings into a work area or any other similarly placed physical barrier sufficient to prevent airborne asbestos in a work area from migrating to an adjacent area.

***Decontamination area*** - An enclosed area adjacent and connected to the regulated area consisting of an equipment room, shower area and clean room.

***Equipment room*** (change room) - A contaminated room located within the decontamination area that is supplied with impermeable bags or containers for the disposal of contaminated protective clothing and equipment.

***Glove bag***- Not more than a 60 x 60 inch impervious plastic bag-like enclosure affixed around asbestos-containing material, with glove-like appendages through which material and tools may be handled. Information on glove bag operations can be found in OSHA's Construction Standard at 29 CFR Part 1926.1101 (g)(5)(ii and iii).

***High efficiency particulate air (HEPA*)** - A filter capable of trapping and retaining at least 99.97% of all mono-dispersed particles of 0.3 micrometers in diameter.

***HVAC system*** - Heating, Ventilation, and Air Conditioning system usually found in large buildings and industrial facilities.

***LEV*** ***unit*** - Local Exhaust Ventilation machine designed to mechanically remove air contaminants from a point of operation.

***Mil*** - Prefix meaning one-thousandth; commonly used to describe thickness of polyethylene sheeting (6 mil poly = 0.006" thick.).

**Polyethylene** ***(poly)*** - Plastic sheeting often used to seal off an area in which asbestos removal is taking place; used to prevent contamination of other areas.

***Project designer*** - The individual responsible for the issuance of project-related plans and specifications. This person must have successfully completed the project designer training requirements specified in EPA’s Model Accreditation Plan (MAP) and may be required to be licensed in some states.

***Regulated area*** - An area established by the employer to demarcate areas where Class I, II, and III asbestos work is conducted, and any adjoining area where debris and waste from such asbestos work accumulate; and a work area within which airborne concentrations of asbestos exceed, or there is a reasonable possibility they may exceed, the permissible exposure limit.

***Regulatory Requirements***

Both OSHA's Construction Standard which is found at 29 CFR 1926.1101 (g) and EPA's Asbestos NESHAP regulation which is found at 40 CFR 61.145(c) and 61.150 specify engineering controls and work practices to be used during asbestos abatement.

***OSHA***

OSHA requires the use of the following engineering controls:

* Vacuum cleaners equipped with HEPA filters;
* Wet methods or wetting agents, where feasible;
* Prompt cleanup and disposal of wastes and debris contaminated with asbestos in leak-tight containers;
* Local exhaust ventilation equipped with HEPA filter dust collection systems;
* Enclosure or isolation of processes;
* Ventilation of the regulated area to move contaminated air away from the employees and toward a HEPA-filtration or collection device; and
* Respiratory protection, where necessary.

***EPA***

EPA requires the following controls in most circumstances:

* Adequately wet friable ACM and Category I and Category II nonfriable ACM in poor condition prior to its removal;
* After wetting, seal all asbestos-containing waste material in leak-tight containers or wrapping while wet;
* Produce no visible emissions to the outside air during collection, mixing, and wetting operations;
* Do not drop, throw, slide, or otherwise damage RACM and use dust-tight chutes or containers to transport RACM to the ground if it has been removed or stripped more than 50 feet above ground level and it was not removed as units or sections;
* Use emission control methods such as local exhaust ventilation and collection systems (designed to capture particulate asbestos); glove bag systems, and leak-tight wrapping.

***OSHA - Class I Work Operations***

Class I work operations involve the removal of TSI and surfacing ACM and PACM. OSHA requires a competent person to supervise Class I operations and allows the following control methods: negative pressure enclosures; glove bag systems; negative pressure glove bag and box systems; water spray process systems; small, walk-in enclosures; and appropriate alternatives. Since asbestos NESHAP enforcement personnel will typically encounter negative pressure enclosures and glove bag systems, these are described below.

A project designer may create plans and specifications for Class I projects. These documents often specify work practices that exceed OSHA and EPA requirements.

***Negative Pressure Enclosure***

The following paragraphs detail typical preparations for establishing a negative pressure enclosure (NPE) for a Class I operation involving the removal of more than 25 linear or 10 square feet of thermal system insulation or surfacing material.

***Work Area Preparation***

Pre-cleaning of the work area is often conducted. HEPA vacuums are used to clean floors, walls and movable as well as immovable objects. Cleaning or wet wiping with amended water may also be done. Carpets may be steam-cleaned or removed entirely. Movable items are taken out of the work area and stationary objects covered with plastic sheeting and secured.

Critical barriers are established. Duct tape, sheet polyethylene (poly), expandable foam, caulking, plywood and particle board are commonly used to seal all windows, doors, drains and other penetrations into the worksite. In the event that other engineering controls fail, these air-and water-tight barriers will help prevent the escape of asbestos fibers from the work area.

Warning signs that meet the requirements of the OSHA asbestos standards must be posted at each entrance to the work area. These signs are meant to prevent unauthorized people from entering the work area. They must be written in the language(s) that can be comprehended by those in the building/area.

The HVAC system is shut down and isolated by sealing with a double layer of 6 mil plastic or the equivalent (OSHA-required) to prevent transfer of asbestos dust throughout the building. The control panel for this system is tagged and locked (to prevent activation of the system) or the breaker associated with the HVAC system removed entirely. Often contaminated air filters are removed from the system and disposed of as asbestos-containing waste. All vents and air ducts inside the work area are sealed, typically with poly and tape. Plywood, sheet metal or other materials may also be used.

The walls of the work area are usually covered with one or two layers of 4-or 6-mil poly. Strapping, nailing blocks, spray adhesive, staples and tape may be used to attach the poly to the walls. Seams in the two layers are offset and the bottoms of the sheets alternately overlapped with the floor poly that extends up the walls 18-24”.

Ceilings are sometimes covered with poly when floor tiles are to be removed via mechanical means.

The floor of the work area is usually covered with a minimum of two layers of 6-mil poly. Seams are sealed using spray adhesive and duct tape, and strapping, spray adhesive, double-sided tape and/or staples may be used to securely fasten the poly at the wall/floor junction.

In certain situations an inspector may encounter a product known as Spray Poly® being used to prepare the walls and floor. This material is applied in equivalent thickness to polyethylene sheeting and serves the same purpose.

Arrows should be applied to the prepared walls to indicate the locations of exits.

A decontamination area (decon) for equipment, materials and personnel is established (Figure 8-1). This structure, required by OSHA for Class I work, must be adjacent to and connected to the work area. It is designed to allow passage to and from the work area while minimizing leakage of asbestos-containing dust to the outside. A typical decon consists of a clean room, a shower room and an equipment (dirty) room, separated by airlocks. The airlocks may simply be two layers of poly hung at the openings to each room of the decon or they may be separate three-foot chambers alternating with and separated from each of the rooms in the decon by overlapping poly. Decon specifications may vary by state. Decon doorways may be of various designs including arches, slits, inverted T's, etc.

Local exhaust ventilation (LEV) machines are brought in and turned on (Figure 8-1). These devices are often referred to as negative air machines. An LEV machine contains a fan that draws contaminated air through a series of filters and exhausts the cleaned air to the outside. The final filter in the series is a High Efficiency Particulate Air (HEPA) filter.

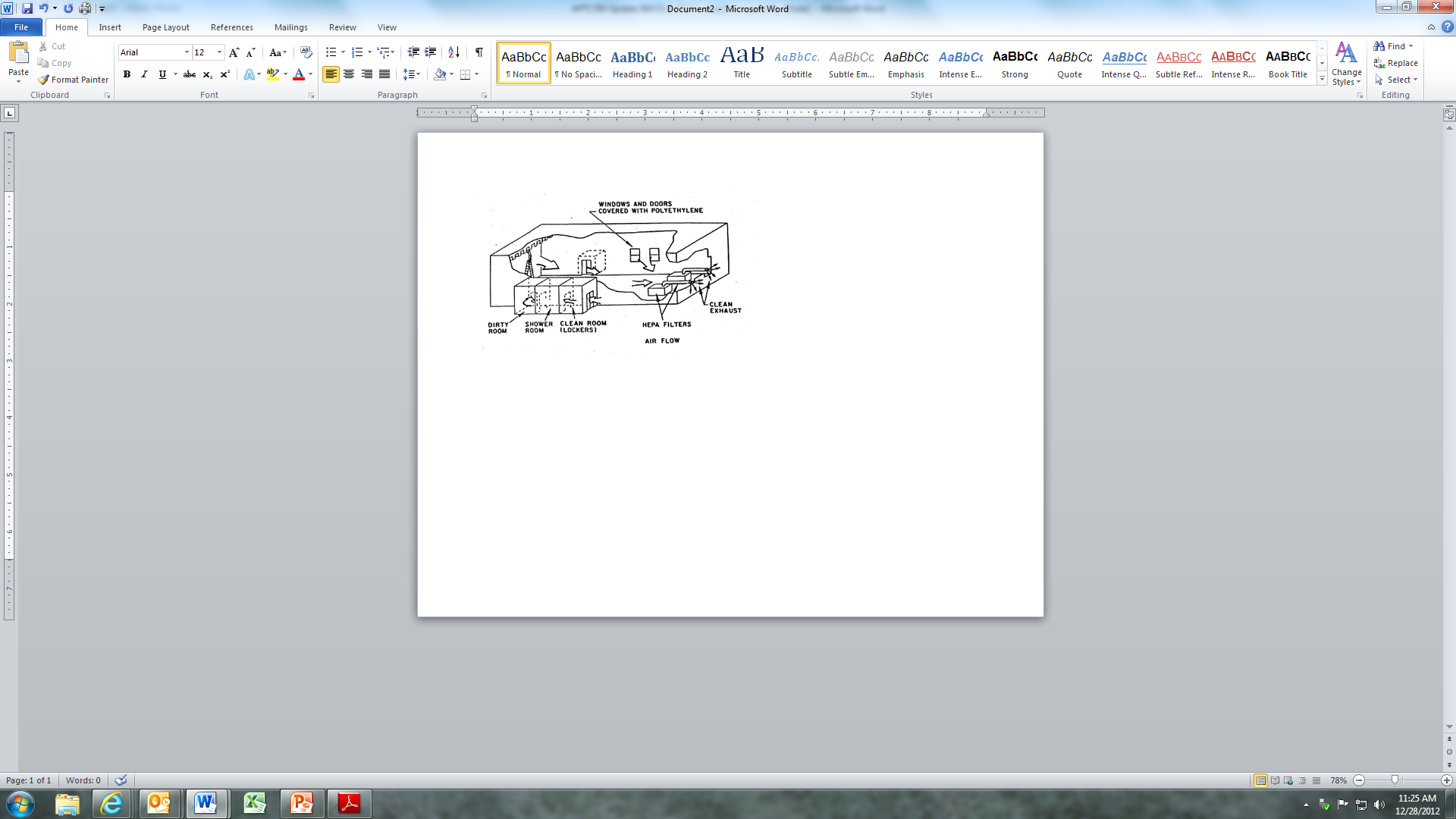
LEV units are used to provide the OSHA-required four air exchanges per hour and minimum -0.02 column inches of water pressure differential relative to outside pressure. Such a reduced pressure environment helps prevent the escape of contaminated air should a breach of containment occur. A manometer is used to measure this pressure differential and is often equipped with strip chart recorders and alarms. If the pressure differential is compromised, an alarm will sound to alert the abatement personnel.

OSHA requires air movement to be directed away from employees performing asbestos work within the enclosure. To provide the best movement of air through the workspace, LEV units should be located as far as possible from the decon and vent to the outside if possible. The number of units needed depends on the volume and configuration of the room. The machines operate 24 hours a day from the beginning of a job until final air clearance is obtained.

***Work Practices***

Before beginning work within the enclosure and at the beginning of each shift, the NPE must be inspected for breaches and smoke tested for leaks, and any leaks sealed.

OSHA requires all electrical circuits in the enclosure to be deactivated unless they are equipped with ground-fault circuit interrupters (GFCIs). The electricity supplying the work area usually is shut off and the control panel locked and tagged. Contractors typically have an electrician wire in necessary amperage at the worksite and connect all electrical equipment in the enclosure to GFCIs.



Source: *Asbestos Waste Management Guidance (EPA/530-SW-85-007, May 1985)*

Figure 8-1. Local Exhaust Ventilation (Negative Air) System

***Asbestos Removal***

Work procedures can vary widely depending on the configuration of the area, barriers to the material to be removed, crew sizes and other issues. The following, however, describes procedures commonly employed in Class I removal projects.

Beginning at the decon and proceeding toward the LEV machines, workers spray the asbestos-containing material (typically with amended water) so that it can be more easily removed and to meet EPA and OSHA wetting requirements. A wide variety of water-handling equipment may be used: airless paint sprayers (the most common devices used in Class I projects), hand-pump garden sprayers, hoses and extension wands. Sprayers are used to thoroughly wet the ACM prior to its removal and to maintain it in the wet state until it is properly collected for disposal. Sprayers are used to thoroughly wet the ACM prior to its removal and to maintain it in the wet state until it is properly collected for disposal. Care must be exercised when using standard garden hoses, for excess water may accumulate on floors and leak out of the work area. Extension wands, ladders and scaffolds may be used to ensure that the wetting agent is properly directed onto the ACM.

Workers use a variety of tools for removing ACM and collecting it for disposal. Removal tools include long-and short-handled scrapers, joint compound knives, paint scrapers, nylon scrub pads, and a large assortment of brushes (ranging from industrial “toothbrushes” to toilet brushes). For cementitious ACM, chisels and hammers and various types of hand saws may be used. For hard-to-reach areas, power washers, whose water stream pressure is measured in thousands of pounds per square inch, may be used to clean asbestos-coated surfaces. These devices differ from standard pressure washers used to clean homes and concrete. Since these devices deliver excessive amounts of water, in most cases specially engineered collection methods must be used to capture the contaminated water.

Debris collection tools include shovels and squeegees that are often made of plastic or rubber to prevent damage to the floor poly.

ACWM is usually loaded into a plastic waste bag that is sealed, washed off in the shower or waste-handling area, placed into a second clean, properly labeled waste bag and removed from the worksite. Where ACWM contains items that could puncture waste bags (e.g., chicken wire, metal lath, etc.), a fiber or metal drum may be used as the outer container. In some cases large items, such as lengths of piping, metal lath, etc., may be double wrapped with 6 mil poly and labeled before being removed from the work area.

Occasionally on large jobs, or where worker access and maneuverability is limited (e.g., crawlspaces), heavy-duty truck-mounted vacuum machines may be employed. The machine transports wetted ACM to the outside equipment via a vacuum hose. Workers may use the hose itself to remove ACM from the substrate or may collect material in a hopper first.

Depending on the type of vacuum apparatus, the removed ACM may enter the tank of a truck that will transport it as a slurry to an approved landfill or it may enter a hopper where it is further wetted and then bagged.

Heavy-duty shredders may also be used at the job site. These break up metal lath and other materials being removed, making it easier to handle and dispose of the waste.

These vacuum machines are a potential safety hazard and workers must be trained in their use. These devices must also be HEPA equipped to avoid visible emissions.

***Post-removal Activities***

Once the “gross removal” is complete, fine cleaning and inspections are done to ensure that all material meant to be removed has been and that no debris is left behind. OSHA and EPA do not dictate how cleaning and final inspection activities must be done; this is left up to the owner/operators.

After a final visual inspection is made, an encapsulant may be applied to the cleaned surfaces (including the poly) to lock down any remaining invisible fibers. On occasion, encapsulants of contrasting colors are applied at angles to one another to ensure complete lockdown.

The first layer of poly is then removed. If the abatement work is being conducted in a school, or if the state or abatement contract requires it, aggressive final clearance air sampling is performed at this point. Some states and project designers specify that ALL poly except critical barriers be removed before final clearance air sampling.

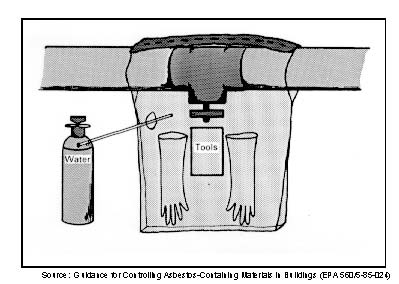
Leaf blowers and/or fans are used to create a worst case scenario in the cleaned work area while large-volume air samples are obtained. Samples are then analyzed by PCM or TEM. A job is often considered complete when the fiber count for each sample, as determined by PCM, is ≤ 0.01 f/cm3 or when the average is no more than 70 structures/mm2 as determined by TEM, or when ambient or contract-specified levels are met.

Once final air clearance is obtained, the area may be reinsulated, the second sheet of poly and critical barriers removed, and the area reoccupied.

***Glove-bag Systems***

Contractors may use the glove-bag technique to remove thermal system insulation (see Figure 8-2). OSHA requires glove bags to be seamless on the bottom and made of 6-mil thick plastic. Linked glove bags, multi-sleeve glove bags, and glove bags which have been designed to permit the removal of horizontal or vertical runs of pipe insulation are available. Those used on elbows and other connections must be designed for that purpose and used without modifications. OSHA also permits the use of a glove bag that has a detachable waste bag.

Glove bags may be used only on surfaces not exceeding 150°F, and may be used only once and not moved.



Source: *Guidance for Controlling Asbestos-Containing Materials in Buildings (EPA 560/5-85-024)*

Figure 8-2. Illustration of a Glove-bag Application.

OSHA requires two persons to perform a Class I glove-bag operation (unless the space is too small to accommodate two individuals). These individuals must seal or render intact adjacent loose and friable material prior to attaching the glove bag.

Necessary tools and other materials are placed in the tool pouch of the glove bag and the glove bag is installed to cover the entire circumference of the pipe or other structure. The glove bag must be sealed airtight, smoke-tested for leaks, and any leaks be sealed prior to use.

The wand of a garden sprayer containing amended water is attached to the glove bag and the insulation soaked, removed and dropped into the bottom of the glove bag. The pipe and upper section of the glove bag are wiped clean and the ends of remaining insulation are often sealed with encapsulant, water-activated repair cloth, or other wrapping material. The reusable tools are grasped in a glove and pulled outward. The sleeve is twisted and taped in two locations and the glove containing the tools is cut off between the two taped sections. When linked bags are used, the worker does not isolate the tools in a glove, but moves the tools to the next attached bag. The enclosed tools are then placed into another glove bag for use or are deposited into a bucket of water and later cleaned. The glove bag is then twisted and loosely taped to isolate the ACM in the bottom of the bag. The sprayer wand is removed and a HEPA vacuum (OSHA-required) is attached and used to remove the remaining air from the glove bag. The glove bag is tightly taped, the vacuum hose is removed. and the glove bag is cut down from the pipe and deposited into another labeled disposal bag.

OSHA also permits the use of other control methods for Class I work. These include negative pressure glove bags, glove boxes, water spray process systems, and mini-enclosures. Refer to OSHA’s asbestos Construction Standard, Section (g)(5) for more details.

***Class II Work Operations***

Class II asbestos work involves the removal of ACM which is not TSI or surfacing material (e.g., wallboard, floor tile and sheeting, roofing and siding shingles…). A competent person must supervise all Class II work, and HEPA vacuums, wet methods or wetting agents, and prompt cleanup and disposal of wastes and debris in labeled leak-tight containers (except for roofing materials) must be employed.

***Flooring Material Removal***

***OSHA Requirements***

For all indoor Class II jobs where a negative exposure assessment has not been produced, where there may be exposure above the PEL, or where the ACM is not removed substantially intact:

* critical barriers must be installed;
* another barrier or isolation method must be used to prevent migration of airborne asbestos from the regulated area; and
* impermeable drop cloths must be placed on surfaces beneath all removal activity.

For removing ACM-containing vinyl and asphalt flooring (or where the absence of ACM in a building constructed no later than 1980 has not been confirmed), employees must comply with the following work practices:

* Flooring or its backing must not be sanded;
* Vacuums equipped with HEPA filter, disposable dust bag, and metal floor tool (no brush) must be used to clean floors;
* Resilient sheeting must be removed by cutting (with wetting of the snip point and wetting during delamination) – “rip-up” is prohibited;
* All scraping of residual adhesive and/or backing must be performed using wet methods;
* Dry sweeping is prohibited;
* Mechanical chipping is prohibited unless performed in a negative pressure enclosure that meets regulatory requirements;
* Tiles must be removed intact, if possible;
* Wetting may be omitted if tiles are heated and removed intact.

OSHA requires all types of removed flooring to be packaged in labeled, leak-tight containers. EPA, however, does not consider floor tiles that have been removed intact to be RACM, so such material can be discarded as construction debris. EPA does consider waste from the removal of asbestos linoleum/vinyl sheet goods (which contain friable backing material) to be RACM, so packaging and labeling requirements apply. The NESHAP exclusions listed here may not be allowed by some states or local authorities.

***Flooring Removal Techniques***

Abatement personnel use a wide variety of techniques/tools to remove flooring. These include mechanical methods, various liquids, dry ice, infrared machines, and shot blasters.

***Water/Amended Water/Solvents***

Water, amended water or solvents may be spread onto floor tiles in order to loosen them. After a period of soaking, the tiles may be removed using long-handled scrapers (ice chippers) or gas- or electrically-powered mechanical chisels. Remaining mastic may be removed using solvents, sanders or hydroblasters. Hydroblasters use high-pressure water to dislodge mastic; the resultant mixture is separated and the water is reused. Gas-powered devices should be used only in areas with adequate ventilation.

If extensive breakage renders the material friable, RACM is produced and the provisions of the asbestos NESHAP apply.

***Dry Ice***

Although rarely employed, dry ice (frozen carbon dioxide) can be used to remove floor tiles. When dry ice is applied to the tiles, the intense cold causes the tiles to contract and detach from the substrate.

***Infrared Machines***

The heat from an infrared machine softens the mastic, allowing easy removal of floor tiles. Infrared machines are most commonly used in small-scale floor tile removals.

Once the tiles have cooled they may become brittle, shatter and become RACM.

***Shot-blasters***

Shot-blasters are used in the removal of flooring mastic. These machines direct a barrage of small pellets (shot) against the mastic and vacuum up and separate the mastic/pellet mixture. The pellets are continually reused and the pulverized material is segregated for disposal.

EPA permits the use of shot blasters only when wet methods are utilized; any other use constitutes dry removal and could result in a major release of airborne asbestos.

***Other Mechanical Methods***

Since friable material is created, the provisions of the asbestos NESHAP (including the use of labeled, leak-tight containers) apply to the removal of regulated amounts of resilient flooring subjected to:

* jackhammers;
* rotating blade scrapers (buffers with blades);
* mechanical sanders;
* rotating blade saws;
* ride-on tile-removing machines; and
* electric chisels and chippers.

***Roof Removal***

***OSHA Requirements***

OSHA requires the following work practices to be followed:

* Roofing material must be removed in an intact state to the extent feasible;
* Wet methods must be used to remove roofing materials that are not intact, or that will
* Be rendered not intact during removal (if feasible, and safety hazards are not created);
* Cutting machines must be continually misted during use (unless safety hazards are created);
* Dust resulting from the use of a power roof cutter must be collected by a HEPA dust collector, HEPA vacuumed, or gently swept and completely wiped up and immediately bagged or placed in covered containers.
* ACM that has been removed from a roof shall not be dropped or thrown to the ground (all removed ACM must be lowered to the ground no later than the end of the work shift);
* Once lowered to the ground, unwrapped material must be transferred to a closed receptacle;
* Roof level heating and ventilation air intake sources must be isolated or shut down; and
* Removal or repair of < 25 SF of intact roofing does not require use of wet methods or HEPA vacuuming (manual methods, no dust).

***Roof Removal Techniques***

Most of the following information has been extracted from *Applicability of the Asbestos NESHAP to Asbestos Roofing Removal Operations* (EPA 340-B-94-001, August 1994).

Shingles are normally used on inclined roofs and may be either asphalt or cement-based. Because of steep slopes, shingles are typically removed manually by workers using shovels and/or pry bars. When removing asbestos-cement shingles, workers may first clip off the heads of the nails, remove the shingles, and then remove the rest of the nails.

With built-up roofs, several methods of cutting the roof membrane are available. The method chosen depends not only upon the nature of the job, but upon local and state asbestos regulations as well. In most cases power roof cutters are used to cut roof membranes into manageable sections, but manual methods are sometimes used.

Generally, for built-up roofs, the membrane is separated (e.g., by cutting, slicing, punching or shearing) into sections approximately 2’ x 2’, or 2’x 4’ or other sizes that can be managed by one or two workers, and that will fit into a cart or wheelbarrow and a 2’-diameter chute.

The sections are pried up using power roof removers, shovels or tear-off bars. Single-ply membranes may be sliced into long strips and rolled up.

Wetting is required whenever the method used may create RACM.

***Manual Methods***

Removal by manual methods usually involves the use of axes, hatchets and utility knives to chop or slice the roof membrane into sections that can be lifted by one or two workers with shovels, spud burs, pry bars, etc.

***Mechanical Methods***

*Rotating Blade (RB) Roof Cutter*

RB roof cutters are used extensively by roofing contractors to cut roof membranes for removal. A gasoline-powered engine turns a blade mounted near or toward the front of the machine. The cutting edge of the blade is blunt with about a ¼” kerf, as opposed to a tapered, sharp edge. This design allows the cutter to be used on gravel-covered roofs that would dull sharp blades. The adjustable-depth blade rotates so that the cutting action is from the underside of the membrane when the cutter is moving forward. RB roof cutters are used on both smooth-and gravel-surfaced roofs and are manually propelled.

Rotating blade cutters render the asbestos roofing friable. EPA considers a roof 5580 square feet or greater to be a regulated renovation when rotating blade cutters are used. If the RB cutter is fitted with a spraying mechanism and HEPA vacuum, however, the job is NOT regulated.

*Slicer*

A slicer is a self-propelled, two-wheeled tractor equipped with a blade that is used to slice through smooth roof membranes. Although this equipment is not commercially available, the slicer can be fabricated by attaching a heavy metal plate that houses an adjustable blade to the rear of the tractor. As the tractor moves forward, the blade neatly slices through the roofing material much like a utility knife.

Slicers do not render asbestos roofing material in good condition friable.

*Roof Plow*

A roof plow is similar to a slicer except that it slices the roof membrane from below. As a result, it is not dulled by roof aggregate and can be used on such roofs. The "plow" is attached to the rear of a self-propelled garden tractor and is pulled along through the membrane. Because the plow slices the membrane, no dust or debris is created during its use. Plows are also not available commercially, but can be fabricated using available materials.

*Concrete/Asphalt Planer*

A planer is a machine used to remove concrete or asphalt from surfaces at controlled depths and profiles. Some models of planers come equipped with a misting device over the cutter assembly and can be used with a vacuum system designed for the planer. Both the concrete planer and vacuum unit are commercially available. The planer, however, has rarely been used in roof removal projects because the cutters are easily clogged with bituminous materials, and the short cutting depth necessitates several passes.

*Power Remover (Power Tear-off Machine)*

A power remover is used as an alternative to manually prying up pieces of sliced roofing material. A power remover consists of a wide actuating blade that can be mounted onto the front of a self-propelled tractor. Power removers also come as a one-piece assembly, i.e., with the blade and tractor as a single unit.

Power removers do not cause asphalt asbestos roofing that is in good condition to become friable.