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Furan resins are used in the manufacturing of corrosion resistant FRP composites because of:

(A) Their excellent chemical resistance. Furans are especially good for handling solvents and aggressive service environments.

(B) Their excellent high temperature properties. There are case histories of furan FRP composite duct performing at temperatures in excess 300°F. Laboratory tests have been conducted on furan laminates at up to 425°F.

(C) Their inherent fire retardant (low flame spread) and low smoke properties. An ASTM E-84 flame spread of less than 25, and smoke development of less than 30 are achievable.

**If furan resins have such wonderful properties, why not use them in all of the corrosion resistant FRP composite equipment built?**

Because of the nature of the cross linking (curing) of the furan molecular polymer backbone, furan resins are difficult to catalyze, fabricate with, cure, and handle within the fabricator's shop.

The conversion (polymerization) of the liquid furan resin to a solid corrosion resistant FRP composite laminate is accomplished by a condensation reaction. This means, that at every point of cross linking on the polymer chain, one mole of $H_20$ (water) is given off. It requires a very high level of skill, technology, and know-how on the part of the fabricator to control the chemical reaction, and to prevent the water from turning to water vapor.

For maximum corrosion resistant and fire proof properties, furan laminates also require a post cure at the fabricator's shop. That cure must occur in carefully controlled temperature stages, or again the water will turn to steam. Water vapor or steam pressure will cause porosity, blistering, cracking, crazing, and delaminations of the furan composite.

**What does this have to do with furan dual laminates?**

In the early days of FRP composites, when the furan resins were first introduced, the furan laminate was simply used as an inner corrosion liner, and then backed with a polyester or epoxy resin for the structural wall. It was thought that with this "dual laminate" the fabricator could minimize the problems of working with furan resins. The concept was that there would only be a "thin" liner to have to worry about. And, part of the theory also went that the water vapor, once the mold was stripped off, would have a shorter distance to travel to escape the laminate. Such dual laminates with furan were the "norm" for most corrosion resistant equipment in those early days. However, what looked good in theory, did <u>not</u> work out well in practice.

Over time, field failures started to crop up with furan lined dual laminate construction. Detailed field investigations found that the polyester and epoxy backing laminates masked, or hid, problems with the

furan construction. Porosity and internal crazing and cracking of the furan laminate did not get detected at the time of fabricating and hydrotesting. The structural polyester and epoxy portion of the laminate hid the problems from early discovery. (Since the natural color of furan is black, visual inspections often will only detect the major problems, such as buckling and large blisters.)

In service, the corrosive environments for which the furan had been used for initially, penetrated the porous or micro-cracked furan inner liner. The chemicals then quickly attacked the epoxy or polyester structural backing of the dual laminate FRP composite vessels, duct or piping. Such chemical attack was also accelerated by any shipping, handling or installation damage that occurred to the corrosion resistant inner furan liner.

Had the structural laminate also been furan, the liner damage would not have been nearly as critical. But, when the furan liner itself got damaged, then the chemicals went right to work on the less chemically resistant polyester or epoxy structural laminate. The resulting equipment failures often proved to be very costly to the end user.

The early end users of furan laminates soon learned to specify solid furan FRP construction. Companies like DuPont, Monsanto, FMC, and Pfizer changed their corporate specifications to allow only the use of solid furan laminates. This way, the furan chemical and corrosion resistant properties went through the entire wall of the structure. Thus, the use of a solid furan laminate also allowed the testing of the completed fittings, vessels, duct, and pipe before putting into service. Any porosity, cracks, or crazing, would immediately show up as weepage; and could immediately be repaired, or replaced.

**Knowing what we know today, why are some people still promoting dual laminates for furan FRP corrosion resistant equipment?**

Probably the most prevalent reason is that it provides a fabricator, that uses dual laminates, a competitive cost advantage over his competition. Polyesters and epoxies are much less expensive than furan resins. In addition, the manufacturing procedures are less costly for the polyesters and epoxies.

As a matter of principal and technology, Industrial Fiberglass Specialties does not build dual laminate furan composite equipment. We feel strongly that our long term reputation is worth more than a "quick buck" made by getting a specific order. We have been producing FRP composite equipment since 1946. While we, as individuals, are probably not going to be around to see it, we expect our company to be in business for another half century.

The second reason some fabricators may still be using a dual laminate is that, as discussed above, it hides and masks manufacturing problems. There is a saying in our industry that a polyester or epoxy laminate backup to a furan corrosion liner can "hide a multitude of sins". At the risk of sounding like a broken record, we believe that it best serves both our company, and the end user, to provide equipment that is "trouble free". This also provides the customer their lowest cost per year of service life.

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There is no question that a dual laminate furan composite, backed by polyester or epoxy, will have a lower initial purchase cost! The material costs going in are less expensive, and the production steps for such dual laminate manufacturing are less costly. And, since problems are masked, the factory reject or rework rate is nil. To paraphrase a slogan from the appliance industry, "the first cost is not always the last cost".

Knowledgeable end users of chemical process equipment are looking at not only the cost per year of service life - but, also the cost of prematurely replacing equipment that fails earlier than its normal expected life. Many companies are now factoring in the cost of lost production. The hourly cost for the down time of a plant can mean many dollars of lost shipments - and the loss of profits on those shipments.

**In summary:** Early furan equipment was built with dual laminates - i.e. furan corrosion liners backed by polyester or epoxy laminates. Field service data quickly demonstrated that solid, or all furan, laminates provided both superior corrosion performance, and a comfort factor in knowing that the equipment could be tested and installed with confidence. Dual laminate furan composites are still available in the marketplace. However, Industrial Fiberglass Specialties recommends against their use. We feel the additional initial cost premium is well worth the service benefits to be gained from using an <u>all furan</u> laminate for your corrosion resistant pipe, tanks, duct or vessels.