Design & Use of Dual Laminate Tanks and Piping

by
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Outline

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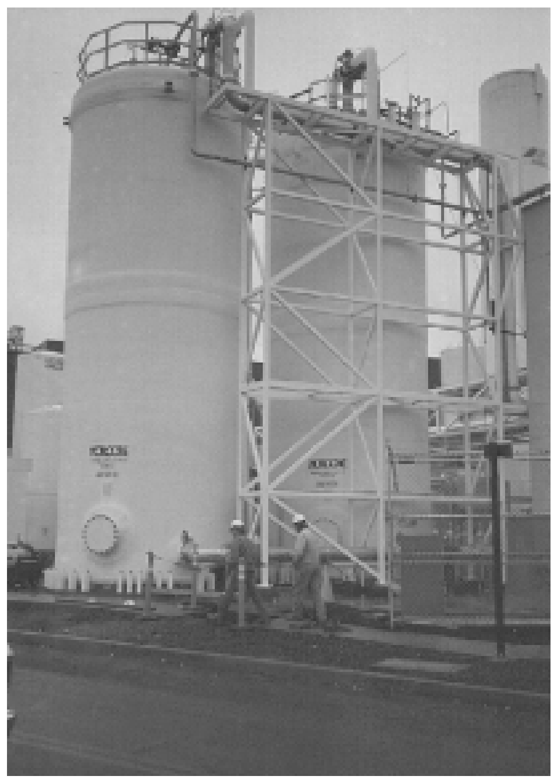

Design and use of Dual Laminate Tanks and Piping

Introduction

Dual laminate construction of chemical resistant tanks and piping has been used for about 40 years. Although utilization of this fabrication approach is continuing to grow, the industry as a whole still lacks adequate knowledge of proper uses and design techniques.

What is Dual Laminate Construction

Thermoplastics have been known for their excellent chemical resistance for over 50 years. However, their relatively weak mechanical properties make design of large or higher temperature tanks and piping very difficult.
Dual laminate construction combines the superior chemical resistance of thermoplastics with the greater mechanical strength and flexibility of fiberglass. The liner is thermoformed and welded and then FRP is chemically or mechanically bonded to it The added cost of this type of construction is often justified by greater service life, lower maintenance costs, and higher process productivity.

Common Thermoplastics Used

Thermoplastics used in fabrication are those that are "melt processable." Their shape can be changed through thermoforming and they can be welded. Many are available in sheet and pipe as well as various other forms made by injection molding or extrusion. Those frequently considered for corrosion applications include:

• PVC (Polyvinyl Chloride)—This amorphous thermoplastic is the most common. It is low in cost and is easy to fabricate with. PVC is excellent in handling many strong acid and alkali solutions and has a temperature capability of about 140 degrees F.

• CPVC (Post Chlorinated PVC)—Similar to PVC but higher in temperature capability (about 190 degrees F.). Welding and fabrication are more difficult than PVC. Fiberglass is chemically bonded to the plastic material as is the case with PVC.

• PP (Polypropylene) — This crystalline polymer has a temperature capability of about 200 degrees F. It is excellent in handling caustics, solvents, and many acids and organic chemicals. It is not usually recommended for oxidative organic materials. Sheet products have a knit or woven fabric pressed into the plastic during extrusion for purposes of FRP bonding. PP has a low modulus of elasticity, low weight (SG .91) and can be degraded by exposure to ultraviolet light

• Fluoroplastics—These plastics all contain fluorine which is highly electro negative making them inert and chemical resistant They also tend to handle high temperatures and are very pure. Like polypropylene, mechanical means are used to bond FRP to the liner. The fluoroplastics are more costly than PP or PVC.

• PVDF (Polyvinylidene Fluoride) — The most commonly used fluoropolymer. It has a high level of purity, excellent chemical resistance and a temperature capability of up to about 280 degrees F. It is frequently used for strong acids, solvents and in the handling of DI water. It is not recommended for caustics.

• PVDF Copolymer (Polyvinylidene Fluoride) — A relatively recent product was developed specifically to adapt the excellent chemical resistant properties of PVDF to metal tank lining applications. The copolymer reduces the modulus and therefore the stiffness to allow for easy application to curved surfaces. It has a temperature capability up to about 250 degrees F.

• ECTFE (Ethylene Chlorotrifluoroethylene) — ECTFE is similar to PVDF in its chemical resistance and has somewhat improved resistance to caustic and chloride environments. It has a temperature capability up to about 300 degrees F but is more difficult to weld and thermoform due to its higher melt point.

• ETFE (Ethylene Tetrafluoroethylene) — is similar to FEP and PFA in chemical resistance and has a temperature capability up to 400 degrees F. It differs from FEP and PFA in having a higher modulus of elasticity.

• FEP (Fluorinated ethylene propylene) and PFA (perfluoroalkoxy) — These have the most chemical resistance and highest temperature capability (400 degrees F and 500 degrees F) of the melt processable thermoplastics. They are expensive but effective in selective difficult environments.

Some Critical Design Factors

In general, thermoplastic design is distinctly different from metal or even thermoset plastics. Many engineering professionals have little experience with thermoplastic which results in a tendency to avoid its use or to make design errors. The following summarizes some of the more critical factors unique to thermoplastics:

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Chart 1 Thermoplastics for Liners

Thermoplastics used for Liners; Summary of Engineering Characteristics

Material	Maximum Service Temperature	Flexural Modulus (1)	Tensile Strength (2)	Melt Point	Heat Distortion Temperature (3)	Coefficient of Thermal Expansion (4)
PVC polyvinyl chloride	140 ⁰F	410,000	7,820	220 ⁰F	135 ⁰F	35
CPVC chlorinated polyvinyl chloride	190 ⁰F	420,000	8,080	230 ⁰F	180 ⁰F	35
PP polypropylene	200 ⁰F	200,000	4,700	330 ⁰F	107 ⁰F	85
HDPE high density polyethylene	160 ⁰F	118,000	3,430	250 ⁰F	110 ⁰F	110
"PVDF, (Solef, Kynar, Halar)" polyvinylidene fluoride	300 ⁰F	300,000	8,450	342 ⁰F	235 ⁰F	70
PVDF Copolymer (Kynarflex) polyvinylidene fluoride copolymer	250 ⁰F	160,000	4900	315 ⁰F	150 ⁰F	80
ECTFE (Halar) ethylene chlorotrifluoroethylene	300 ⁰F	240,000	7,000	465 ⁰F	170 ⁰F	40
ETFE (Tefzel) ethylene tetrafluoroethylene	300 ⁰F	170,000	6,500	515 ⁰F	270 ⁰F	75
FEP (Teflon) fluorinated ethylene propylene	400 ⁰F	90,000	3,000	525 ⁰F	118 ⁰F	50
PFA (Teflon) perfluoroalkoxy	500 ⁰F	120,000	4,000	590 ⁰F	118 ⁰F	70
FRP fiber reinforced plastic	218 ⁰F	1,000,000	15,000	N/A	210 ⁰F	18

Notes:
1. Flexural modulus in psi at 20 ⁰F per ASTM D790
2. Tensile strength in psi at break at 20 ⁰F per ASTM D638
3. Heat Distortion Temperature (HDT) per ASTM D648 at 264 psi.
4. Thermal expansion 10 -6 in/in ⁰F per ASTM D696
5. Hand laid vinylester FRP

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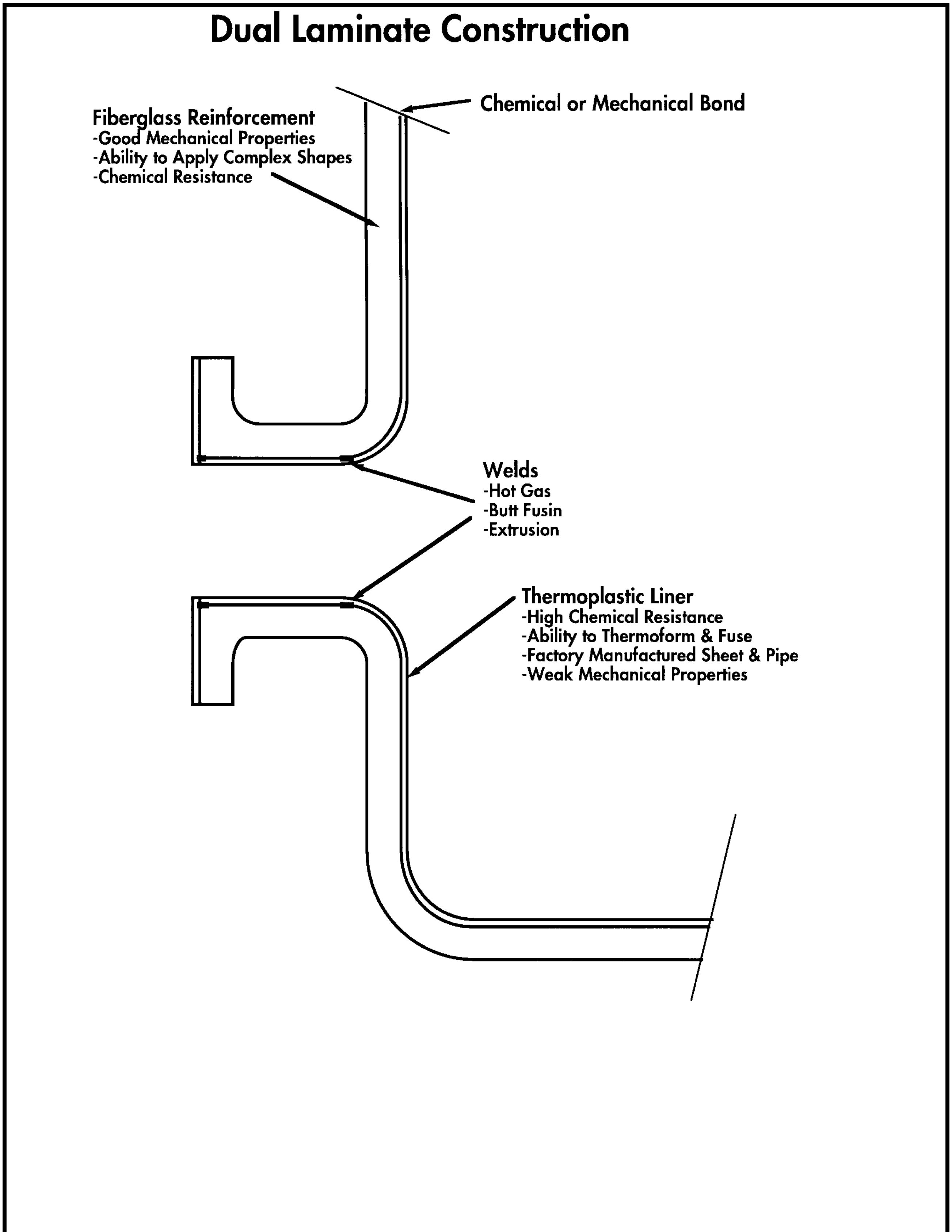

Figure 1 Dual Laminate Construction

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1. Creep Properties — Tensile and flexural moduli values are low for thermoplastics. Furthermore, thermoplastics creep and these properties become lower over time as material is exposed to operating stress. For this reason, careful attention must be given to design to allow for the impact of the temperature / pressure environment over time.

2. Differential Expansion—In a dual laminate structure the thermoplastic liner generally expands and contracts at a greater rate than the thermoset reinforcement For this reason careful attention must be given to both the liner thickness and the bond strength between the liner and the reinforcement. The thickness of the liner must not exceed about 3 / 16". Greater thickness of the liner can result in higher interface sheer stress between the liner and reinforcement. The strength of the bond between the liner and reinforcement is also of critical importance. Expected changes in temperature need to be accounted for in calculating the required bond. Bond strengths for the polyolefins and fluoropolymers tend to be consistent and predictable due to the fabric impregnated bonding system. Chemical bonding to CPVC and PVC can be more variable, however, and needs to be regularly checked during fabrication.

3. Weld Factors and Techniques — In recent years there has been increased use of butt fusion and extrusion welding as compared to the traditional hot air hand welding. Butt fusion uses a coated heating plate and careful control of temperature, pressure, and movement. Long term weld factors for butt fusion are 50% to 100% higher than hot air welding. Design calculations should take into account these weld factors and the highest quality welds should be used whenever possible.

4. Some Other Design Issues — Another important design issue involves proper thermoforming in high stress areas. Corners of rectangular tanks or bottoms and tops of storage tanks need to be thermoformed. Appropriate radiuses need to be created to spread the load in these critical stress areas. Welds also need to be placed in other than critical stress areas.

Potential for permeation is another important consideration in determining liner thickness and other design factors. For example HCL and HF molecules can penetrate a thin laminate. Some thermoplastics such as ECTFE have better resistance to permeation.

Purchasers of dual laminate equipment need to make sure that fabricators are sufficiently qualified to deal with the complex dual laminate engineering factors. With proper design and quality of fabrication there is no reason to shy away from the use of these structures which have superior chemical resistance.

Cost and Long Range Benefits

The capital cost of dual laminate tanks and piping is almost always higher than fiberglass and many metals. The following table summarizes the cost per gallon of a typical dual laminate tank compared to a fiberglass tank:

	Cost per Gallon	
Material	2,000 Gal.	10,000 Gal.
FRP	3.20	1.70
PVC / FRP	4.70	2.50
PP / FRP	4.80	2.16
PVDF / FRP	7.60	4.60
ECTFE / FRP	8.00	3.90
FEP / FRP	17.09	11.30

As can be seen, the cost can be anywhere from 50% to as much as 600% greater for dual laminate. For this reason, a more careful purchase analysis needs to be made. Estimated life and maintenance costs need to be more carefully analyzed to determine the return on the investment. Completing such an analysis is difficult making it hard for plant personnel to justify higher capital expenditures. Such analysis is essential, however.

Needs for the Dual Laminate Industry

As we have seen, dual laminate structures are distinctly different from either thermoset or metal. They have a very high level of corrosion resistance. They have unique design and engineering considerations and their cost is significantly higher making long range present value analysis essential.

In Europe, dual laminate structures have been used for a much longer period of time than in North America. There seems to be more research and a greater understanding of the proper use and design of dual laminate vessels. In selecting tanks and piping for the chemical process industry, it is necessary to properly assess the alternatives to make the best possible decision. Attention is being given by the industry to all of the following:

1. Standards for Design and Fabrication— Specific criteria need to be developed for construction design, fabricator qualification and welder training and certification. More and more sophisticated users of dual laminate structures are developing their own criteria to evaluate potential fabricators and designers. An industry wide effort under the auspices of the RTP-1 committee should result in a Dual Laminate component being added to RTP-1 sometime in 1996-97 period.

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2. Research on Long Range Cost Benefits—Plant production and engineering personnel frequently do not have the time or information to carefully evaluate the present value of a dual laminate vessel as compared to other alternatives. Therefore, it is necessary to develop a body of information on potential savings through longer life, lower maintenance, and flexibility of use. This information needs to be based on actual case studies and must have a high level of credibility. It is also necessary to outline improved decision making techniques that can be used by plant personnel.

3. Materials Capability Data and Research—It is also necessary to combine the efforts of vendors, educators, and fabricators to develop accurate information on materials capability. Too often in the past, users have been working with different "vendor based" corrosion guides. In Europe, much of the research is a shared effort between vendors, educators and fabricators. Consideration should be given to supporting such efforts in North America.

4. Engineering, Education and Assistance —North American engineering schools still tend to emphasize design using metal and other materials but not necessarily thermoplastic or thermoset materials. To insure best possible practices it is necessary to make sure that engineering schools are aware of alternative corrosion resistant materials in construction. It is also necessary to make sure that they have proper up-to-date information for educating their students in chemical resistance, design, etc. The next generation of engineers needs to be more comfortable when considering alternative materials.

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