Procedures for Remedial Repair and Lining of Existing FRP Composite Equipment

These procedures have been developed for our Field Service Journeymen Laminaters to use as a guideline when relining and repairing existing FRP composite equipment.

I. Scope

A. These procedures apply to the application of a fiberglass reinforced plastic (FRP) laminate lining over fiberglass reinforced plastic substrates.

B. The following partial list describes types of FRP equipment that may be repaired with laminates made with thermoset resins.

- Tank and vessel shells, large diameter duct, sumps, nozzle interiors, flange faces, baffles and other appendages exposed to the process fluids. Also exteriors of FRP pipe, vessels, duct, vaults, etc.

C. The final laminate shall consist of multiple layers of laminates reinforced with 1-1/2 ounces per square foot of chopped strand mat; followed by two laminate layers reinforced with surfacing veil. The exact composition of each remedial laminate should be determined by FiberSystems' Material Technology Department, after reviewing the intended chemical service.

Generally, a minimum two mat reinforced layers are used for mildly corrosive applications, and a minimum of three mat reinforced layers are used for more corrosive applications.

D. The method of application will be the contact molded method.

E. Materials, surface preparation, and application procedures are covered in this guideline.

II. Materials

A. Resins:

1. The thermoset resin used for the primer or bond coat shall be an elastomeric modified epoxy vinylester, such as Ashland Chemical's Derakane 8090, Interplastic's CoRezyn 8550, or approved equal. To provide maximum adhesion between the base laminate and the laminating sequences to follow; this elastomeric modified primer shall have a minimum elastomer content, as formulated, of 12%.
2. The actual "grade" of epoxy vinyl ester resin to be used for the corrosion laminate layer will be selected for the specific chemical service environment and application, after consultation with the resin manufacturer, and obtaining their recommendations of the appropriate resin matrix for the specific project. Again, the final specific resin will be selected and specified by FiberSystems' Materials Technology Department.

3. To ensure full and enhanced laminate quality all resin used in laminating will include in the formulation an air release agent, such as BYK 515, or an approved equal; and a wetting surfactant agent, such as BYK 555, or an approved equal.

4. To provide maximum adhesion between overlapping laminates, and between layers of laminates, the specific resin promoter catalyst system shall be selected that will give a long open pot life, a slow and controlled cure, and low peak exotherm, as determined by gel cup testing by the resin manufacturer, and/or recommended by the catalyst manufacturer. The specific promoters, catalysts, and formulation for the field will be provided by FiberSystems' Materials Technology Department.

B. Reinforcements:

1. The recommended chopped strand mat is 1-1/2 ounces per square foot with silane finish and a styrene-soluble binder. Unless otherwise advised in the job specific instructions, that mat will be Owens Corning M-723A.

2. Surfacing veil reinforcements for the final layers of the laminate will be C-veil, A-veil, or synthetic veil (such as Nexus) as determined is best for the service environment by FiberSystems' Materials Technology Department.

3. Fillers: A hydrophobic fumed silica (Cab-O-Sil TS-720 or equivalent) may be used to make a putty for filling pits and filleting corners only. Any filling to be done must be approved by FiberSystems' Materials Technology Department.

C. Solvents: Styrene and Acetone--for clean-up only.

III. Surface Preparation

A. All surface area to be lined shall be abrasive blasted with an abrasive that is of sufficient size to achieve a minimum 2 to 3 mil surface profile. The abrasive blasting process shall remove all contaminated FRP, and expose a sound FRP laminate base.

B. All abrasive and grinding dust must be removed from the surface by vacuuming before laminating.
C. Wiping any surface to be laminated with a rag wetted with a solvent, such as styrene or acetone, is not permitted. A solvent wetted rag may contain contaminants that will act as mold release agents. Any contaminants remaining after vacuuming must be removed by additional grinding, sandblasting, etc.

D. If a significant portion of the structural wall is removed during surface preparation, it must be restored to the original thickness, and a fresh surface prepared before the primer is applied.

E. Test patches shall be applied and pulled off to determine soundness of the exposed FRP before laminating commences. (See testing elsewhere in this procedure.)

IV. Primer Application

A. Immediately after the dust has been removed by vacuuming, the surface shall be brush or roller coated with 2 to 3 mils of the catalyzed elastomeric modified epoxy vinyl ester resin specified in II.A.1. The resin should be formulated so that it will cure, dry to the touch, in no more than 2 hours under the existing conditions.

B. The primer should be top coated as soon as practical after being allowed to cure until dry to the touch. If top coating is delayed, the primed surface must be protected from dust and other types of contaminants. Any contamination that will compromise the ability of the top coat to bond to the primer must be avoided.

C. If the surface temperature is below 60° F, it will be necessary to add heat to properly cure the primer coat.

V. FRP Composite Laminating Procedure

A. All inside corners shall be filled to a minimum 1" radius with resin putty. All pits and holes must be filled to obtain a level surface. Refer to section II.B.3.

B. The laminate lay-up shall be applied in multiple phases to the specified total thickness.

1. Laminates shall not be applied in laminate layer thicknesses greater than 1/8" at a time (3 plies of 1-1/2 ounce mat reinforcement or equivalent). Controlling the thicknesses and wet out of laminate sequence is important to prevent reinforcement movement, wrinkles, and to prevent problems with thorough wet out.

2. Succeeding phases of laminates shall consist of not greater than 3 ply of 1-1/2 ounce mat reinforcement, if required to achieve the specified thickness. Joints on succeeding phases shall be positioned so as not to be directly over joints of the proceeding phase of the lining.
3. Overlaps on all joints of reinforcements shall be a minimum of one inch (1"").

4. All chopped strand reinforced laminate layers must be covered with a final two (2) layers of surfacing veil.

5. Any laminate lay-up that has an elapsed time of more than 18 hours between the prior lay up and the subsequent laminate layer shall be roughened, sanded, or ground before the next layer of laminate is applied.

C. A non-air inhibited top resin coat shall be applied over the final surfacing veil phase. This top coat should be applied as soon as the veil surface is tack free. If wax is used to make this non-air inhibited resin, the wax content should be 0.3 to 0.4%; and gel time of this top resin coat should be 10-15 minutes.

D. The flatness of the repaired flange faces shall not vary more than +/- 1/32" from a plane surface.

E. Final thickness of the total laminate shall be as specified in the project work order.

F. An absolute minimum of two layers of chopped strand mat, two layers of surfacing veil and a wax top coat of catalyzed resin shall be applied on all areas of the current FRP laminate that have been ground, sanded, or sandblasted.

VI. Post Curing

Once all laminates have been completed to the thickness specified by the engineer, and the non-air inhibited resin top coat has been applied - the entire part, or the entire vessel interior, where feasible and practical, shall be post cured at a 176° F for a minimum of 2 hours at temperature. This cure shall be documented by use of thermocouples and a data logger - showing time at temperature.

VII. Laminate Quality

All new remedial and repair laminates are to meet the visual standards of ASTM D-2563, Level 2 for the interior corrosion barrier (process side), and Level 3 for structural laminates (non-process side). Achievement of these visual standards will be the basis of an inspection by the customer, the customer's designated engineer, or appointed inspector. See Attachment #A for visual standards that are to be met.

VIII. Journeyman - Laminaters Qualifications

A. All Journeyman Laminaters shall have a minimum of one year experience in making FRP composite lay-ups, either in the shop or in the field, of thermoset FRP composite laminates.
B. All field Journeyman Laminators employed for field remedial laminating are to have had an initial minimum 8 hours of classroom and hands-on training in making laminates and lay-ups in the field, and a 4 hour refresher course within the last 12 months (if it has been longer than 12 months since the 8 hour course).

C. All qualified Journeyman Laminators are to have made a 12" by 12" by 3/8" clear laminate, demonstrating their ability to meet ASTM D-2563, Level 2. This laminate is to be retained in the Journeyman's qualification file and made available for inspectors and/or customers upon request. The date and Laminator's name are to be clearly engraved on the sample. All such samples are to have been made no less than 24 months prior to the actual field work being performed.

D. For all mission critical projects, the Journeyman Laminators, in addition to the training and ASTM D-2563 laminate panel, are to also have made qualified overlay welds in accordance with ANSI/ASME B31.3 protocol, per Section A328. Their laminate lay-up shall have successfully passed a hydrostatic test to failure, and the sample shall have exceeded a burst test of 450 psi to be considered qualified. All qualified Journeyman Laminators shall have demonstrated that they have made these types of laminates and lay-ups within the last 12 months, having successfully passed, and received a certificate of satisfactory completion from the testing facility.

IX. Safety Training and Procedures

A. All trained, qualified, and experienced Journeyman Laminators used for a project are to have a minimum 8 hours Hazardous Materials Handling (HazWop) training, prior to commencing the project. In addition, when the work is inside of a vessel, trench, pit, or other confined space - the Journeyman Laminators are to have confined space training, along with training on the proper use of retrieval equipment, and furnished such equipment.

Such training shall be documented as having been given by a certified trainer, and evidenced by certification.

B. Where bonding and laminations are to be performed at elevations, as defined by OSHA, that would present fall hazards - all such Journeyman Laminators are to also have fall training by a certified instructor, and training and fit of fall prevention harnesses and tie offs.

C. Every project that involves confined space or work being performed at higher elevations off the ground, shall have a safety officer designated and present at all times at the job site.

In addition, at the job site is to be a book containing Material Safety Data Sheets (MSDS) for all materials being used on that project. A copy of our Field Service Manual is to
accompany field service Journeyman Laminaters and Technician to the job site, and be made available to the customer, their engineers, or the end user's safety department for their review and approval.

D. Many of our customers will have job site specific training that is required before a project can commence. Our field service Technicians are to participate fully in all such project and site safety training, including testing. We encourage Passport training by our Journeyman Laminaters, as evidence of prior full safety training and knowledge.

X. Test Patch Procedure

A. If the equipment was in service prior to remedial action, it will be our practice to apply a test patch to check the soundness of the prepared surface before the actual laminate is applied.

1. The success of a remedial repair or relining job starts with ensuring that a good bond can be obtained on the existing FRP composite substrate.

2. Many factors effect the strength of this secondary bond, such as soundness of the existing substrate, infused chemicals into the substrate, the temperature of the substrate, the development of cure of the substrate, the type of resin in the substrate, the surface preparation of the substrate, etc.

3. Conducting a few small test patches in various areas will confirm that we can start the job off by getting a good bond to the existing substrate. If a good bond can not be obtained, then a decision as to how to proceed with the project must be made, in consultation with FiberSystems' Materials Technology Department.

B. To do a test patch, first prime a 12" x 12" area with 3-5 mils of catalyzed elastomeric modified epoxy vinyl ester primer. Allow it to cure until dry to the touch. Then apply four laminate layers, 3" x 8", reinforced with 1-1/2 ounce glass fiber mat reinforcement, placing a piece of Mylar film under one end to prevent bonding. Allow the laminate to fully cure. After the test patch is cured, pry it off by placing a chisel under the Mylar film. If the test patch is good (pulls glass from the primary laminate), you may start the remedial repair or lining process.

C. If the test patch separates cleanly and easily from the mat, wash the surface with hot water to remove any contaminants, let the substrate dry thoroughly, then abrasive blast with an abrasive that is of sufficient size to achieve a 2-3 mil surface profile.

D. When the surface is completely dry, prime a 12" x 12" area of the mat with D.E.R. 383 epoxy resin and Air Products PACM amine epoxy hardener. When the primed area is cured (consult with FiberSystems' Materials Technology Department for the proper cure schedule), apply another test patch as described above.
E. If the epoxy test patch is good, prime the remaining surface as described above with the epoxy/hardener combination, allow a full field cure, and begin lamination.

If the epoxy test patch separates cleanly and easily again, it is likely that the surface is too contaminated to accept a secondary bond, and field remedial repair or lining.
### Table 9. Allowable defects

<table>
<thead>
<tr>
<th>Defect</th>
<th>Process side</th>
<th>Non-process side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cracks</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Crazing (fine surface cracks)</td>
<td>None</td>
<td>Max length 1/2 in., max density 5/ft^{2}, min 2 in. apart</td>
</tr>
<tr>
<td>Blisters (rounded elevations of the laminate surface over bubbles)</td>
<td>None</td>
<td>Max 1/4 in. dia. 1/8 in. high, max 1/ft^{2}, min 2 in. apart</td>
</tr>
<tr>
<td>Wrinkles and solid blisters</td>
<td>Max deviation, 20% of wall</td>
<td>Max deviation, 20% of wall thickness, but not exceeding 1/8 in.</td>
</tr>
<tr>
<td>Pit (craters in the laminate surface)</td>
<td>Max dimensions, 1/8 in. dia. x 1/32</td>
<td>Max. dimensions, 1/8 in. dia.</td>
</tr>
<tr>
<td></td>
<td>in. deep, max number 10/ft^{2}</td>
<td>1/16 in. deep, max density 10/ft^{2}</td>
</tr>
<tr>
<td>Surface porosity (pinholes or pores in the laminate surface)</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Chips</td>
<td>None</td>
<td>Max dimension of break, 1/4 in. and thickness no greater than 20% of wall thickness, max density 1/ft^{2}</td>
</tr>
<tr>
<td>Dry spot (nonwetted reinforcing)</td>
<td>None</td>
<td>Max dimension, 2 in. /ft^{2}</td>
</tr>
<tr>
<td>Entrapped air (bubbles or voids in the laminate)</td>
<td>1/16 in. max dia., 5/in.^{2} max density, but none to a depth of 1/32 in.</td>
<td>1/8 in. max dia., 4/in.^{2} max density, 1/16 in. max dia., 10/in. max density</td>
</tr>
<tr>
<td>Exposed glass</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Burned areas</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Exposure of cut edges</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Scratches</td>
<td>None</td>
<td>Max length 1 in., max depth 0.010 in.</td>
</tr>
<tr>
<td>Foreign matter</td>
<td>None</td>
<td>1/16 in. dia., max density 1/ft^{2}</td>
</tr>
</tbody>
</table>

*Pits are defects that do not expose any underlying reinforcement. Magnification will be required to distinguish pits and surface porosity by visual inspection.*
Attachment #A (continued)

Joint is close fitting; strapping is neat and shows
excellent adherence. Interior wall is devoid of pits,
permitting smooth flow of gases or liquids. Absence
of "steps" in joint area indicates that parts are
concentric.

FIGURE 1 - MITERED JOINT

Good, Surface is devoid of pitting and pinholes.
Lack of pits is good indicator of skillful fabrica-
tion and proper handling techniques. Pits can
not as collection points for corrosive substances.

Poor, Amount of pitting shown would be cause
for rejection.

FIGURE 2 - PITTING
Attachment #A (continued)

**Figure 3 - Resin Drainage**

Good. Even color and surface indicate good saturation of evenly applied surface, and consistent resin distribution.

Poor. White splatsy areas indicate resin drainage that has left laminate dry and pithy. Such areas have low tensile, flexural, and impact strengths, and may permit leakage.

**Figure 4 - Entrapped Air**

Excessive air in a laminate can be spotted by visual examination of the resin-rich surface. On unpigmented structures, detection is facilitated by placing a light bulb behind the wall or structure.

**Figure 5 - Exposed Glass Fibers**

Absence of a resin-rich surface and protective surfacing may or may well result in a prominence of reinforcing fiber bundles on the surface of the plate. This condition will reduce corrosion resistance drastically.
Attachment #A (continued)

**FIGURE 6** - WELDING OR ALLIGATORING

**FIGURE 7** - PINHOLES OR POROSITY

**FIGURE 8** - CRAZING