Industrial Fiberglass Specialties, Inc.
521 Kiser Street
Dayton, Ohio 45404-1641
Telephone (937) 222-9000 - Fax (937) 222-9020

Date: 02 February 2004

White Paper - FRP Composite Flue Gas Stack Liners

The use of FRP composite stack "liners" has long been recognized as an appropriate and cost effective way of providing extended service life for existing and new stacks (chimneys). This paper looks at the past FRP composite stack liner experiences, and makes recommendations for future stack lining projects.

While the physical size of stack to be lined can be challenging (diameters can range from 12 feet to 40+ feet, and heights of hundreds of feet); the technology of making FRP stack liners is by now well established. These fabrication methods can include: Filament winding of "cans" or spools for placement in lifts inside of the stack. Contact molding and laminating in place. Vacuum assisted resin transfer molding, etc.

The success of past FRP composite stack liner installations has been mixed. Some FRP stack liners are continuing to provide years of trouble free life. On other projects the FRP stack liners have already had to be extensively repaired, or replaced. There appears to be a direct correlation between the fabricator selected to make and install the FRP composite stack liner - and initial project problems and/or the service life of that installation. Low initial costs for the stack liner can mean more initial or delayed headaches, and a higher cost per year of ownership.

Any material of construction; if not properly designed, fabricated, and installed; can present installation and service problems, and shortened service life. FRP composite materials are no exception to this rule. What has been different for FRP stack liners, partly because of the costs involved, is the reaction of engineers to now "over-specify" the FRP stack liners for new projects. Some engineers have used previous problems with FRP stack liners to take the position that it is better to be ultra conservative with all aspects of their specifications.

Unfortunately much of the concentration of specifications for new FRP composite stack liners addresses areas that were not the "real" problems with prior under-performing stack liners. Looking at the some of those non-problem areas:

Structural Design: No one would deny that an FRP stack liner must be properly engineered and designed. But, past FRP stack liners that required remedial repair or replacement were not replaced because of any structural failures or collapse of the FRP liner. A stack liner is just that - a "liner" placed inside of a stack, with the outer stack body providing the structural integrity. The design considerations for an FRP stack liner are significantly different than those for a free standing FRP composite stack. (A free standing stack is one of the most complex civil engineering structures to design.)

FRP Laminate Perfection: All owners of corrosion resistant FRP composite equipment want, and have the right to expect, the highest possible laminate quality. Here again though, those prior FRP fume stacks that provided less than optimum service life, did not have to be replaced because of the quality of the laminates. Failures were not because the as-built laminate did not meet arbitrary ASTM visual inspection standards established for consumer products, or for extremely severe liquid chemical service. To put it bluntly, the short service lives of earlier stack liner installations were not caused by pits in the inner liner, discontinuities in the stack laminates, or other non-critical visual factors.

Translucent FRP Composite Laminates: Much-to-do has been made about the need for translucent laminates for FRP stack liners - so that inspections can be made for visual defects within those laminates. And, there is nothing inherently wrong with specifying "clear" laminates, when doing so does not limit the use of appropriate fire retardant additives and corrosion barrier enhancers. Again, there never has been a reported FRP stack liner failure that was, directly or indirectly, the result of the type of laminate "problems" that would be picked up by inspection of translucent laminates.

Insisting on so called translucent laminates also ignores the fact that often in heavy laminates (1/2" or thicker) you can not easily see small discontinuities. And, each year there are literally hundreds and hundreds of miles of FRP composite commodity pipe installed in severe chemical process plant service environments - where the pipe is pigmented throughout the entire pipe liner and structural wall. Translucency is, and should be, a non-issue in the specification of FRP stack liners.

Fire Retardant Laminates for FRP Stack Liners: It seems that almost endless debates go on about the importance of fire retardancy for FRP stack liners. Heated arguments occur about the importance of a Class I ASTM E-84 rating of 25 or less; the desirability of using a resin requiring the addition of antimony versus resin not requiring antimony; and, even over the merits of one type of antimony versus another. Looking backward at those stack liner installations that have had to be replaced, not one was solely because of fire.

We feel that fire retardancy is not a real specification issue. If the end user feels more comfortable having a fume stack constructed with a fire retardant resin, and is willing to pay the extra cost, by all means specify such a premium grade fire retardant resin system for that fume stack liner. But, at the same time do not spend sleepless nights over five or ten ASTM-E84 rating points. The results of the tunnel burn test are visually "scored", and subject to interpretation as to the flame advance.

What Did Cause "Shortened Life" of Previous FRP Composite Stack Liners?

There have been two primary causes for reduced life of FRP stack liners.

1: The most common "problem" was from cracking and crazing of the inner corrosion barrier/liner because of thermal shock and thermal cycling. This phenomenon is often characterized as "mud cracking". The loss of integrity of the corrosion liner could then allow accelerated chemical service environment attack of the deeper layers of laminate. But, the primary root cause of initial failure was because of thermal shock and thermal cycling of the stack liner.

In those earlier FRP stack liners that have not lived up to service life expectations, often the resin was selected on the basis of low initial cost. That meant that the rigid polyesters, and even isophthalic polyester resins were used (or substituted) for the FRP stack liners. These older rigid thermoset resin systems simply lack the toughness and tensile elongation required to handle thermal shock and cycling for FRP stacks and stack liners. These stack liners made with brittle and rigid resins never even had a chance to provide the end user the long service life expected.

2: Stacks are often used with scrubbers removing SO_2 from the fume stream. Any carry over SO_2 can be converted to low concentrations of sulfuric acid. Concentrations of less than 1% sulfuric acid, because of the very small molecule, may readily penetrate the inner corrosion barrier/liner. The liquid will collect and concentrate between the corrosion liner and the first or second layer of structural laminate. That liquid which has penetrated the corrosion barrier will collect - until the liquid pressure in the "pocket" builds to the point it will cause blistering and/or delaminations.

Many times the "finger will be pointed" at the stack liner fabricator as having provided a stack laminate that has porosity and delaminations. Typically this is not the case or cause of the blistering in a fume stack, or stack liner. For example: An in service inspection will usually show that any secondary interior laminate layups will very rarely show such blistering and delaminations. It has been theorized that these secondary layups are more porous, and any condensed sulfuric acid can migrate back out to the fume stream. Similar blistering and delaminations, for the same reasons, can be found in stacks, towers, and scrubbers where very low concentrations of hydrochloric acid are present.

What is Important When Specifying FRP Composite Stack Liners?

Certainly use an experienced FRP composite engineer for the structural design of the composite liner. And, specify levels of translucency and visual inspection that make you feel comfortable. And, if fire retardancy is important to you, by all means include that in your specification. But, also keep in mind that none of these factors will be the controlling criteria that will provide many years of trouble free FRP stack liner life.

Your number one criteria must be the selection and specification of the proper resin matrix system. Without exception, we believe that the resin system for the FRP stack corrosion liner **must** be one of the high elongation epoxy vinylesters. For the inner corrosion barrier/liner and the first structural laminate, we believe that the best resin system would be a blend of 70% Dow Chemical's Derakane 441-400 high-temperature high-performance epoxy vinylester resin, and 30% Dow Chemical's Derakane 8084 elastomeric modified epoxy vinylester resin.

This unique blend of the epoxy vinylester resins will provide the optimum physical and chemical resistance properties for the typical high temperature service environments of fume stacks; and, at the same time, the toughness and high elongation to handle the thermal shock and thermal cyclic loadings.

For the balance of the stack liner structural wall the resin system could be changed to a straight Derakane 441-400 high performance resin. Or, the enhanced blend of Derakane 441 & Derakane 8084 resins could be continued throughout the entire stack liner wall.

If fire retardancy is deemed important, we believe that for high volume applications Dow could provide a brominated fire retardant version of the Derakane 441-400 and Derakane 8084. Or, the fabricator could add the bromine and antimony at the time of fabrication.

The selection, specification and use of the proper resin systems for FRP composite stack liners is so important; that we recommend that the selected fabricator be required to provide certified copies of paid invoices documenting that the proper resin has been procured, in the quantities required, to build your FRP composite stack liner.

If low concentrations of sulfuric acid (< 1%) could occur in the stack we recommend that a barrier enhancement additive be specified and used for the inner corrosion barrier and liner. Some of the inorganic additives, such as basalt and barite, would be worthy of consideration. Organic additives such as teflon and nylon powders might also be considered. Nano-sized graphite tubes, while expensive at this time, also would provide an enhanced corrosion barrier and performance. We would welcome the opportunity to work with you in evaluating and selecting the optimum barrier enhancement additives for your specific FRP composite stack liner application.

To reduce and minimize thermal shock on the FRP stack liner, anything that can be done to limit high temperature upset excursions in the gas stream should be implemented. Slow cool downs and startups should be implemented to reduce drastic temperature changes. Controls, alarms, fresh cool makeup, should all be considered and implemented to the maximum extent feasible. (We even provided one scrubber stack installation where live steam was injected to "cool" down the gas stream.)

To prevent the osmotic pressure on the corrosion barrier from low concentrations of sulfuric acid, keep the velocity of the fume stream up to reasonable flow rates. A good target might be a surface velocity of 1,000 feet per minute. If static buildup and "sparking" could be a problem, consult with us for practical ways of controlling and grounding off static charges in FRP composites.

In Summary: If you were going to build a $1,000,000 home, you would probably not conduct a reverse auction of builders - to see how you could drive down the cost to the lowest, corner cutting, price. Instead, you would first meet with and interview potential and qualified builders. Then, you would probably select the builder you felt most comfortable with, and negotiate a fair to all parties contract with that builder.

Our recommendation would be that when selecting a "partner" for a fume stack FRP composite liner, that you use the same selection procedure of first interviewing, and conducting quality assurance audits, of qualified vendors. Then select the manufacturer and installer that you believe has the best engineering resources, is the best at understanding materials of construction technology, and has the best commitment to proper resin selections and barrier enhancements. These are the true "keys" to your lowest cost per year of service life.

To implement your FRP composite stack liner requirement it is recommended that you enter into an Engineering and Manufacturing Service Contract (EMSC) with the selected fabricator. This will also help you to ensure your lowest initial cost for a quality FRP stack liner. The EMSC will in turn provide you a long and trouble free service life. Obviously, we hope that Industrial Fiberglass will be selected to be that supporting partner. Give us a call to discuss your specific FRP composite stack liner projects; and how we can save you, or your client money, and a no-worry FRP stack liner.