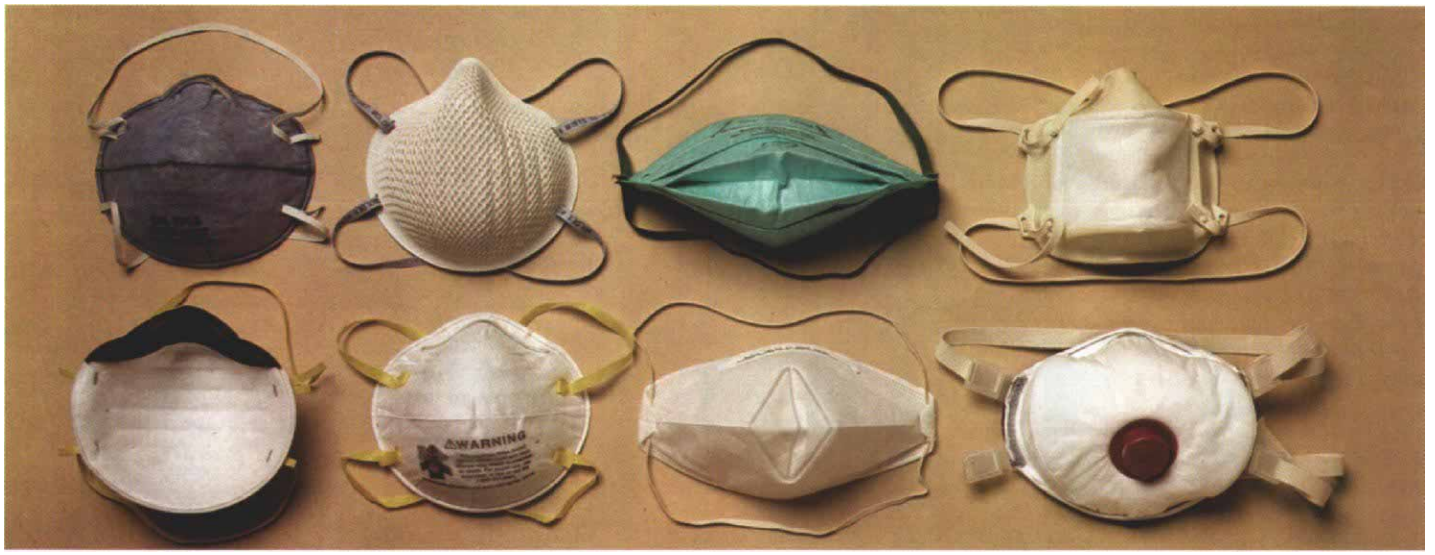
Protecting Your Lungs on the Job

Know the risks, and if you can't eliminate them, choose the right respirator

by Charles Miller

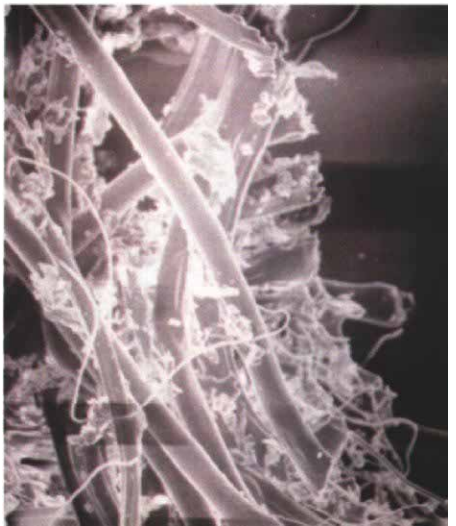


Disposable dust/mist respirators. **These NIOSH-approved respirators filter out particles down to 1 micron in dia. The mask in the lower right corner has an exhalation valve, which lets the mask run cooler in hot weather; the one in the upper left corner neutralizes nuisance levels of acid gas. Top, left to right: 3M #9915; Moldex #2200; GPT GR-500; Willson #1410. Bottom: 3M #8715; 3M #8710; Racal Delta 1+; 3M #9970.**

A cabinetmaker friend of mine works out of his two-car garage in a residential part of town. The neighbors don't exactly know that they have a full-time woodshop in their midst, so he keeps the big overhead door down while he's working, and he wears a dust mask when the air gets clogged with particles. The last time I visited he was making a solid-surface countertop, and the polystyrene dust kicked up by the router hung in the shop like a thick plastic fog. He handed me a dust mask, and as I stretched its single rubber-band strap over my head, I spied a disclaimer printed in red ink on the facepiece. It said, "Warning. This mask will not protect your lungs. Misuse may result in sickness or death".

I'm not sure why a company would make a dust mask that isn't intended to safeguard the user's lungs. But the notion of wearing one of these uncomfortable muzzles while remaining unprotected made me want to find out just what kind of mask *does* protect lungs. The first thing I found out is that before you can choose the right respirator, you need a basic understanding of what the likely airborne hazards are going to be on a job site (see sidebar facing page) and what happens if you don't protect yourself.

Trapped in the mesh. **In the micrograph above, layers of nonwoven fibers snag redwood dust particles in a 3M #8710 mask. At a higher magnification (below), you can spot the ragged individual particles of wood.**



The body's defense—Most particles that get past your nose hairs are deposited in the air passages that lead to the lungs. The body then takes measures to remove them. For example, when particles settle on the bronchial walls, tiny hairs called cilia sweep the particles (in a coating of mucous) toward the exit, where they are coughed up encased in phlegm.

Respirable particles are small enough to get into the alveolar sacs, where carbon dioxide is expelled and oxygen taken into the bloodstream. There aren't any cilia in these sacs. Instead, macrophage cells perform a similar duty. These custodial cells roam around the innermost reaches of the lungs, swallowing bacteria and then poisoning them. Macrophage cells can also swallow particles and then convey them back to the bronchioles, where the cilia take over.

Particle and fiber risks—People who work with wood face respiratory problems that range

Bottom photos: Mark Floyd and Jesse Fisher, Forensic Analytical Labs

from runny noses to permanent lung damage. Because they work mostly outdoors, carpenters usually aren't exposed to the dust concentrations experienced by woodworkers. But that changes when carpenters move indoors. Zander Brennen, a carpenter from Berkeley, California, found that out when he built a house that included a lot of kiln-dried redwood trim. He and his colleagues set up the table saw inside the house and ripped moldings for a couple of weeks. Unlike wet framing lumber, particles from dry wood hang in the air for a long time, so the house was filled with airborne dust. Brennen's sporadic use of a dust mask didn't keep him out of the emergency room, where he ended up one night because he was unable to breathe. The diagnosis: occupational asthma. Brennen's bronchial tubes had become inflamed by the redwood dust, which caused mucous-secreting cells to go into overdrive, constricting the diameter of his air passages. Once sensitized in this manner, air passages overreact to any kind of dust. Brennen had to take bronchial dilation medicine for five years before his respiratory system returned to normal.

Redwood and red cedar both have volatile oils in them that exacerbate the irritating effects of the particles in the air passages. But other kinds of wood dust can have the same effect over time.

Even more insidious are silica particles. Silica, which is a component in such omnipresent materials as concrete and joint compound, is dangerous when it becomes airborne from sanding, grinding or cutting. Silica particles can become embedded in the lung's alveolar sacs. When a macrophage cell swallows a silica particle, the particle kills the cell, which then releases its bacteria-fighting poison. This starts a vicious cycle that can compromise the body's ability to ward off infection. Meanwhile, scar tissue develops around the particle, causing irreversible damage to that part of the lung (silicosis).

When airborne, asbestos isn't a particle—it's a fiber. Enlarged under a microscope, asbestos fibers resemble swords. They can be up to 50 microns long, but a mere ½ micron in diameter. The aerodynamic shape of asbestos fibers allows them entry into deep reaches of the lungs, where they get trapped and enveloped in scar tissue.

Vapor risks—Most vapors and gases encountered by a builder don't damage the lungs. Instead, the lungs provide a route for poisons to enter the blood, where they can damage the central nervous system. Symptoms occur in two stages. First are the acute symptoms—light headedness, dizziness and nausea. Sometimes the symptoms show up hours after exposure, which can make the cause difficult to track down. Once they're in the blood, the liver often detoxifies the organic poisons. Liver and kidney damage often result from prolonged exposure. Sometimes the liver converts one poison into another one. For example, methylene chloride is converted by the liver into carbon monoxide, which can put people with heart conditions at serious risk.

Damage to the central nervous system from organic vapors is cumulative. If you're continually exposed, acute symptoms turn into chronic symptoms. Depression, insomnia, loss of muscle control, a reduction in reaction time and memory loss all are results of damage to the central nervous system.

The order of precautions—With nasty airborne evils lurking on the job site, wouldn't it make sense just to eliminate the source of the problem rather than swathing the face with a respirator that can clog or leak? Yes. That's the first step, according to Dr. Edward Petsonk, chief of the Clinical Section of the Division of Respiratory Disease Studies for NIOSH (National Institute for Occupational Safety and Health). Petsonk says the first thing to do with a respiratory hazard is to try to eliminate it or minimize it. For example, use a water-based lacquer instead of the traditional nitrocellulose lacquer, which contains methyl-ethyl-ketone—a well-known central nervous system depressant. You'll still need a respirator, but your risks will be dramatically reduced.

Second, if you can't make a materials substitute, try to control the problem at its source. For example, cut tile or concrete with a saw that directs water onto the cut, mixing the silica dust into a harmless slurry. Similarly, install a dust-collection system in a woodshop with intake ports that gather the dust before it becomes airborne. And make sure your edge tools are sharp. A dull sawblade will make finer dust than a sharp one.

The third step is to ventilate the area, which isn't always possible when it's freezing outside. If you can't ventilate, filtration—wearing a respirator—is your last choice. But remember, respirators are the least-effective means of reducing exposure. Try to minimize exposure as you wear your respirator by avoiding obvious concentrations of particles and by ventilating the area.

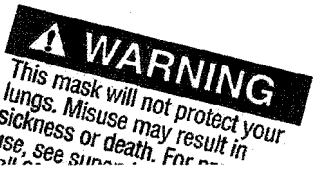
Disposable respirators—The flimsy little paper cup with the rubber band my friend handed me wasn't a respirator. It was a nuisance-dust mask. Dust masks like these lack approval from NIOSH, the agency responsible for monitoring the effectiveness of respirators. For the mask to be a respirator, NIOSH has to say so, and the stamp of approval appears on the product. The stamp means that the respirator, when used exactly as intended by the manufacturer, will remove a certain amount of airborne particles, fibers and vapors under allowable concentration levels.

Respirators can look like dust masks (top photo, facing page). These are disposable respirators and are typically designed to filter dusts and mists. Disposable respirators have a pair of heavy rubber bands instead of a single flimsy one, and they've got a better seal where they bend around the bridge of the nose.

Disposable respirators trap particles down to 1 micron in diameter. As you breathe in, you create a vacuum (negative pressure) inside the mask. As air passes through the filter material, these respirators trap particles in a net of tiny, nonwoven plastic fibers (bottom photos, facing page). Disposable respirators actually work better after they've been used for a while because particles stack up inside the mesh, helping to trap other incoming particles.

So when should you dispose of a disposable respirator? It depends on how much dust has

Respiratory hazards



Humans have pretty good built-in air-filtration systems for the kinds of dusts that occur in nature. That's what nose hairs are for. But respiratory evolution hasn't kept up with the tiny particles that can be produced by power tools such as sanders, grinders, paint sprayers and welding rigs. The particles generated by these tools are so tiny that you can breathe them deep into your lungs.

Particles can be divided into two groups—those that are respirable and those that aren't Respirable particles are smaller than 10 microns in diameter and can be sucked into remote corners of the lungs (1 micron equals 1 millionth of a meter). Respirable particles present a serious hazard to the builder, but breathing in measurable doses of particles larger than 10 microns isn't a good idea, either. They get trapped in the larger passages of the respiratory system, where they are enveloped by mucous and eventually coughed up. Repeated exposure to these larger particles can lead to allergic reactions and lower the body's ability to fight off infections.

***Particle hazards*—There are three categories of particle hazards. *Dusts* are generated by cutting, sanding or grinding building materials such as wood, drywall or concrete. Studies have shown that the fine wood dust generated by sanding can be as small as 1.3 microns in diameter. By comparison, the larger particles of wood made by cutting with routers or saws are on the order of 33 microns.**

***Mists* are particles that are formed when atomized liquids condense. The typical example encountered by a builder is spray paint. When you spray enamel, for example, some of the paint that doesn't land on the target becomes airborne particles in the 5- to 6-micron range.**

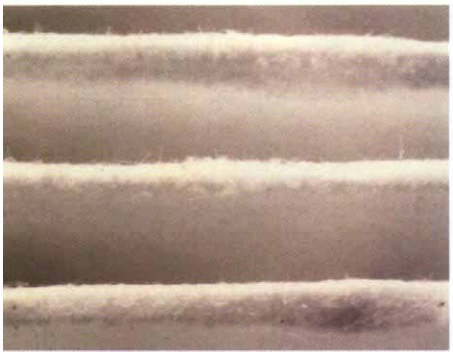
***Fumes* are condensed particles that are produced when metals are heated to the boiling point by welding or soldering. Fumes from a MIG welding rig are on the order of .5 micron in diameter.**

***Gases and vapors*—Tiny particles aren't the only airborne hazard faced by the builder. Gases and vapors work their damage at the molecular level. Gases, such as methane and carbon monoxide, are substances that are airborne at room temperature. Vapors are gaseous forms of the solvents that evaporate from coatings and glues such as paints, varnishes, lacquers, contact cements and organic mastics.**

Fibers*—Asbestos, a proven carcinogen, is the most well-known fiber in this category. Other fibers to avoid breathing are rock wool and fiberglass, especially the chopped fiberglass used for blown-in attic insulation. —*C. M.

Half-mask respirators. **The best half-mask respirators have a yoke-style top strap, which holds the facepiece in place with pressure applied evenly. Some facepieces, such as the one shown above by Glendale Protective Technologies, have a double-seal feature to ensure a snug fit against the face. This rig is outfitted with HEPA filters, which are identified by the magenta stripes.**

HEPA filter. **Your best protection against toxic particles and fibers is a high-efficiency particulate air filter (HEPA). This filter is made up of glass fibers (photo right) arranged on a folded paper armature (photo below).**



been filtered through it. You should toss it when it becomes difficult to breathe through. If you persist in breathing through a clogged respirator, contaminated air will simply find its way through the leaks around the mask. But these types of masks usually suffer broken rubber bands before their filters get clogged. By the way, vacuuming the mask from the exterior side to clean it doesn't do any good. The particles are tangled in a fiber matrix that won't let them back out.

A decent disposable dust/mist respirator, such as 3M's model 8710, costs about $2.50 at the hardware store. But you can buy them in bulk for a lot less money from mail-order suppliers (see Sources of supply). Recent versions of these masks have activated charcoal in them, which reduces the smell of nuisance vapors. But they aren't NIOSH-approved as vapor respirators.

Another modification to the basic disposable respirator that makes it more comfortable to wear is the exhalation valve (top photo, p. 72). Masks with this feature let you exhale more easily, which can make a big difference on a hot day.

The biggest problem with disposable dust/mist respirators is that they just don't seal very well around their edges. To get them to pass their filtration test, NIOSH technicians have to seal the edges of a disposable respirator to a mannequin with hot wax. A study by the Center for Disease Control reveals that disposable dust/mist respirators can leak up to 20%. Of course, you could always hot-melt glue the mask to your face to achieve NIOSH's results.

Reusable respirators—You get the best air seal and widest selection of filtering capabilities with a reusable respirator (top photo, left). There are two types—the half-mask and the quarter-mask. The facepiece of the half-mask respirator covers the nose, the mouth and the chin, and the quarter-mask facepiece stops just below the mouth. The half-mask facepiece has more bearing surface, so it makes a more stable seal on your face.

Half-mask facepieces are made by plenty of companies (see Sources of supply). Filter cartridges screw into the one or two ports on the front of the facepiece. They are not interchangeable from one brand to another. Manufacturers typically offer the masks in a couple of quality grades. The best facepieces have beefy straps and sturdy clasps and buckles, and you can get replacement parts for them.

The masks with a cradle-style top strap are best at maintaining a good fit. And a good fit means a good seal around the edges of the respirator where it meets your face. Most facepieces are made of rubber, but some companies, such as Willson and Glendale Protective Technologies, also make them out of silicone, which is softer and therefore better at maintaining a seal against "problem faces." Expect to pay in the realm of $35 for a facepiece plus a pair of cartridges for a standard-grade half-mask respirator. Add another $10 for a top-of-the-line silicone version.

I actually heard a guy claim that his beard acted as a primary filter. Nope. A beard acts as an open door under a half-mask respirator, seriously compromising the effectiveness of the respirator. Common sense would suggest that wearing a res-

Bottom photos: Mark Floyd and Jesse Fisher, Forensic Analytical Labs

pirator over a beard would still be better lung protection than wearing nothing at all, but I couldn't get anybody in the industry to concur with that logic. Bearded folks can still breathe easy in dusty places (photo p. 77), however, with the help of a powered air-purifying respirator (more on these later).

A good fit is critical to a respirator's efficiency, and you should perform two tests when fitting the mask. First, put the respirator on, inhale and lightly cover the exhalation valve with the palm of your hand. Now exhale. If there's a leak around the edge of the facepiece, you should feel it on your face. If you've got a leak, adjust the straps until it stops. If the mask is uncomfortably tight, loosen the straps but always shy of the exhalation leak. A common mistake is overly tightened straps. You shouldn't see red welts across your neck when you take the thing off.

In the second test, cover the filter cartridges with your hands and inhale. If it fits properly, the mask should collapse.

If you're sharing respirators, you should disinfect them between users. Respirator manufacturers sell solutions of quaternary ammonium for this purpose. You can also use household bleach at a ratio of 4 cc per 1 gal. of 120° water. Remove the cartridges and soak the facepiece for two to three minutes. Pat dry and store in a plastic bag between uses.

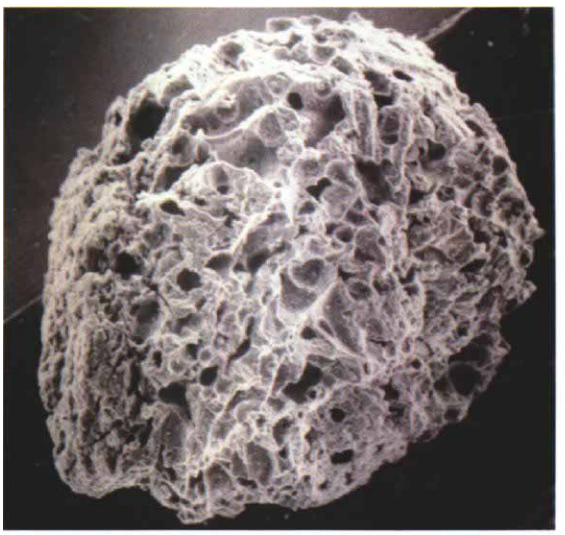
Different kinds of cartridges—The screw-on cartridges that complete a half-mask respirator trap different kinds of contaminants. The agencies that certify cartridge standards have assigned standard colors to the various types of filters. The two most common cartridges necessary on a job site are the organic-vapor cartridge (black), and the HEPA filter (magenta).

Like its name implies, the organic-vapor cartridge is the one you want when working with paints and solvents that contain volatile organic compounds (VOCs) such as lacquer thinners or naphtha. The cartridge (bottom photo, right) is filled with activated charcoal to which airborne organic molecules adhere. This process, called adsorption, continues until all available nooks and crannies of the charcoal (middle photo, right) are covered with organic molecules. At that point, which is called breakthrough, you can start to smell the vapors. This is your warning to change cartridges.

Painters using spray rigs should put prefilters over their organic-vapor cartridges and change the prefilters every day (top photo, right). Prefilters will trap heavy mists that would prematurely clog the cartridges.

Activated charcoal doesn't know if you're breathing through it, or if it's just sitting around. In either case, it keeps filtering organic vapors. So to prolong the life of the organic cartridge, you should always put the respirator in its plastic bag between uses.

A HEPA (high-efficiency particulate air) filter is your best defense against small particles (bottom photos, facing page). The filters snag particles down to .3 micron in diameter. The cartridge-style HEPA filters for reusable respirators have paper filters that are folded, accordion style,



Organic-vapor cartridges. **Painters should use mesh prefilters (photo above) to catch paint mists before they clog the organic-vapor cartridges. The used prefilter shown here next to a clean prefilter is loaded up with a day's worth of paint mist. Organic-vapor cartridges use activated charcoal, shown in the micrograph to the left, to remove organic molecules. As they're drawn across the surface of the charcoal, the molecules condense and then cling to the charcoal. When you can smell organic vapors through the mask, it's time to replace the cartridges (photo below).**

Top photo: Charles Miller

Powered air-purifying respirators. **These PAPRs use a battery-powered fan to pull air through a filter. Clean air is then piped to the helmet, where it washes across the inside of the face shield. The positive pressure inside the helmet, along with a foam or Tyvek face guard, keeps particles out of the respirator. Above left, Racal's Airlite; above right, Racal's Air-Mate 3; below left, Willson's 6000 series; below right, 3M's Airhat W-316.**

into a labyrinthian airway. Tiny glass fibers coat the paper and catch incoming particles.

HEPA filters are very efficient at trapping particles—on the order of 99.97%. While a dust/mist respirator is almost as efficient (98% to start, improving with use), to be on the safe side it's a good idea to use a HEPA filter when working indoors with dangerous particles or fibers, such as fine sawdust, joint-compound dust, concrete dust or asbestos. Use a combo organic-vapor/HEPA filter when both hazards are present.

Airborne dust particles have either positive or negative electrical charges. To take advantage of this, some disposable HEPA filters use electrically charged fibers to trap particles. They work well in dry weather, but these filters can be compromised when it's hot and humid because the moisture neutralizes the charged fibers.

Battery-powered respirators—My woodshop is in the basement, and it's often too cold outside to encourage cross-ventilation. So I typically wear a HEPA filter on a half-mask respirator. But in researching this article I got a hold of some powered air-purifying respirators (PAPRs). Sometimes called dust helmets, these rigs use a battery-powered fan to suck air through a dust/mist filter (photos facing page). The filtered air is delivered through a hose to the helmet, where it washes across the inside of the face shield. The positive pressure inside the mask keeps out dust while providing filtered air that evaporates the condensation that would otherwise build up on the inside of the face shield. And because the rig doesn't require an airtight seal, you can keep the beard. On some models the face shield flips up, so it's easy to pause and take quick sips of your coffee before it gets cold and dusty.

Be aware that some PAPRs are only effective against particles while others can be fitted with organic-vapor cartridges. And if you've got a PAPR with a belt-mounted fan, be prepared to relive last night's black-bean soup when your own organic vapors stir.

With all the paraphernalia they require, PAPRs are expensive and bulky. I asked wood turner Dennis Elliott, of Sherman, Connecticut, for his opinion about the comfort and durability of his air helmet. Elliott has worn a Racal AGH1 daily for eight years and wouldn't be without it. He says he's dropped the rig numerous times without damaging it, and he's yet to replace the rechargeable battery. What's more, he values the face shield so much that he wears the air helmet out in the woods when using his chainsaw.

An inexpensive PAPR is $350, and it's easy to get into the $800 range. But for a woodworker who stands in predictable, upright positions, this is a respirator you don't mind using.

Warning labels—Paint cans and other such containers will have cautions on the back, listing a witch's brew of toxic chemicals along with admonitions to provide adequate ventilation. But the labels don't tell you what kind of respirator to wear, or perhaps more importantly, whether a respirator will do you any good. Some vapors, such as methylene chloride in paint strippers or the isocyanates in some urethane coatings, cannot be controlled with negative-pressure respirators. By the time the vapors break through—the point at which you can smell them—you've already inhaled damaging amounts of the chemicals. The only way to use them safely is with a positive-pressure respirator that uses an outside air source (akin to a diving helmet).

To learn about the specifics of a product, you need to study the MSDS (material safety data sheet). Manufacturers and suppliers are required by OSHA to provide this document to those who purchase products with toxic ingredients. Suppliers to contractors should have the sheets on hand. If not, call the manufacturer and get one by fax. The sheet lists the hazardous components and tells what precautions need to be taken with the product. Contractors who assign their employees to work with hazardous materials are required by law to have the MSDS posted in a prominent place on the job site and to provide their workers with appropriate safety gear.

You'd think that the MSDS would be enough to make a decision about what kind of respirator to wear, but it isn't, according to technical adviser David Koch at Willson Industries. Koch says some of the MSDSs he's seen give inaccurate advice about what cartridges to use. He says the best way to protect yourself is to call the manufacturer of a hazardous product to get the list of ingredients (the phone number should be on the can). Then call the technical-advice line at a respirator company to find out how to protect yourself.

Have I changed my respirator habits?—Yes and no. Researching this article convinced me that I have to put up with a respirator for a lot more of the construction activities that I do—especially when I'm working indoors sanding drywall or furniture, installing insulation or spraying paints. But I also discovered that wearing a high-quality half-mask respirator isn't nearly as unpleasant as gasping through the cheapo disposable jobs that I used to wear. There's a big difference in comfort and performance between a top-of-the-line half-mask respirator (particularly the silicone ones) and the flimsy disposables.

I'm sticking with the HEPA filters for particle protection. They're more efficient than the dust/mist filters, and they trap the really small, dangerous silica particles and asbestos fibers encountered on job sites—especially remodels.

I used to think that organic-vapor cartridges were all I needed when spraying oil-based paints, but I didn't know about the prefilters that extend the life of the cartridge. Without the prefilters, my cartridges were clogging prematurely.

Finally, I know I should wear my respirator when I'm working outside, ripping red cedar on my portable table saw. But that's going to be a tougher sell for me. If there's a breeze blowing, the particle concentrations aren't going to be very hazardous. So I'm a lot more inclined to put the saw downwind, and hold my breath if it changes direction. □

Charles Miller is the managing editor of Fine Homebuilding. *Photos by Robert Marsala except where noted.*

You can keep the beard. **As this bearded trim carpenter runs moldings on a router table, filtered air from a belt-mounted battery pack washes across the inside of his face shield. The Tyvek face guard helps keep dust particles from entering below the shield.**

Sources of supply and technical information

Glendale Protective Technologies, Inc.
109 Carpenter Dr., Sterling, Va. 20164
(800) 645-7530

3M Occupational Health and Environmental Safety Division
3M Center Bldg., 275-6W-01
St. Paul, Minn. 55133-3275
Technical info: (800) 2434630

Willson Safety Products
P. O. Box 622
Reading, Pa. 19603
(215) 376-6161

Racal Health and Safety, Inc.
7305 Executive Way
Frederick, Md. 21701
(800) 682-9500

Mail-order sources

Lab Safety Supply, Inc.
P. O. Box 1368
Janesville, Wis. 53547-1368
(800) 3564)783

Northern Safety Co., Inc.
P. O. Box 4250
Utica, N. Y. 13504
(800) 631-1246

Airstream Dust Helmets
P. O. Box 975
Elbow Lake, Minn. 56531
(218) 685-4457

Photo: Charles Miller