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Getting the Best Value Out of Your Fiberglass Equipment

Gary Arthur, *President at Fiberglass Reinforced Plastics Institute, Inc.*

Getting the Best Value Out of Your Fiberglass Equipment

by Gary L. Arthur

Fiberglass-reinforced plastic (FRP) is a great material of construction. It is strong, lightweight, chemical resistant, customizable, readily available, and very cost competitive with alternative materials.

One of FRP's most outstanding features for the odor marketplace is its ability to minimize corrosion despite the extremely harsh environments characterized by the wastewater, biosolids, and chemicals used to control the odors. Accordingly, it is often the material of choice for odor control technology vessels, ductwork, stacks, covers, chemical storage tanks, etc.

Simply boasting about the material though does little to help with getting the best value out of your fiberglass equipment in the wastewater and water treatment industry. The truth of the matter, technologically speaking, is that FRP is essentially stuck in the 1970s to 1980s. The product an owner needs and believes they are paying for is too often not the FRP manufactured product that is delivered.

Understanding the FRP Market

FRP equipment prices based on nearly half-century old practices have proven to be as much as 130% lower than prices based on advanced approaches to operating modern day reliable equipment. Technology-driven FRP manufacturers have tried to advance design, engineering, laminating, and secondary bonding practices in the municipal industry. Most have been defeated when attempting to pass through higher value/cost and exited this market due to the low bid price pressure, payment retainage, contract abuse, plus off-spec equipment delivered by others.

FRP is a complicated material that generally has been very challenging for inquisitive specifying engineers and owners to master. Valuable lessons learned are routinely forgotten by specifiers due to infrequency of FRP project involvement and large FRP equipment needs as well as retirements of experienced professionals. In today's decentralized and remote specifier workplace, corporate authority over master specifications and quality assurance has given way to cost reduction. This has further fueled FRP specification development and administration challenges from design through construction.

Overall, the specifying community has inadvertently stymied advancement of FRP and too many owners are living with the ongoing cost of premature failure. Those that have lived through failure, or know others who have, understand this dilemma and pursue modern day remedies. They are the minority though, where most are not aware of premature failure let alone the underlying causes and tend to fall victim to putting themselves at risk. These circumstances, combined with forgotten lessons learned, are what continues to seed the cycle that keeps FRP stuck in the 1970s to 1980s and owners at risk.

Bringing FRP to the 21st Century

The time has come for specifying engineers to break the stalled FRP technology cycle, move FRP well into the 21st century and help owners get the best value out of their fiberglass equipment. It is long overdue. Reliability in 2022 and going forward has a whole new meaning in the wake of the COVID-19 pandemic. Trust, fact-checking, and caution have moved front and center in our minds. FRP manufacturing company advertising claims such as "Industry Leader," "Expert" and "Quality" merit a deeper level of vetting now more than ever before.

To help with getting the best value out of your fiberglass equipment, we are going to share a few discussions around results from decades of research and audit findings that will establish the foundation for FRP technology change. Data supporting findings to be presented were gathered from across the United States. It entails hundreds of FRP equipment failure situations, current standards stories, a few manufacturer databases, dozens of engineering firm master specification libraries, and tens of millions of dollars in FRP equipment submittal audits.

The facts to be presented will validate the vulnerability of FRP process equipment mechanical reliability and provide practical guidance for related risk mitigation. The extent of work to be shared includes quantifying premature failure, assessing industry standards scope, investigating supply side issues plus reviewing specification effectiveness. Conclusions to be presented will summarize lessons learned and provide guidance to help move FRP technology well into the 21st century.

Premature Failure

Premature failure is defined as any event causing unexpected cost associated with in-operation FRP process equipment, such as odor control vessels, round and rectangular ductwork, covers, exhaust stacks and aboveground chemical storage tanks. To better understand premature failure, a look at the nature of fiberglass equipment and fiberglass equipment failure studies will provide a good starting point for specifiers.

The Nature of Fiberglass Equipment

Fiberglass equipment design and manufacturing are complicated. As depicted in the background photo of ***Illustration 1***, a fiberglass laminate is made up of several plies of glass reinforcement. The type and number of plies are determined through engineering work for each equipment component. This illustration shows a cross-section of the laminate, where total structural cross-section is made up of the inner corrosion barrier, structural layer and outer corrosion barrier. These laminate sections are further subdivided into the inner surface, interior layer, structural layer, exterior layer

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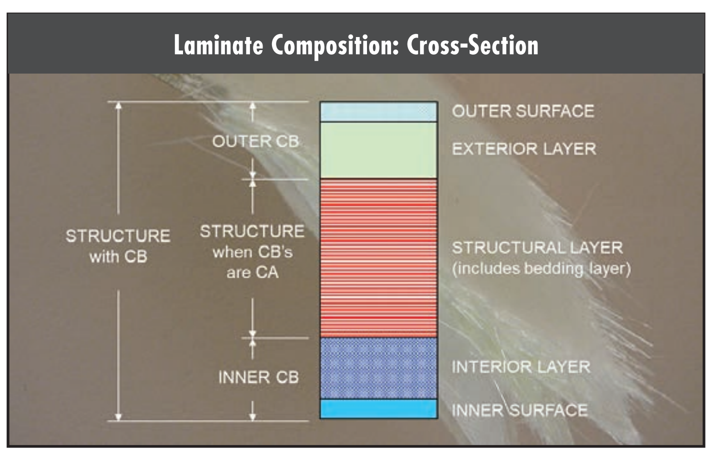

Illustration 1. Laminate composition cross-section. *FRPI*

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and outer surface. These layers are manually laminated one ply at a time, with cylindrical shapes typically spiral wound during the laminating process.

Fiberglass equipment fabrication is laborious. The components that make up a piece of equipment, once laminated, are demolded, trimmed, ground, drilled, fit up, secondary bonded (or welded, if you will), accessorized and finally resin finish coated. A ton of skilled labor hours goes into laminating and fabricating. As a result of being laborious, equipment quality varies directly with hired skill level variation day-to-day, month-to-month and year-to-year. Since a high level of retained skill can cost up to 50% more than entry level, skill plus labor cost is a remarkable portion of total cost. Meeting excellent specifications to achieve best value does cost significantly more.

Fiberglass equipment is not a catalog commodity like pumps, valves, pressure gauges, calibration cylinders and other related process equipment. A lot of design, engineering and specification writing is required for bid documents. It takes a FRP subject matter expert to adapt existing master specifications to a project, correct specification issues or effectively write them from scratch.

The complicated and laborious nature of equipment manufacturing combined with a wide range of specification effectiveness results in FRP equipment market price instability. The graph in ***Figure 1*** shows seven levels of specification effectiveness on the X-axis from "F" (poor effectiveness) to "A" (excellent effectiveness). On the Y-axis is the price, which ranges from $43,000 to $97,000 for a typical 12-foot diameter sodium hypochlorite tank at different levels of specification effectiveness. Price instability, resulting in bid value/cost spread illustrated by the red line, ranges up to 130% due to the market being flooded with a wide range of specification effectiveness.

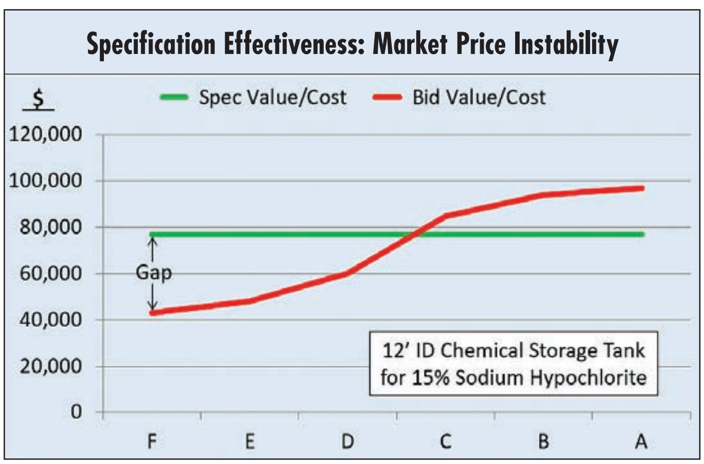


Figure 1. Specification effectiveness and market price instability, where the X-axis ranges from "F" (poor specification effectiveness) to "A" (excellent specification effectiveness). The wide range of specification effectiveness in the market results in price instability (the gap between Bid Value/Cost and Spec Value/Cost) of up to 130%. *FRPI*

Fiberglass Equipment Failure Studies

The only published FRP industry study on types and causes of premature failure in the past few decades quantifies hundreds of cases *(Arthur 1991)* and still helps define root cause for equipment reliability risk resulting from specification ineffectiveness to this day. ***Figure 2*** shows findings for 754 cases for types of failure, where 62% of types are fiberglass laminating related. ***Figure 3*** shows findings for 865 cases for causes of failure, where 73% of causes are manufacturer related.

Failure study findings are exemplified by the following case histories.

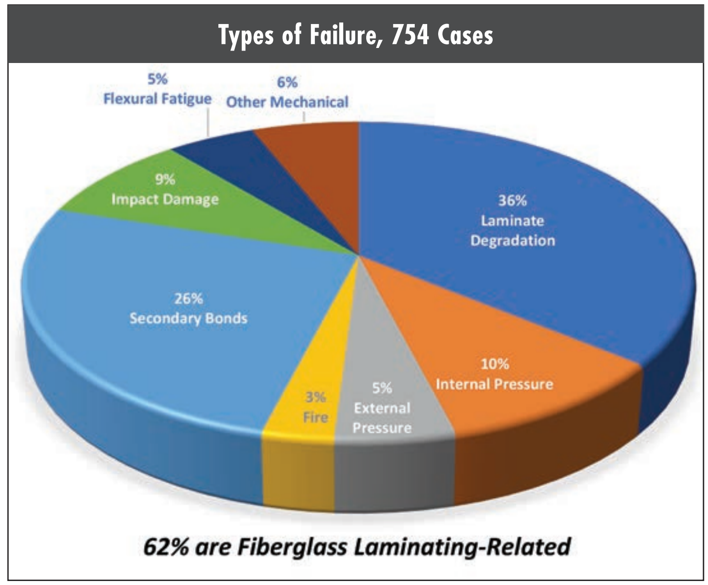


Figure 2. Premature fiberglass equipment failure by type of failure. A published fiberglass industry study *(Arthur 1991)* found that most failures were due to errors in fiberglass laminating. *Gary Arthur*

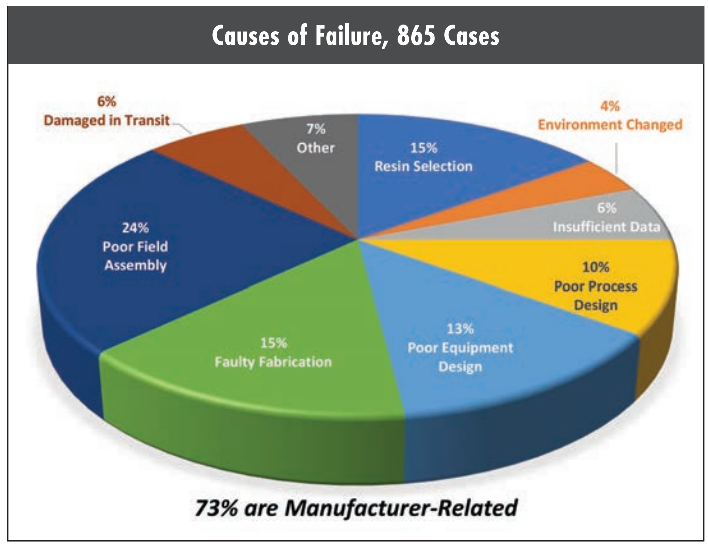


Figure 3. Premature fiberglass equipment failure by causes of failure. The fiberglass industry study *(Arthur 1991)* found that most failures resulted from manufacturing-related issues. *Gary Arthur*

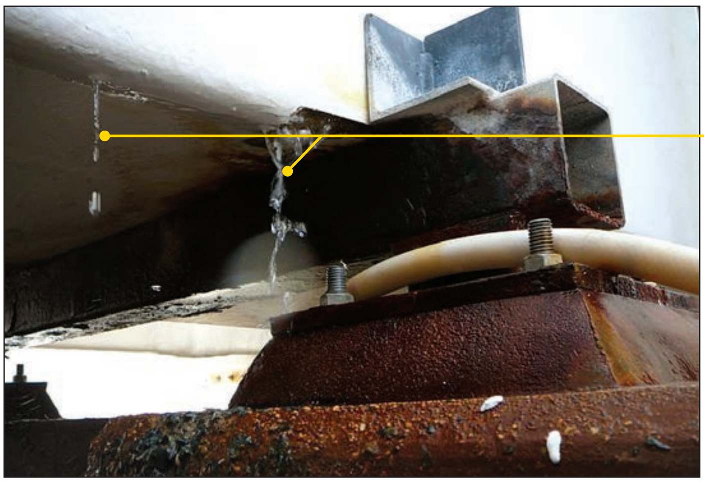
Photographs 1 and ***2*** show a carbon absorber operating at 10 pounds per square inch that failed catastrophically within five days of startup, where the anchor system failed, and bottom blew out. ***Photographs 3*** and ***4*** show a repaired vertical scrubber duct section that was improperly supported, cracked, and continuously leaked hazardous corrosive condensate beginning 12 years after startup. ***Photographs 5*** and ***6*** show a pair of sodium hypochlorite tanks that were replaced after seven years of service due to excessive FRP deterioration and through-wall leakage. A 20- to 30-year, maintenance-free equipment life was presumably expected and should have been realized for each of these case histories.

Costs and Risks

Let us now look at estimated cost and risk of premature failure. According to the most current American Composites Manufacturers Association (ACMA) report on fiberglass market segment performance *(ACMA 2011)*, the total fiberglass industry market is composed of the electrical, consumer, aircraft, marine, transportation, construction and corrosion market segments. The

Photograph 1. A carbon absorber failed catastrophically within five days of startup, when the anchor system failed, and bottom blew out. *Gary Arthur*

Photograph 2. Close-up of the blown-out carbon absorber. *Gary Arthur*



Photograph 4. Close-up of the cracked, leaking area of the vertical scrubber duct section. *Gary Arthur*

Photograph 3. A repaired vertical scrubber duct section that was improperly supported, cracked and leaked hazardous corrosive condensate. *Gary Arthur*

corrosion segment covers fiberglass process equipment, which accounts for 22% of the market. This equates to $5.1 billion in corrosion equipment purchased in 2016, a $3.86 billion average in purchases per year over the past 30 years and a $115.8 billion installation base that gets to a premature failure cost of $357 million per year or 7% of purchases.

Let us now compare the top 10 insurance claims for small business reported a few years back *(Insurance Journal West Magazine 2015)* to FRP equipment premature failure risk of 7%. Interestingly, FRP is as much of a risk exposure as other perils, such as burglary or vehicle accidents ***(Figure 4)***, which we all know well and for which we are usually insured.

Top 10 Insurance Risks

- Burglary and Theft (20%)
- Water and Freezing (15%)
- Wind and Hail Damage (15%)
- Fire (10%)
- Customer Slip and Fall (10%)
- Vehicle Accident (<5%)
- Product Liability (<5%)
- Struck by Object (<5%)
- Reputational Harm (<5%)
- Customer Injury and Damage (<5%)

Figure 4. Top 10 Most Common Property and Liability Claims, as published in April 2015. *Insurance Journal West Magazine*

Industry Standards Scope

Committees of ASTM International (ASTM) and the American Society of Mechanical Engineers (ASME) promulgate FRP industry standards covering tanks, vessels, ductwork, flanges and materials of construction. While they are very good for content published,

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Photograph 5. Pair of sodium hypochlorite tanks that were replaced after seven years of service due to excessive FRP deterioration and through-wall leakage. *Gary Arthur*

Photo 6. Close-up of FRP deterioration on one of the sodium hypochlorite tanks. *Gary Arthur*

these standards are significantly lacking on their own merit. They have incomplete design scope; multiple decisions are required with no guidance and important details are missing for a complete design specification. They do not include other common structures such as grease filters, exhaust stacks and cover applications plus are deficient for odor and air pollution control systems.

The FRP industry's very first voluntary product standard – PS 15-69 published by the U.S. Department of Commerce National Bureau of Standards – and a Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) construction manual published by the sheet metal industry are other standards often referenced by specifiers. PS 15-69 was published in 1969, never updated, delisted in 1996, superseded by ASTM standards and had a less conservative design than ASTM and ASME. Yet it is still specified, and manufacturers continue to claim they build in accordance with it. On the other hand, the SMACNA manual some also claim compliance with conflicts with ASTM and ASME, compromises safety factors, is less conservative plus has a narrow and shallow industry review. Other ASTM pipe standards are also misapplied when specifying tank and vessel internal piping plus ductwork.

Supply Side Issues

Out there in the sea of fiberglass equipment supply lies a convoluted chain of vertical and horizontal integration. As one can see in ***Illustration 2*** for example, a general contractor has three options to buy an odor control system:

1. From a system supplier Type A, who does turnkey design/build systems.
2. From a system supplier Type B, who does process design only.
3. From mechanical or HVAC contractor that pieces together their own system or provides purchased ductwork only.

Then the Type A supplier can either manufacture inhouse or outsource manufacturing, while the Type B supplier and mechanical or HVAC subcontractor outsources manufacturing. Then the FRP inhouse or outsourced manufacturer may use an inhouse or outsourced professional engineering service who often relies on outsourced pipe stress or finite elemental analysis when required.

About 80% of the time there are four suppliers involved in delivering fiberglass odor control equipment to the owner. This convoluted chain of supply creates remarkable risk for specifiers and owners to receive reliable FRP equipment. It is a significant underlying root cause of off-spec equipment and premature failure. Reliability risk includes but is not limited to control of FRP supplier expertise and capabilities, professional engineer scope of engineering performed, limited drawing disclosure for specification compliance auditing, manufacturing and quality control, technical and commercial tactical cost maneuvering plus cracks and loopholes throughout the entire procurement process.

Another discovery in the convoluted chain of supply that was uncovered during Fiberglass Reinforced Plastics Institute (FRPI) auditing is manufacturer's licensed professional engineer (PE) ethics and stamp risk. As the licensed community of engineers know, their oath of ethics requires them to only practice in an area of demonstrated expertise, have and exercise responsible charge over their work and not to apply their stamp where such has not occurred. With nearly all specifications requiring a FRP PE stamp in the state where equipment will be installed, manufacturers need to outsource licensed engineering on most if not all projects. The risk in this is many engineers hired may have over five years of experience, but their depth and breadth of experience over those years may have been very minimal. This limited experience leaves them ill equipped to provide a thorough, accurate design report, especially at a level of pipe stress or finite elemental analysis when required.

Beyond manufacturer's outsourced PE expertise though, the biggest issue with outsourcing the FRP PE is equipment selling price pressure. This causes the manufacturer to limit their outsourced PE's scope and responsible charge over work to a bare minimum for equipment approval. Cases of simply plan-stamping without PE design and responsible charge were also uncovered during FRPI auditing.

Specification Effectiveness

Informal engineering firm specification audits have been conducted for dozens of regional and national engineering firms over the past 30 years. This support evolved into formal engineering firm risk audits based on a 21-point score card as shown in ***Figure 5***.

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The Sea of Supply: A Convoluted Chain

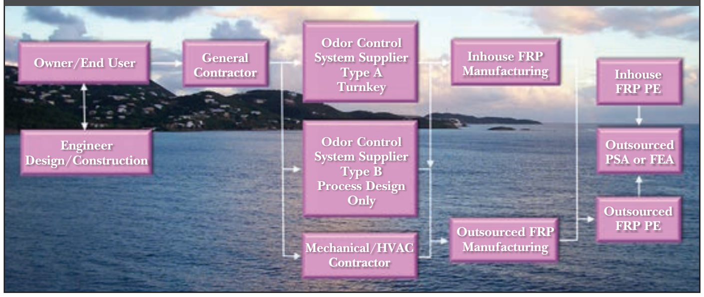

Illustration 2. In the sea of fiberglass equipment supply lies a convoluted chain of vertical and horizontal integration. *FRPI*

These points follow Construction Standards Institute specification formatted subjects. A series of 106 questions centered around the 21-point card were raised to arrive at a risk score. Scores from 1 to 5 were determined given answers to questions raised for each of the points, where 1 is low risk and 5 high. The benchmark for scoring was FRPI master specifications developed by a balanced team of industry experts.

As you can see on the card bottom in ***Figure 5***, this firm's specification scored a 4.2, representing high risk of premature failure. This score is typical of most, if not all, specifications audited. The top 10 general audit findings include improper use of industry standards, unsatisfactory audit trail established, poor manufacturer and PE prequalification, incomplete product and laminate design, deficient fabrication details, inadequate use of sample submittals, limited quality verification, insufficient installation guidelines, ineffective use of third-party subject matter expert and/or certification programs plus errors, omissions and conflicts.

FRPI auditing has shown specification effectiveness is usually poor for FRP equipment, establishes a very low industry price floor and puts equipment at risk. The graph in ***Figure 1*** shows the FRP equipment market price instability findings presented earlier, where "F" (poor effectiveness of specifications) and a price floor of $43,000 are represented by the red line. The green line on the graph represents the price ceiling during bid time, with improved reliability afforded by a specification approaching the value of "C" at a cost of $78,000. The value/cost gap to police from floor to ceiling is now 80%. With this size gap, audit findings show that one in three to three in five bids are off spec, and this equates to a 30 to 60% risk exposure for specifiers to uncover during submittal review. Findings also show this value/cost gap creates too great of a technical challenge for non-FRP subject matter experts to specify and police effectively, especially within the timeline of construction schedules.

Specification Effectiveness: Engineering Firm Risk Audit

CONTENT	RISK SCORE
SPECIFICATION Scope:	**4.2**
Notes to specifier	4
Tank Configuration Range	5
Wastewater and Drinking Water	4
Number of Chemical Services	5
Non-Fire Retardant and Fire Retardant	3
PART 1 General:	**4.1**
Reference Standards	4
Definitions	4
Submittals	3
Quality Assurance	4
Delivery, Storage and Handling	5
Sequencing	5
Warranty	5
Tolerances	2
Manufacturers Representative	5
PART 2 Products:	**3.8**
Fiberglass Tanks	4
Laminate Materials	4
Accessories	4
Manufacturer's Quality Control	3
PART 3 Execution:	**4.7**
Installation	4
Inspection and Testing	5
Cleaning	5
RISK RATING	**4.2**

Figure 5. Engineering firm specification risk audit 21-point score card. *FRPI*

Conclusions

The research and audit results presented validate the vulnerability of fiberglass equipment reliability. Industry standards are lacking, supply side convolution is challenging, specifications are generally poor and resulting premature failure is reality. Dozens of reliability risk issues presented exist throughout the project lifecycle. From drawings and specs developed during design, through construction including submittal approval, manufacturing and installation. Together these issues necessitate moving away from poor, performance-oriented specification language that leaves reliability to chance covered by a limited manufacturer warranty, and compels moving toward comprehensive, prescriptive specification language supported by a specific process that assures compliance with stringent requirements and reliability.

The final objective of this research and audit findings story is to provide practical guidance for reliability risk mitigation, so best value can be consistently obtained. The place to start is to write a new great prescriptive specification, rolling in lessons learned. As we know, standards, an audit trail, pre-vetted suppliers, design, fabrication details, sampling, quality control, installation, third party certification programs plus error, omission and conflict free specifications are hot topics. Be sure to budget for and engage a FRP subject matter expert in specification development, as opposed to salespeople, starting with the specification in design and keep the expert engaged through construction. Engaging a FRP expert is not a matter of if, but rather when and where. A third-party FRP equipment reliability risk assessment is a good place to start.

There are three FRP subject matter expert selection options to choose between or that can be leveraged simultaneously during stages of the project lifecycle:

1. Hire an inhouse expert.
2. Contract a third-party specialty FRP consultant.
3. Specify industry standard certification programs.

If contracting a consultant, be sure they are not otherwise hired by the contractor or manufacturer, have no manufacturer and PE conflict of interest, are vetted to specific expertise criteria, have a complete detailed scope of work plus mandatorily perform the scope they have been contracted for. Engaging industry certification programs assures a bona fide auditing process is in place. There are five certification programs to choose from, where four are industrial consumer protection agencies and one is a standards organization. Each serves a different purpose and has from one to nine listed suppliers prequalified. They include Underwriters Laboratories, Factory Mutual, Air Movement and Control Association, FRPI and ASME.

FRP is a highly specialized engineering material that requires special attention to assure getting the best value out of your fiberglass equipment. When this value is achieved, lowest owning and operating lifecycle cost is realized.

Gary L. Arthur is the executive director and president of the Fiberglass Reinforced Plastics Institute, Inc., of Orchard Park, New York, and may be reached at garthur@frpi.org.

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Fiberglass Reinforced Plastics Institute, Inc.

The FRPI is a nonprofit group that was founded in 2003 by a group of wastewater and water treatment industry owners, engineers, FRP manufacturers and FRP consultants to address the issues plus opportunities validated by research and audit findings presented in this article. The Institute's SP9000 Manufacturer Certification industry standard, coupled with the SP9100 Equipment Certification standard, were developed by this group to cover risks from specification development in design through equipment installation during construction. These certification programs also include submittal, manufacturing, and installation auditing on a project-by-project basis. Under federal guidelines, FRPI is a Professional Trade Certification Organization that holds U.S. Patent and Trademark Office registered certification marks governing its auditing practices.

Properly specifying Fiberglass Institute SP9000 and SP9100 standards is like obtaining insurance coverage required for other perils. These standards provide protection against risk of premature failure by setting the value/cost price ceiling higher for expected reliability while policing the resulting gap for specifiers. They also enable great FRP equipment manufacturers to compete on a level playing field and get fairly paid to deliver the design life specifiers expect.