Composite Cautions

Plastics have revolutionized homebuilt aircraft, but there is danger in the fumes, dust and liquids.

BY FORBES AIRD

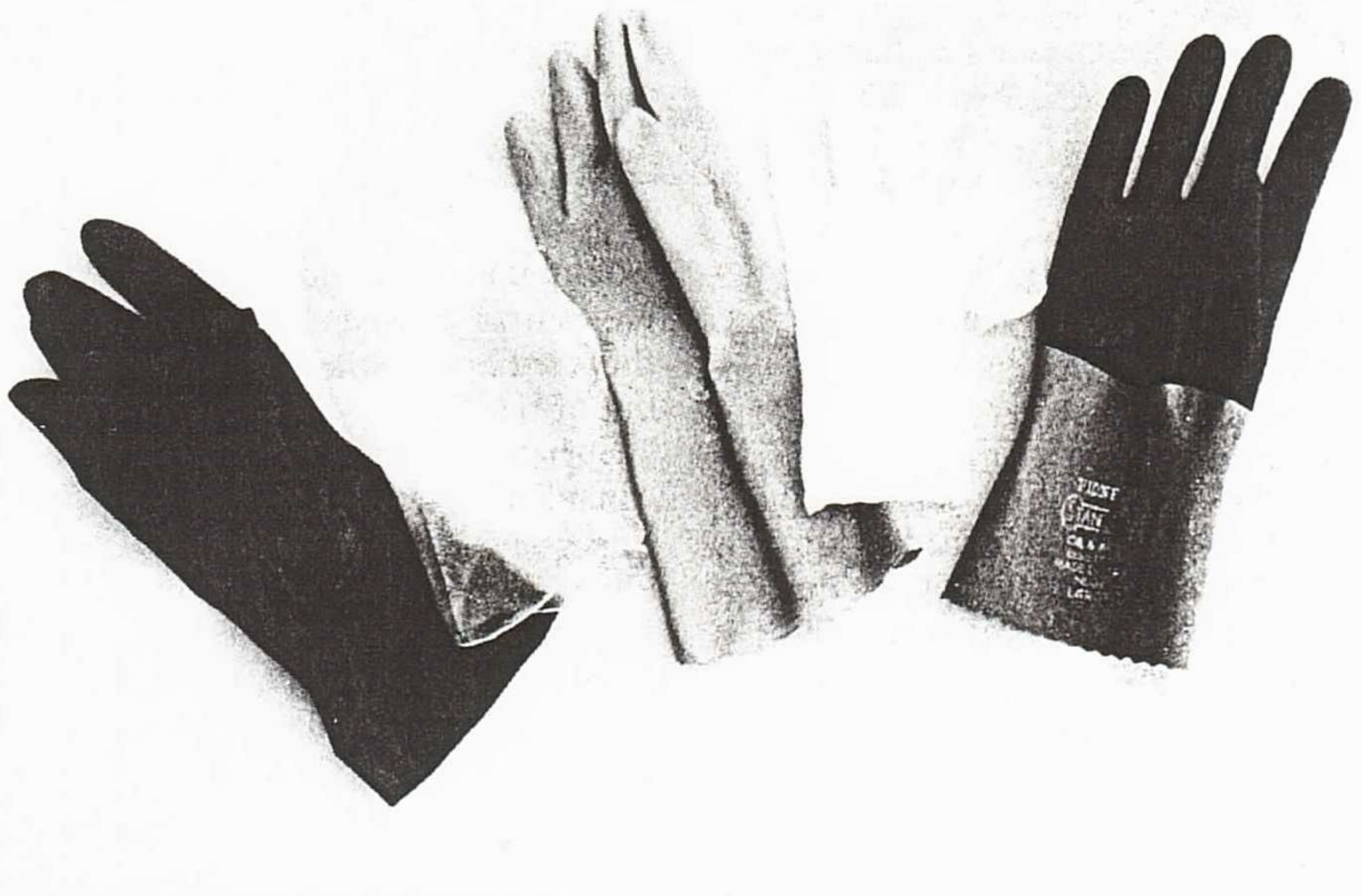
From the simplest homebuilt to the most sophisticated jet fighter, composite plastics are revolutionizing aircraft construction.

They are light, stiff and resistant to corrosion and, for the homebuilder, they require relatively few sophisticated and expensive tools.

Yet working with these composites can be difficult and dangerous if certain precautions are not taken.

The hazards from dust, fumes and liquids are less visible and thus perhaps less obvious than the injury a saw can inflict, for example.

Those who manufacture and market reinforced-plastic materials are required by law to provide a material safety data sheet (MSDS) for each product, identifying its known health and safety hazards and providing instructions on its safe handling and use. You should insist on an MSDS for every chemical product you purchase. Read it. And heed it.



Photos: Kate Aird

Gloves vary widely in material and thickness. Nitrile, neoprene and butyl rubbers are best for protection against epoxies and solvents. Thicker material offers greater protection, but impairs dexterity. Cotton inner liners improve comfort in all gloves.

The Materials and Their Hazards

Years before any aeronautical structure was made from reinforced plastic, fiberglass was well established as the preferred medium for small-boat construction. The glass reinforcement and polyester resins used there are relatively cheap, light and strong but lack the stiffness and strength necessary for structural use in airframes. For lightly stressed aircraft parts, though, such as fairings and cowlings, glass/polyester remains popular for its economy and ease of working. Polyester resin, as usually purchased, actually contains an assortment of other chemicals.

Styrene monomer is one of them and it serves as a diluting solvent for the resin, thus making it more workable. Styrene monomer accounts for about 40% of the mix and for most of the familiar fiberglass shop smell. Styrene—also known as vinyl benzene—is a clear, colorless, highly flammable liquid with a very distinct and pervasive odor which can be detected at a concentration of less than one part per million (ppm). Because styrene is fat-soluble, the liquid effectively degreases the skin on contact, which causes symptoms ranging from mild local irritation to severe dermatitis, including blistering. Liquid styrene is readily absorbed by the skin.

Styrene is volatile, and 10 to 15% of the styrene in polyester or vinylester resins can evaporate into the workplace air during manual layup. The vapors are irritants to the eyes and upper respiratory tract. Prolonged inhalation at 15 ppm and higher can cause burning eyes, sneezing and coughing and can have narcotic effects (headache, dizziness, drowsiness, vomiting); 50 ppm and higher can cause central nervous system depression. Exposure even to levels below 50 ppm over months or years—such as a full-time worker in the industry may experience—can lead to chronic health effects including liver and kidney damage. A recent re-examination of the long-term effects of styrene by a division of the World Health Organization has also increased concerns about its potential as a human carcinogen. Its strong odor and irritating effects help to discourage extended exposure, however.

Not only is liquid styrene highly flammable, its vapors form an explosive mixture in air at volume concentrations of 1.5% to 6.7%. To put this into perspective, however, 1.5% corresponds to 15,000 ppm, so the critical limit is human exposure rather than the formation of an explosive mixture.

Dimethyl aniline (DMA) and/or cobalt naphthenate (CoNap) are usually present in polyester resins as accelerators, which speed up the curing process. There also may be a wide assortment of fillers, inhibitors, pigments and plasticizers, to obtain

special properties, such as ultraviolet resistance, longer storage life or reduced weight.

Dimethyl aniline is supplied as a clear light-yellow-to-brownish solution that is strongly alkaline and so can cause skin burns. Both liquid and vapor may be absorbed through the skin and act as a central nervous system depressant. DMA vapors are both flammable and an irritant, and inhalation of the vapors may be fatal, as may swallowing of the liquid. Chronic health effects from exposure include liver and kidney damage.

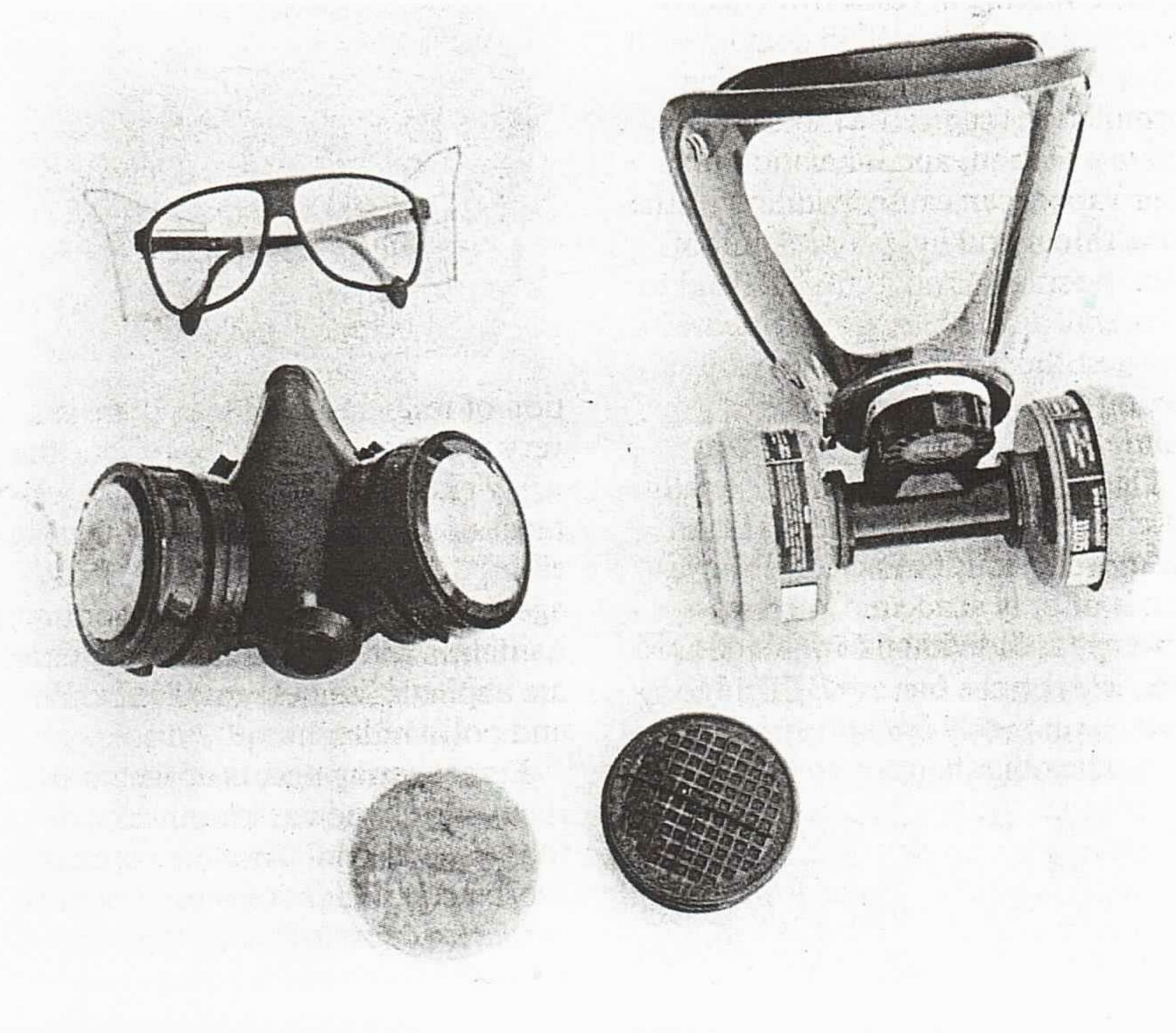
Cobalt naphthenate solution is a combustible red-violet liquid with a mineral-spirits odor. As liquid or vapor, it is irritating to the eyes and skin and may be absorbed through the skin. Breathing of concentrated vapors may cause headache and loss of coordination. It is especially harmful if swallowed, with symptoms including gastrointestinal irritation, vomiting and depression.

In addition, a catalyst, usually methyl ethyl ketone peroxide (MEKP) or benzoyl peroxide (BPO), is added by the user at the time of processing to initiate the cure.

MEKP is a clear colorless liquid and is explosively unstable in its pure form. As a result, it is supplied dissolved in a buffering liquid. While it is not itself highly flammable, it is a powerful oxidizer that may cause some readily flammable substances such as paper, rags or sawdust to ignite spontaneously if it comes in contact with them. It is also quite corrosive, and prolonged contact will cause skin burns. MEKP splashed in the eyes can cause serious, permanent eye damage. The vapors may cause headaches and intoxication and corrosive damage to nose, throat and lungs.

BPO is less commonly used as a catalyst in curing polyesters and vinylesters. It is usually supplied as a paste, dispersed in some stabilizing medium; otherwise, this powerful organic peroxide can be regarded as similar to MEKP.

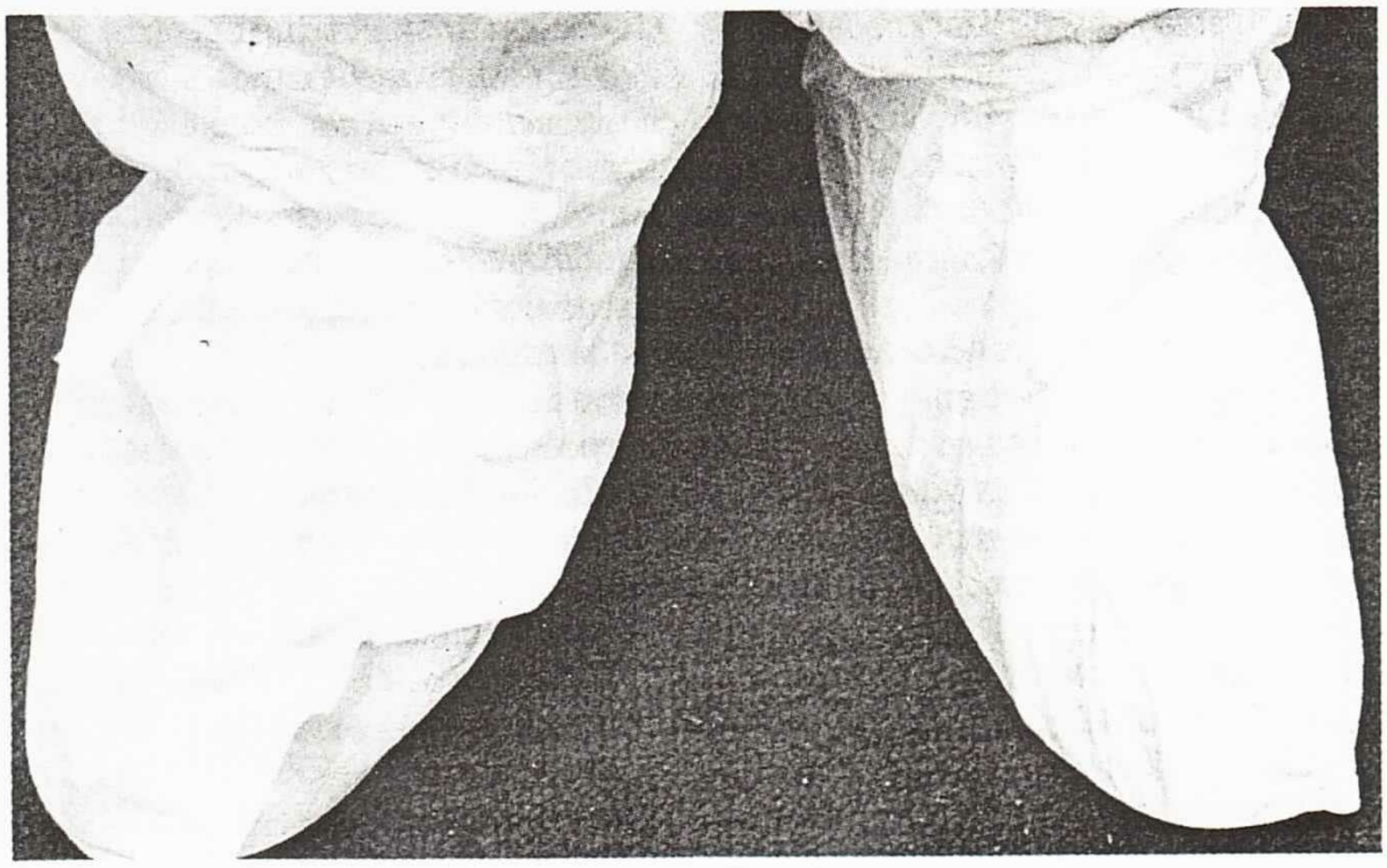
The relative weakness of aircraft parts made with polyester resin was first answered by the adoption of **epoxy** resins which are significantly more expensive and more difficult to handle than polyester, and also have different health hazards associated



Illustrated safety gear courtesy of Safety Supply Canada.

Respirator masks with replaceable reactive cartridges are available in half-face and full-face styles. If there is any risk of liquid splashes, half-face masks must be accompanied by eye protection.

Overboots prevent soiling shoes.



with them. Where the greatest strength and stiffness is sought, epoxy has the edge and is chosen when the structural results justify the handling problems and expense.

Epoxy resins, as used in homebuilt fabrication, are moderately viscous liquids, varying in color from nearly clear to dark amber. Skin contact with either the liquid or vapors of some formulations can cause moderate to severe irritation, and inhalation of their vapors can cause irritation of the nose, throat and lungs. Ingestion of even the smallest amounts can lead to an overall allergic response. One way to ingest them it to eat lunch with incompletely scoured hands, for example.

The lower-viscosity resins generally have a greater hazard potential than the more viscous ones. This observation is of only academic interest, however, as individual formulations can yield, on the one hand, highly viscous yet highly irritating products or, on the other hand, something like the popular "safety" epoxies, which combine low viscosity with very low irritation potential. These differences are to some extent attributable to which of various glycidil ethers are present in the resin as a reactive diluent.

Glycidil ethers are colorless liquids of low viscosity and slightly sweet odor. They vary from negligible to severe in potential for irritation, and some (notably phenyl glycidil ether and butyl glycidil ether) are suspected carcinogens. Major resin makers say products containing the nastier glycidil ethers are not sold to amateurs.

As many workers have discovered to their dismay, a sensitization can occur with epoxy systems. If an allergic reaction is ever triggered—whether by a single severe exposure to a particularly irritating resin, or by long-term exposure to low doses of a relatively innocuous one—subsequent exposure to small doses of even the most benign epoxy can cause a recurrence. The same kind of sensitization can occur with glycidil ethers, and a cross-sensitization can occur between epoxies and glycidil ethers, and vice versa.

Another characteristic of epoxy systems is that, unlike polyester and vinylester, the cure rate cannot be adjusted by varying the catalyst-resin ratio because for any given combination of resin and hardener, there is a very narrow range of proportions that will yield a proper cure. Thus, adjustment of the cure rate requires altering either the temperature or the curing agent used. Among the more common hardeners for room-temperature cures are aliphatic amines, modified amines and polyamides.

A metal safety can with a spring-closed pouring spout should be the only container for solvents in the shop. A dry-chemical fire extinguisher is a must for any shop. The 5 lb.-capacity unit shown here is too small; 10 lb. of dry-chem should be regarded as a minimum.

Epoxy-curing agents of the unmodified amine type are seldom seen in the amateur field. They are corrosive substances of high irritation potential, can cause dermatitis, severe burns and may have other serious long-term health effects. Amines in direct contact with the eyes will produce severe damage.

Modified amine curing agents are now available that have much-reduced potential for both irritation and sensitization. Nevertheless, prolonged contact with either liquid or fumes may cause both effects in some individuals. To compound the irony of sensitization, some people exhibit cross-sensitivity among epoxies *and* glycidil ethers *and* amine curing agents.

Polyamides are viscous liquids with a distinct odor of ammonia. They are probably safer than any of the amine curatives, but are uselessly thick unless diluted. Dilution to workable viscosities is achievable, but so much reactive dilutent is required that the hazards of the dilutent may defeat the purpose and also result in a structurally inferior end product.

More recently, **vinylester** resins have received favorable attention among homebuilders because they resemble polyester in their ease of handling, yet yield mechanical properties similar to epoxy.

Vinylester resin systems, like polyester (and for the same reasons), include large amounts of styrene. They also generally use the same catalysts and accelerators as polyesters, with the exception that the accelerator is not usually premixed into the resin, but rather must be added by the end user, prior to catalyzing.

Once cured, none of the three basic types of resin can be dissolved. Until fully cured, however, they are all at least partially soluble in solvents such as acetone, which is thus widely used for general cleanup.

Acetone is a clear, colorless liquid with a strong solvent odor. It is highly flammable. Exposure to liquid acetone can cause dermatitis due to its fat-solvent properties. Liquid acetone may be absorbed by skin, though the vapor probably is not. As it is very commonly used for cleanup, its vapors —which are irritating to the eyes and upper respiratory tract—are likely to be present in large concentrations in the shop. Prolonged exposure to acetone vapor at 310 ppm and greater can cause loss of coordination and central nervous system disturbances.

Reinforcing Fibers and Finished Laminates

Although virtually everything will burn under the right circumstances, cured thermoset resins (polyesters, vinylesters and epoxies) do not represent a particularly severe fire hazard.

Yet when they do catch fire, they can be tough to put out and meanwhile make lots of very nasty smoke. The reinforcing fibers themselves—at least glass and carbon—are completely benign, from the point of view of fire. **Aramid fiber,** sometimes used as a reinforcing fiber, is inherently fire resistant, but it chars above 800°F and *will* burn if an ignition source is maintained.

Of greater danger is contact with resins that are not fully cured, cuts from jagged edges of dried glasswork and the dust from grinding, sawing and drilling.

While the dust of some materials, like asbestos, is demonstrated to be carcinogenic, fine particles of anything are bad for your respiratory system. Otherwise harmless substances like wood, flour and stone can cause grief if inhaled as a dust.

Six simple, inexpensive items (plus good ventilation and common sense) make the difference between near-zero health risks and near-certain harm: goggles; disposable, non-woven coverals with hood; barrier cream; clean, impermeable gloves; reactive respirator; suppliers' MSDS's.

The Precautions

Almost all of the materials referred to above have at least some potential for adverse health effects. But by taking common-sense precautions, such as insuring adequate ventilation, protecting eyes and skin with appropriate clothing, and the use of a respirator mask, the health risks are minimal. If these simple acts of self-preservation are observed, probably the greatest real hazard is fire.

Precautions must be taken against fire and explosion. Flammable solvents and resins should be kept in their original containers and stored in a well-ventilated cool place, away from any source of heat or ignition. Only as much as is needed for a single work session should be brought into the shop, in suitable closed vessels. Obviously, smoking and any sort of open flame must be banned from the work area. A dry-chemical fire extinguisher and a bucket of sand should be nearby.

Solvents are to clean uncured resin off tools, not people. Apart from the horrible prospect of a worker half-drenched in acetone suddenly becoming a human torch, the solvents serve as vehicles to drive nasty chemicals further into the skin. Skin contact with a solvent which has been contaminated with resin should never, ever, be allowed. This is a spectacularly efficient way of getting the resin deep into the lower layers of the skin.

Catalysts and accelerators also require cool storage, but particular care must be taken to prevent these two classes of materials from ever coming in undiluted contact with one another, because of the risk of fire and explosion. Because of their potential to cause spontaneous combustion, peroxide catalyst spills of any consequence should be soaked up with sand, never sawdust, rags or paper towels. Any residue should be thoroughly washed down with water.

Satisfactory ventilation is a must. Air should flow from behind the worker, across the work and away. (Actually, there is no "away." Check your local codes for possible trouble with the law; also, consider your neighbors downwind.) If, as is likely, you are using a fan to draw air out of the shop, aim it downwind under typical prevailing wind conditions. Because most of the troublesome vapors are heavier than air, exhaust fan inlets should be located close to the floor, with fresh air supplied close to the worker, higher up. Similarly, fumes will tend to accumulate in high concentrations in any sort of hollow depression such as a fuselage half being worked on open-side up. Portable fans can be sited to dissipate such local pockets of vapor, but care must be taken to avoid inundating other unprotected workers.

With really good ventilation, there are some jobs you can do without a respirator. These include admiring yesterday's work and taking coffee breaks. Some loonies will laminate without a mask. These people have—or soon will have—brain pans filled with yogurt. You really must wear a mask anytime you have plastic brewing. Certainly any spraying, sanding or grinding operation, cutting or tearing mat or cloth, cleaning anything with acetone, mixing two-part polyurethane foam, hotwire foam cutting and all resin mixing and laminating absolutely require a mask.

A good mask is definitely not the pathetic little granny-rag the local paint dealer hands out free with a quart of lacquer. These hardly block dust and tiny fiber fragments and do absolutely nothing about fumes and vapors that can damage your liver and/or brain. The mask you need is the authentic Darth Vader model, with a honker out both sides, each with a *reactive cartridge.* To prevent the cartridges from plugging up with dust, there is usually a mechanical particle filter upstream of the reactive cartridge. These felt-like strainers should be changed weekly—if you're working steadily—and the reactive cartridges should be replaced as soon as you start to smell what you're working on.

Some form of eye protection is mandatory, if only to guard against

SAFETY

continued

splashes. Catalysts, curing agents and accelerators, especially, can cause severe and almost instant damage to the eyes. In view of the eye irritation characteristic of many of the above substances, there is a case to be made for a more elaborate respirator device that incorporates a partial face shield.

With an effective respirator, itchy, scratchy eyes are the remaining cue that vapor concentrations are becoming excessive. Conventional safety goggles provide protection against splashes but do not exclude fumes from the eyes. For any kind of grinding, sawing, cutting or sanding operation, you definitely need shatterproof eye protection.

Most resins work best at temperatures higher than most people work best, and all common thermosetting resins undergo an exothermic cure. That is, they put out heat when they cure. Nonetheless, resist the temptation to work in shorts and a T-shirt.

Well-covered means lightweight coveralls with sleeves rolled all the way down. By far the best arrangement is disposable coveralls with an integral hood that makes you look like Commander Hygiene. Made of a paper-like material called Tyvek (a registered trademark of E.I. du Pont de Nemours, Inc.), these are widely available (try an auto body shop supply outfit), sturdy enough for many days of light duty and relatively inexpensive.

For dusty operations like cutting and grinding, the hood is a godsend although it may be hot and uncomfortable. Nevertheless, you'd better cover your head: if you splash plastic in your hair, you can get it out later—with scissors. There is no other way. A painter's hat works fine, but you'll want to amputate most of the peak or wear it backward to prevent bumping into your work when peering closely at an air bubble.

Also, you will want protective gloves. The disposable vinyl plastic kind are hopelessly clumsy and keep falling off; pure latex surgical gloves are far too flimsy, impossible to get on or off, and are not effective barriers against the various resins and solvents. On the other hand, anything heftier than the ordinary household type are too thick and clunky.

Butyl, nitrile and neoprene rubbers are claimed to be effective barriers to epoxy and related compounds. Conventional domestic rubber gloves—such as those for dish-washing—are mostly latex. Theoretically, these do not provide an adequate barrier to epoxies and some others of the above nasty fluids. They also are not strongly resistant to solvents. In practice, many workers find them adequate if replaced frequently.

Commander Hygiene—the well-dressed laminator!

Whatever you settle for, you may want to add a barrier cream, which is applied to the skin prior to the work session and then washed off afterwards. Claims are made that some of these creams provide adequate protection all by themselves. Certainly they can be a useful backup to gloves, especially if you opt for thinner, more flexible gloves, which are more permeable and more prone to accidental tears.

With all gloves, mop off the worst of the gunk, leave them turned inside-out after you remove them (to let the sweat evaporate), sprinkle talcum powder on the inside before using them again, and throw them away at least once a week. Gloves should be worn outside cuffs.

Also, you will get an astonishing number of dribbles on your shoes and thus disposable booties should be considered.

Good housekeeping should obviously be practiced in the shop. Dust should be vacuumed up, not blasted away with an air hose. Resin dribbles and spills should be cleaned off all surfaces. Disposable paper coverings for mixing tables and elsewhere are an excellent way to keep things clean and to avoid extraneous contact with uncured resin. Waste of all types should be disposed of responsibly.

The most environmentally responsible way to dispose of waste resins and/or hardeners is to *react* them, leaving an inert solid. Beware, however, that a container of reacting resin generates much more heat than the same quantity of material spread over the large area of a laminate, and may represent a fire risk. One technique is to set the whole container in a bucket of water.

You should have a locker on the upstream side of the airflow where you can keep your street clothes and your supply of clean Commander Hygiene outfits. If at all possible, install a shower nearby. This may seem like a luxury but working with composites is pretty messy work in the best of times . . . and gritty and awful the rest of the time. At the very least, there must be a wash basin and plenty of hot water and soap nearby. The best-known formulator of epoxy systems for homebuilt use suggests the use of alcohol (presumably isopropyl "rubbing" alcohol) to clean up tools and mineral spirits or a waterless hand cleaner to remove inadvertent splashes of resin from the skin, followed by soap and hot water.

If this personal hygiene business sounds like a lot of work, you'll find it's worth it. If you breathe fiberglass dust from grinding, you'll get itchy lungs and cough blood. Later, you may die. Breathing two-part polyurethane foam while it's reacting also can cause severe problems. Ditto fumes from hot-wire cutting of polystyrene foam.

If you get certain epoxy agents on you often enough, you will get a horrible sensation like you just sandpapered yourself and feel compelled to tear your skin off. Either that, or it will fall off all by itself. More likely both.

You're still going to get itchy and sticky from time to time. Sensible precautions, however, will vastly improve your sense of humor, your chances of staying healthy and the quality of your work. It's hard to concentrate and be patient when you're uncomfortable. So: fan cranked up, non-porous, clean Commander Hygiene outfit, pink rubber gloves, Darth Vader mask. You look lovely! Now, *follow the directions on the can!* □

Forbes Aird wrote about the structural properties of some composites in the January 1988 edition of KITPLANES.