How to Evaluate Chemically Resistant Adhesives

A guide to selecting the adhesives, sealants and coatings that can withstand harsh chemical environments
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Of all the factors that should be considered when selecting adhesive products, chemical exposure too often gets short shrift. A quick peek at a few data sheets or a chemical resistance chart may be all the work that goes into evaluating an adhesive product for use in a specific chemical environment.

Yet this kind of half-hearted effort simply won’t cut it if you want to make sure that adhesives, sealants and encapsulants will withstand the chemicals found in so many industrial, medical, automotive and aerospace applications.

All polymers, including adhesives, have potential chemical vulnerabilities that can result in a loss of physical properties (see sidebar). The challenge is knowing exactly how those vulnerabilities will come into play given all the variables that govern the effects of chemical exposures.

These variables start with the interaction of material systems with specific chemicals. The challenge here is that there are literally thousands of combinations of substrate materials, adhesives and chemical agents to consider. The variables also include the type of exposure, which can range from a splash to continuous immersion. Finally, chemical resistance can vary substantially under different mechanical and thermal loads.

Getting a handle on how all these variables interact can be difficult and time-consuming. But the information that follows will give you a head start in picking adhesives that will hold fast against any chemical onslaught.

Understand Chemical Interactions

The first thing to understand about adhesives and chemicals is that there is no single adhesive that’s the best.

Product Guide By Application

Engineers today have to account for a large number of individualized chemical exposures when designing products, which can complicate the adhesive selection process. Yet, there are some adhesives and sealants that have established themselves within specific industries. Here’s a closer look at them:

**Aerospace.** EP41S-IHT and EP62-1, epoxies for bonding and sealing applications, have a broad resistance to aviation fuels and hydraulic fluids, including Skydrol.

**Electronics.** EP21ARHT is an epoxy well-suited to the acids encountered in semiconductor and other electronics manufacturing processes.

**OEM.** EP41S-IHT has a track record as a coating material for chemical tanks. EP21TPND makes a good tank coating material for acid environments.

**Medical.** EP42HT-2 and EP62-1MED are epoxies that hold up particularly well to repeated, aggressive sterilization methods—including autoclaving and chemical sterilization.

**Oil and Gas.** Downhole applications can subject adhesives, sealants and coatings to temperatures up to 450°F and a variety of polymer-aggressive oils, hydraulic fluids, gases and abrasives. Supreme 45HTQ, an extremely durable mineral-filled epoxy, is one of the few adhesives that perform well in this environment.
choice for every chemical environment. It is true that some adhesive families are known for having a broad resistance to many types of chemicals. Epoxies clearly lead the pack in this regard. Polyurethanes, silicones, UV curables and polysulfides can all provide acceptable chemical resistance against a more limited range of chemicals, though they cannot stand up to nearly as many chemical environments as epoxies.

It’s also true that within each adhesive family, thermal and chemical resistance often go hand in hand. Cross-linked adhesives, like the ones just mentioned, tend to have the best chemical resistance below their glass transition temperatures (Tg). So grades with higher Tg can often beat the heat and tolerate more chemicals.

Generalities, however, will only get you so far in the adhesive selection process. Keep in mind that adhesive chemistries can vary substantially even within a family. Individual grades of adhesives can have different functional additives and curing reactions that will affect their ability to withstand chemicals.

Consider epoxies. As a family, they are the most chemically resistant adhesives, encapsulants and coatings available. But individual epoxy formulations do differ in their specific chemical resistance traits. You can see just how different epoxies can be in Table One, which shows the relative resistance of epoxy coatings to a lineup of industrial chemicals, solvents and fuels. For example, assuming that all epoxies will resist ethyl alcohol just because some grades resist ethyl alcohol can be a big mistake.

So it’s always important to consider the resistance of individual grades to specific chemical exposures. This strategy applies not just to epoxies but also to any other adhesives that will see use in a chemical environment.

Understand the Exposure Variables

Figuring out which adhesives will withstand which chemicals is really only half the battle. It’s also necessary to understand the type of exposure. On the most basic level, exposures should be characterized by the intensity of contact with a chemical agent. Low intensity exposures are best thought of as a splash. Higher intensity exposures would involve immersion that could be intermittent or continuous. Note that exposures can involve gases, not just liquids.

Chemical exposures should be considered in the context of the application’s thermal and mechanical loads. Many adhesives can experience an incremental loss of chemical resistance at elevated temperatures—especially above the Tg. High stresses also exacerbate any adverse effects that a chemical agent has on adhesive or cohesive strength. Adhesive and chemical combinations that make the grade under one set of loading conditions won’t necessarily make it in others.

All these of variables may sound straightforward, but mischaracterizing the type of exposure is a surprisingly common mistake. And it’s a mistake with potentially serious ramifications. Understating the intensity of exposure or the severity of the loads can obviously result in adhesive products that don’t perform as well as expected, perhaps even to the point of failure.

Usually, prudent design engineers tend to overstate exposure or loads. That strategy, while safe and appropriate up to a point, can limit the number of suitable adhesive products for a given application. Why? Because for any potentially harmful chemical agent, there are many more adhesives that can resist splashes, low temperatures and low stresses than there are adhesives that can resist continuous immersion, high temperatures and high stresses.

The consequences of over-engineering for chemical resistance are two-fold. One is that you could end up trading off other desirable adhesive properties for a level of chemical resistance the application doesn’t really require. The other is that adhesives with the very best chemical resistance are apt to have more difficult mixing and curing regiments, potentially bumping up assembly costs unnecessarily.

Understand Testing

Because it’s crucial to get the details of chemical exposure right, it is a good idea to test bonding, sealing and encapsulation applications that could be subject to harmful chemical interactions. There are dozens of ASTM and industry-specific tests that attempt to capture these
interactions. General Motors alone has more than 30 adhesives specifications, many of which contain conditions related to chemical or moisture exposure.

Whatever the test that is most accepted in your particular industry, keep in mind that testing at best only approximates real-world conditions. Consider that ASTM D896, one of the most widely cited standards for adhesive chemical resistance, does not make any distinction between chemical adsorption in the bulk adhesive or penetration at the adhesive-substrate interface. Yet this difference is one of the key factors in an adhesive's chemical degradation behavior.

Most test regimens also require shorter term exposures than real-world applications. Some military tests subject adhesives to immersion in fuels and hydraulic fluid for just one week and to high-humidity conditions for 30 days. Real-world exposures can obviously last much longer.

Here at Master Bond, our technical service engineers don't put much credence in short-term test data, relying instead on our unique own database of long-term exposure data. Some of this chemical exposure data comes from immersion tests that have lasted as long as ten years. And our long-term data covers many combinations of adhesives and chemicals—including many organic and inorganic acids, alcohols, chlorinated compounds, hydrocarbons, solvents and more.

A related issue involves accelerated testing, which exposes adhesives to exaggerated loading conditions for short time periods in an effort to yield predictions about much longer service life. Many times, these test regimens will elevate temperatures to the point that they introduce thermal effects that a product would never experience in the field. Because actual service temperature is such an integral part of any adhesive's true chemical resistance, accelerated testing can actually point engineers in the wrong directions. For example, epoxies that might be an excellent choice in a room-temperature chemical environment can be made to fail at accelerated testing temperatures.

None of these warnings should be construed as an argument that testing should not take place. It should. Just bear in mind that test conditions often deviate substantially from real-world exposure conditions and time scales.

An effective adhesives selection strategy, then, requires engineers to evaluate specific chemical-and-adhesive combinations in the context of exposure and loading conditions that are as close as possible to the expected service conditions. That's a lot more effort than picking adhesives from a chemical resistance chart, but it's a small price to pay for some confidence that you've picked the right adhesive for the job.

**For further information on this article, for answers to any adhesives applications questions, or for information on any Master Bond products, please contact our technical experts at Tel: +1 (201) 343-8983.**