New laws are forcing manufacturers to produce paint formulations that pollute less. Here's a look at these environmentally friendly finishes and what you can expect of them.

By TIMOTHY O. BAKKE

CLEAN AIR PAINTS

JOHN B. CARNETT

New York-based architect Mary Anderson knows her paint, or at least she thought she did.

"I had always specified solvent-based alkyd paint because of the exceptional sheen and smoothness of its finish," she told me. "It is also extremely hard and durable, especially important on high-wear interior surfaces. Nothing could compare with it."

But then something changed. New air-pollution controls went into effect in parts of New York last year—and in New Jersey this year—and they affected the paint on which Anderson had been relying.

"Starting last year, I began to hear complaints from painting contractors that the paint I was specifying was hard to apply and took too long to dry," Anderson told me. "When I tried using some new alkyd semigloss on a wall myself, I found that, indeed, the paint was not as easy to roll out as it used to be. The skim-coated plaster wall I was painting with a fine roller had been worked over and prepped well, so I should have been getting the best finish possible. Instead, no matter what I did, I ended up with an orange-peel-textured surface. And it took three or four days to dry. I was disappointed and confused."

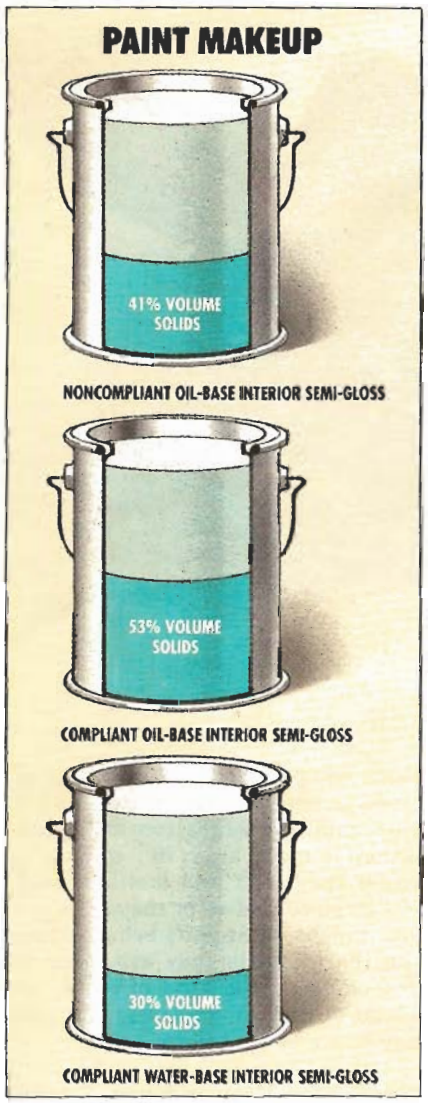
Anderson is not alone. The entire architectural coatings industry is reeling because of legislation across the country that restricts the emission levels of paint and other finishes. Most latex paints—interior flats and semiglosses as well as exterior house and trim paint—are not affected; they are formulated in a water base and thus have low emissions. Most oil-based finishes *are* affected, however. To cope with the new regulations, manufacturers are reformulating these finishes, withdrawing some from the market, and coming up with new water-base technology to take their place.

The alkyd products that result are different from their predecessors in almost every way. They are more benign to the environment, but they also have greatly altered application requirements and performance characteristics—and generally higher prices. All this leaves painting contractors and homeowners in many areas in a quandary. Either they can't find familiar products on store shelves or they are faced with finishes that don't behave at all like the products they are used to. Depending on the kind of paint you intend to use, your future paint jobs may never be the same.

Emissions from oil-based finishes are called volatile organic compounds (VOCs). They come mostly from solvent chemicals—hydrocarbons like toluene, xylene, and naphtha—that are given off during application and curing.

"The VOCs combine with other hydrocarbons in the atmosphere and react photochemically with oxides of nitrogen to form lower atmospheric ozone," says Tom Graves, director of federal affairs for the National Paint and Coatings Association (NPCA). Lower atmospheric ozone is a potent pollutant that contributes to smog. It is not to be confused with stratospheric ozone, which shields Earth from the sun's ultraviolet radiation.

"There are one hundred or so areas of the country that don't meet air-quality standards for ozone under the current Clean Air Act," Graves points out. As a result, legislation to limit VOC emissions is being enacted across the country, albeit in a piecemeal fashion—in some cases differing from county to county. Parts of Arizona, California, Texas, and New York al-



ready have laws on the books. New Jersey has passed statewide regulations. And state and local restrictions are being considered in Illinois, Indiana, Maryland, Massachusetts, and Wisconsin. This fragmentation plays havoc with the formulation and distribution of paint. Consequently the NPCA is recommending a federal regulation—based on the strict California Air Resources Board rules limiting emissions in flat and non-flat architectural coatings, for example, to 250 grams per liter—as an amendment to the new Clean Air Act expected to be passed later this year. Currently, many unrestricted alkyd coatings routinely exceed 400 grams per liter.

How are manufacturers complying with the regulations? To understand the answer, you first need to know what goes into these finishes. All contain some solid materials and some solvent; the ratio depends on the kind of finish. A traditional alkyd paint, for example, is somewhere around 60 percent liquid to 40 percent solid. The liquid is generally made up of linseed oil and volatile solvents, which help the paint spread and dry properly; the solid materials comprise pigments, alkyd resins that act as binders, and other additives. Conventional stains are about 80 percent solvent, while sealers are 90 to 95 percent solvent.

"To keep alkyd paints on the shelves, manufacturers are essentially reducing the amount of solvent, which increases the proportion of solids," Carroll Bennett, architectural market manager for Sherwin-Williams told me. "The paint therefore becomes somewhat thicker, so it may become harder to apply. It also goes on in a thicker film, which is good—and bad. It's good because the thick film may give you extra protection; but drying time is extended, from about forty-eight hours to ninety-six hours."

Also, durability is reduced. To maintain an acceptable viscosity in the higher-solids product, formulators changed the structure of the alkyd molecule. The alkyds' role is critical: These are the molecules that polymerize to form the paint film. Normally, alkyds are large long-chained polymer molecules that gain strength by forming chemical bonds with other large molecules, like long strands of spaghetti that intertwine. The newer alkyds are shorter-chained, like smaller strands of spaghetti. They flow more easily, but they aren't as strong.

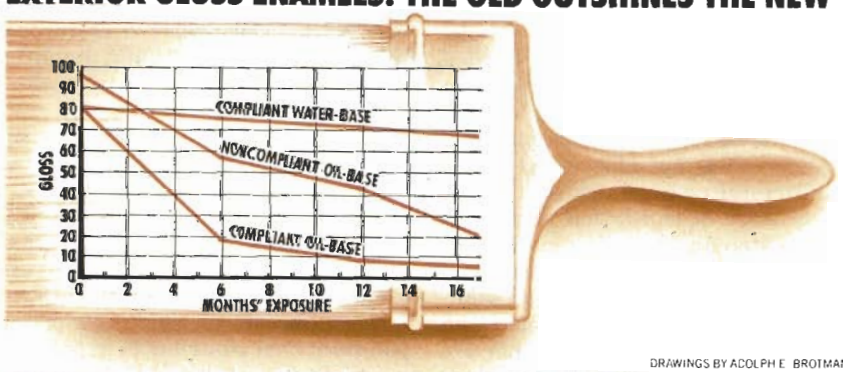
"With some kinds of finishes, such as interior flat wall paint, interior semi-gloss, and exterior house and trim paint, there have long been high-quality latex alternatives to alkyds, so a maker may or may not reformulate—it might simply withdraw the oil paint from the market," Bennett continued. "Since most consumers use latex anyway, they won't miss the oil paint." In other categories, like gloss enamels, outdoor varnishes, and most industrial coatings, however, there were no acceptable alternatives that complied with the new laws. Thus manufacturers have been *forced* to develop new formulations.

Oil-based gloss enamel, the primary attribute of which has always been its glasslike finish, is especially hard hit. Currently there is no substitute—either a reformulated alkyd or a latex—that exhibits its qualities of smoothness and high initial gloss, although acrylic enamels are coming close and actually *retain* their sheen longer (see drawings and graph).

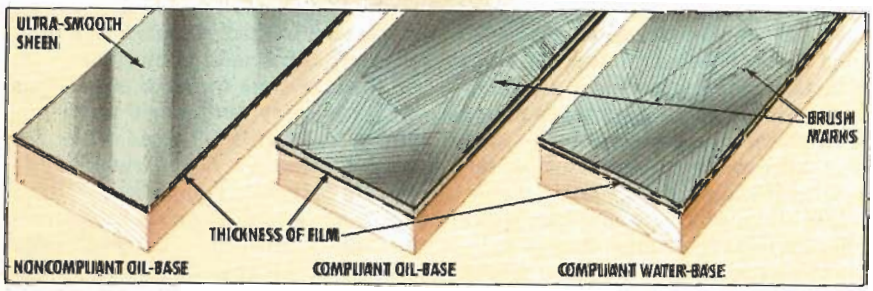
The solids contents are being increased in clear finishes and stains as well. "Clear coatings have typically been formulated in the thirty-eight-to-forty-five-percent solids range. With the new regulations you're in the sixty-three-to-sixty-five-percent range," says Barry Oppenheim, technical manager for McCloskey's, a division of Valspar (see box, New Clear Finishes). "In stains, people are used to seeing very thin products, in the fifteen-to-twenty-eight-percent solids range, maximum. They have a viscosity pretty much like water. The new stains have to be in the sixty-five-to-seventy-percent solids range."

The new-formulation stains are so

EXTERIOR GLOSS ENAMELS: THE OLD OUTSHINES THE NEW

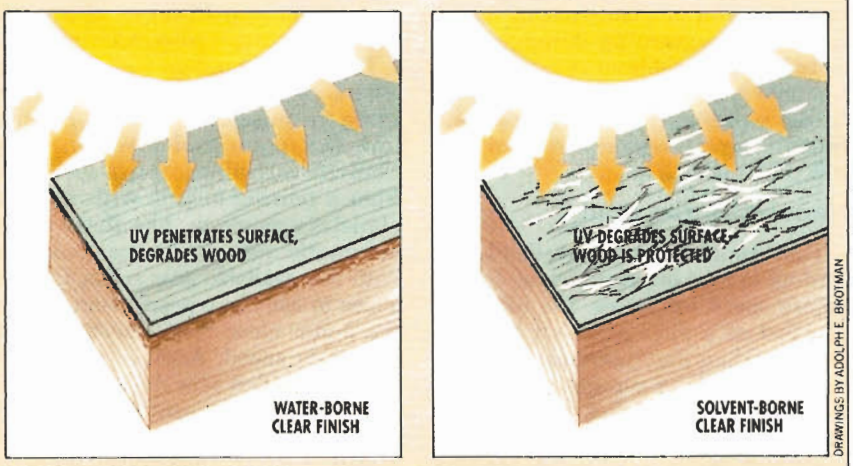


DRAWINGS BY ADOLPH E. BROTMAN



New gloss enamels don't measure up in initial gloss (graph) or smoothness (above) to traditional products. Latex does, however, surpass its alkyd cousins in gloss retention (see graph).

NEW CLEAR FINISHES: PROMISES, PROBLEMS



Most formulators of clear finishes are complying with VOC regulations by increasing the proportion of solids rather than by developing water-based formulations. Why? 1) Water-soluble resins used in clear finishes are transparent to ultraviolet radiation, allowing the UV radiation to degrade the wood below (drawings). Conventional solvent-based resins absorb UV radiation and are "self-sacrificing." The finish itself is degraded by UV radiation, protecting the wood. 2) Water-borne acrylic polymers are not hard enough ["Water-Based Varnish," Jan. '89]. Catalysts make the product stronger, but difficult to work with.

Though the first problem has yet to be solved, Flecto, with its Varathane Diamond Finish, BonaKemi USA (Woodline Waterborne Urethane), and Pratt & Lambert's Fabulon Division (Crystal Finish) have addressed the second. These new water-based finishes use polymers whose atomic structures have been rearranged so that they will interconnect, unaided by catalysts, forming a strong network of bonded molecules.—*T. O. B.*

thick that you should wipe rather than brush them on. And the drying times are extended ["Gel Stains," Feb. '89]. "The good news," says Oppenheim, "is that you no longer need a presealer on softwoods because the gels stain much more evenly."

That kind of tradeoff is common in VOC-compliant alkyd paints too, says Robert Nelson, director of environmental affairs for the NPCA. Here are some other examples.

- Application: Brush out, which is the ability to prevent visible brush strokes, and rolling characteristics are worse with newer alkyd paints. The new products don't flow and level out as the well as older, thinner alkyds. However, like all alkyds, the new paints still have application advantages over latexes: They can be applied over a wider surface-temperature range because they are not formulated with water, and they have better wet-edge retention, which means you can brush back into the paint once it has been applied without getting lap marks as you do with latex.
- Hardness is reduced because the paints' shorter-chain molecules do not polymerize as completely as long-chain molecules. Therefore, the film does not become as rigid.
- Resistance to chalking and fading is reduced because the polymer film is not as stable. But resistance to cracking and peeling is improved because the film is more flexible.
- Mildew resistance is degraded somewhat because there is more organic material on which the mildew can grow. (In a related development, the national Centers for Disease Control has urged the EPA to ban the use of mercury in paints. Mercury is often used as a mildewcide.)
- Holdout, or the ability to resist penetration over porous surfaces, could be worse in the newer paints because they do not set as quickly and have more of an opportunity to penetrate.
- On the positive side, odor is reduced, as is fire hazard.

Also on the positive side, of course, is the fact that the new finishes will pollute the air less. Sherwin-Williams' Bennett thinks that, "In the long run, environmental legislation is obviously the right thing to do, with two caveats: There must be consistent regulations across the country, and we as an industry should not be forced into moving faster than technology allows us to move."

Congress seems to agree: At press time the NPCA's Graves was confident that his association's strict but realistic clean air amendment would be passed by year's end. PS

SOME MANUFACTURERS OF ARCHITECTURAL COATINGS
BonaKemi USA, 5450 Joliet St., Denver CO 80239; **De Soto, Inc.**, 1700 S. Mount Prospect Rd., Des Plaines IL 60017; **The Flecto Co.**, Box 12955, Oakland CA 94604; **The Glidden Co.**, 925 Euclid Ave., Cleveland OH 44115; **The McCloskey Corp. (Division of Valspar)**, 7600 State Rd., Philadelphia PA 19136; **Minwax Co.**, 102 Chestnut Ridge Plaza, Montvale NJ 07654; **Benjamin Moore & Co.**, 51 Chestnut Ridge Rd., Montvale NJ 07645; **The O'Brien Corp.**, 450 E. Grand St. S., San Francisco CA 94080; **Olympic Stain Co.**, 2233 112th Ave. N.E., Bellevue WA 98004; **PPG Industries**, 1 PPG Pl., Pittsburgh PA 15272; **Pratt & Lambert**, 75 Tonawanda St., Buffalo NY 14207; **Sherwin-Williams**, 1101 Prospect Ave., Cleveland OH 44115

VOLATILE ORGANIC COMPOUNDS AND INDUSTRIAL MAINTENANCE COATINGS

Regulations governing VOC emissions apply not only to household paints and finishes but to coatings for structures like bridges and industrial plants as well. According to Sherwin-Williams' Carroll Bennett, the two most popular and rugged products, vinyl and chlorinated-rubber coatings, which are resistant to acids and other corrosive chemicals, cannot currently be reformulated to meet VOC restrictions. And, Bennett says, there are no viable water-borne systems to replace them as yet. The Golden Gate bridge, for example, stands scarred by gray primer, waiting until a safe coating can be found for it. But according to Parke Schaffer, general manager of Inorganic Coatings in Malvern, Pa., New York is painting the Hudson River's Tappan Zee Bridge with a water-borne high-ratio zinc silicate primer that has been newly formulated by NASA and a new acrylic top coat, both sold by his company.

In another development, Epolin, Inc., headquartered in Newark, N.J., has developed a low-VOC corrosion-resistant polymer coating that is tough enough to be used on jet aircraft. It exhibits a unique feature: When it cures, it expands slightly. Other coatings shrink when their component molecules, called monomers, form long-chain polymers as they turn from a liquid to a solid state. During this polymerization, the chemical bonds become more closely spaced than in the uncombined monomers, thus the compression. During shrinkage the coatings may crack, and on a microscopic level they tend to adhere to the higher levels of a surface, leaving the valleys unprotected.

Epolin based its product research on polymer work done at the University of Maryland. In its stretching aerospace finish, the monomers are in the shape of tight rings. As they polymerize in the presence of ultraviolet light, the monomers open up to form polymer chains, expanding to a minute degree. The company is forging ahead with plans to develop a commercial alternative to solvent-based paints, according to vice president Dr. Morton S. Lefar, although those products are still in the distant future.—*T. O. B.*

Sun racers

[Continued from page 53]

It remains to be seen whether this innovative design can run through a rough section of road without losing control or sustaining damage. "We tested it on a cobblestone road, and it is stable and durable," says Quadrini. "If the suspension develops a hairline fracture we can repair or replace it in less than two hours."

Repairs on the road

That would be a major setback. According to race director George Ettenheim's speed estimates, the race will proceed at a pace of about 30 mph —slower than the Australian race due to lower levels of sunlight and a route with more hill climbing. At this rate, Quadrini's theoretical two-hour repair could cost the team 60 miles, sending SunDragon to the back of the pack.

Making up that distance will mean running at close to the limit for the remainder of the day. As far as top speed goes, Western Washington University's Viking XX is indicative of the pack of solar cars. While capable of running faster than the race's 55-mph speed limit, it will be at the expense of draining the batteries. The team's strategy will be to maintain a cruising speed of around 40 mph, saving battery power for short bursts of speed.

Piacesi says The Pride of Maryland can cruise at about 40 mph on level terrain under good sunlight without using any battery power. The key is a combination of the power trackers that keep the solar array at peak efficiency and the car's direct-current brushless motor built by Unique Mobility of Englewood, Colo. At 13.5 pounds, this motor boasts a peak efficiency rating of 96 percent. About half of the solar cars will be driven by this 20-horsepower motor, though even under the most strenuous conditions no more than about four hp will be used. According to Quadrini, "It has all the power we'll need and more."

While the Unique Mobility motor is small and light enough to be easily held in your hand, it requires a controller that supplies pulse-width modulated power keyed to the motor's speed to optimize performance. Teams using the Unique Mobility motor and controller system get a fringe benefit—regenerative charging all the way down to zero mph.

Church of Rose-Hulman thinks that the Unique Mobility motor and controller (up to 34 pounds by itself) are overkill and a luxury the team's ultralight entry cannot afford. So the Solar Phantom uses a compact three-hp motor fed by a small controller that weighs less than 10 pounds. "We're going to be extremely stingy on both weight and power with this car," says Church. Still he expects to be able to compete wheel to wheel with the heavier, more powerful cars.

The Solar Phantom will, like many others, drive a single rear wheel. But while the majority will use a chain to link the motor and wheel directly, Church's car will use a five-speed hub from a touring bicycle with internal planetary gearsets, like those on an automatic automotive transmission. With five available gear ratios, Church hopes to use the transmission to keep the motor close to its most efficient operating speed. Another innovation that has spilled over from automotive technology is the continuously variable transmission that Stanford University is currently working with, according to student coordinator Heck. Operating on the same principle as the transmission in the Subaru Justy ECVT, it does fixed gear transmisions one better by providing an infinite variety of gear ratios.

Knowing the route

Knowing the twists and turns of the route will also be a definite advantage. Last summer the Sunraycer traveled some of the roads the race will cover, and Drexel's Quadrini was there, video camera in hand. He has compiled the data into an optimization program that will attempt to preserve battery charge. Here's how it works: A computer in the chase van keeps track of performance data, including speed, power consumption, and power generation. It compares actual data with the theoretical optimum for a perfect energy-saving drive, and the operator radios the driver to adjust his driving technique.

How will each team fare in this 11-day endurance contest? It's anyone's guess, but several cars appear to be at an advantage under certain conditions.

- The two-person Viking XX with its large energy-collecting array could run past the pack traveling north on a sunny day, but could lose ground when the road bends to the east or west.
- The lightweights, like the Drexel SunDragon and Rose-Hulman Solar Phantom, could break into the lead in hilly areas with their Spartan designs.
- The University of Maryland car should be a contender on rough roads.
- The Stanford SunSurfer might be able to overhelm the competition with its efficient solar array.

For the top finishers of this race, the competition will not be ending, but just beginning. Three teams will win GM sponsorship to compete in the World Solar Challenge in Australia this November. PS