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An Update on the Use of Fiberglass Casing and Tubing in Oil and Gas Wells

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Abstract: *Thirty years after the last paper on the subject, an update is required. This paper initially outlines a basic review of fiberglass piping in the industry and the manufacturing process. Field issues identified through literature, interviews and operator experiences have been presented and analyzed. Methods and avenues to address these issues have been researched, and a look to the future of fiberglass in the field is provided. Pipe failure, logging, joining methods, fire safety, and handling have been addressed. Generally, as fiberglass accumulates further field-experience, issues and obstacles have been overcome generating many successful case histories around the world.*

1. Introduction

Fiberglass or Fiber Reinforced Plastic (FRP) tubulars have been in use in the oil and gas industry since the 1980's. A wide range of applications have been identified including, but certainly not limited to: storage tanks, production risers, flowlines and offshore platform support systems (sewage, water disposal etc.) The main reasons for employing FRP as opposed to conventional materials such as carbon steel are the FRP's strong resistance to corrosion, high strength-density ratio, low installation cost, versatility and damage tolerance (Mouring et. al 2013). Fiberglass is also referred to as FRP (Fiber Reinforced Plastic), FRE (Fiber Reinforced Epoxy), GRE (Glass-fiber Reinforced Epoxy), FCP (Flexible Composite Pipe), RTP (Reinforced Thermoplastic Pipe), or Composite Pipe. These terms are interchangeable, but will be referred to as fiberglass from this point forward. These terms should not be confused with hybrid applications where carbon steel pipe is often lined with or wrapped in fiberglass in order to retain the steel's temperature resistance and to employ the fiberglass' strong resistance to corrosion. However, this methodology has been reported to cause premature leakage and seepage of corrosive substances in the steel-fiberglass interface (MacLaughlin 1986).Our area of focus is on downhole tubulars, mainly production tubing and casing, made completely of fiberglass.

It is already a well established fact that it is economically viable and safer to employ fiberglass tubulars in low pressure, sensitive chemical and highly corrosive applications. However, when it comes to production tubing and casing, the pressure and temperature requirements are increased by several magnitudes and little published research exists on the subject. The last comprehensive paper on the exact subject was written in 1987, underscoring a need for an update almost 30 years later.

As mentioned, the primary reason to employ fiberglass tubulars are their resistance to corrosion when compared to carbon steel counterparts. This is especially significant when down hole tubulars, storage flow lines and surface facilities are interacting with, storing and transporting corrosive substances. These include, but are not limited to corrosive formation fluids, produced water, sulfur compounds (sour gas and oil), bacterial oxidants and mineral ions within any number of solutions. The large number of corrosive agents is the underlying cause behind corrosion becoming one of the most extensive and expensive problems in the oil and gas industry (Kermani 1996). Corrosion renders the steel tubulars to fail, unable to withstand their respectively rated burst and collapse pressure ratings. Replacement of the metal equipment or assembly is then required to avoid failures, accidents, or losses in production/profit (Hawkins 2008). A large number of operators employ fiberglass tubulars to migitate corrosion control costs. Aside from the obvious cost-savings, secondary corrosion-related costs are also completely removed from project scopes such as corrosion-inhibitor injection, pig runs, and standby replacement piping. The additional advantages of fiberglass like easier handling, transport and installation outweigh the disadvantages and uncertainties associated with these tubulars, some of which will be addressed in this paper.

We aim to address the concept of employing fiberglass casing and tubing in the field, and the reasons for and against this application. Before exploring the technical and field experiences of fiberglass when employed in the field, it is necessary to explore the manufacturing background of the material. The methodology to manufacture fiberglass varies greatly with the application in which the fiberglass will be employed.

2. FIBERGLASS PIPE MANUFACTURING

Fiberglass consists essentially of two substances, epoxy resin and glass rovings. The epoxy, which is a plastic polymer resin, is reinforced with the thin strands or fibers of glass (**Fig. 1**). The epoxy provides the high strength to density ratio of the fiberglass whilst the glass provides the actual strength under compression and tension (Abdul Rauf 2015). The variations innaming of fiberglass can also be explained by the fact that it is composed mainly of glass fibers and resin, such as Glass Reinforced Epoxy or Composite pipe. The ratio of these components varies greatly depending upon the application the fiberglass will be used for, but essentially the low density of fiberglass pipe is due to the polyester resin used in the fiberglass matrix, and the high strength is due to the high tensile strength of the glass fibers (Yao 2003). The epoxy resin is alspo varied depending on the type of application. The epoxy or hardener may be chosen for specific chemical, mechanical or thermal properties (NOV 2012). However, out of these the most common resins used in fiberglass piping manufacturing are Aromatic Amine Epoxy, Anhydride Amine, and Aliphatic Amine (Swanstrom 2014). The latter two of these are utilized in more benign, low pressure conditions.

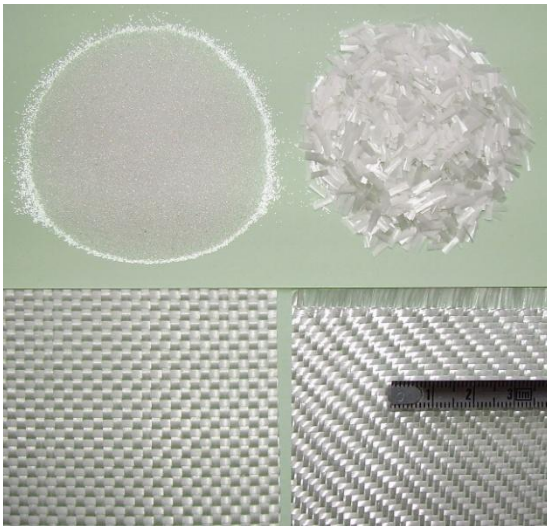


Figure1. *Glass powder and fibers may be used to reinforce the plastic matrix in fiberglass.*

A short explanation of how fiberglass tubing and casing is manufactured is necessary at this point. The two most common methods amongst manufacturers are the Filament-Winding Process and the Centrifugal Casting Process (**Fig.2**). Essentially, the winding process involves feeding continuous glass rovings through a resin bath. This bath contains the required ratios and mixtures of resins and epoxy depending on the application. The fibers are fed through this bath and pulled tight through a fiber placement head. These are then wound onto a rotating spool. The angles at which these fibers are wound onto the spool depend greatly on the application of the tubing or casing. There may be a single-angle wind or a double, even triple-angle wind. These angles of winding determine how and what kind of mechanical stress the tubing will be subjected to (Abdul Rauf 2015).

The second process is less labor-dependant. Glass rovings are pre-woven according to the producer's specifications and placed in a steel mold. The required resin is injected into this mold while it is heated and rotated at high speed. This method results in a denser, more weather-resistant tubing that cannot be spooled, however it is less versatile and only provides for specific applications such as disposal well tubing or sewage pipelines (Beckwith 2006). Both of the above methods require a specific curing period relavant to the pressure and temperature requirements of the tubular, in addition to the type of resin used.

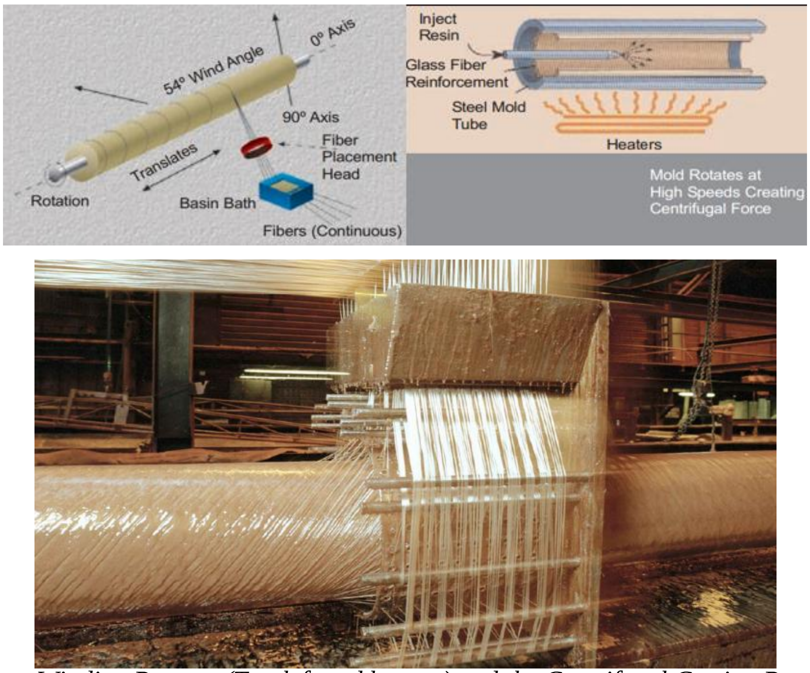


Figure2. *Filament Winding Process (Top left and bottom) and the Centrifugal Casting Process (Top right)*

In combination with the curing time, the resin also determines the type of resistance (micoribalcorrosion, CO_2etc.) that the pipe will exhibit. As glass rovings are one material, the primary factors that determine the mechanical strength and resulting performance of the pipe are the resin and manufacturing methodology used (Swanstrom 2014). In contrast to manufacturing processes for steel, the design workflow for fiberglass pipe is case specific, as opposed to following established diameter-strength relationships as with carbon steel. (**Fig.3**) illustrates a typical design workflow for fiberglass casing and tubing (Future Pipe Industries, 2016). We can see that the target well parameters need to be taken into account in the design of individual pipes, the ratings and critical loading conditions are determined directly from well data. This process explains the relatively high cost of downhole fiberglass when compared to steel, as the pipe is often tailor-made for the specific well, to ensure pressure and critical loading requirements are met (Peralta et al. 2006).

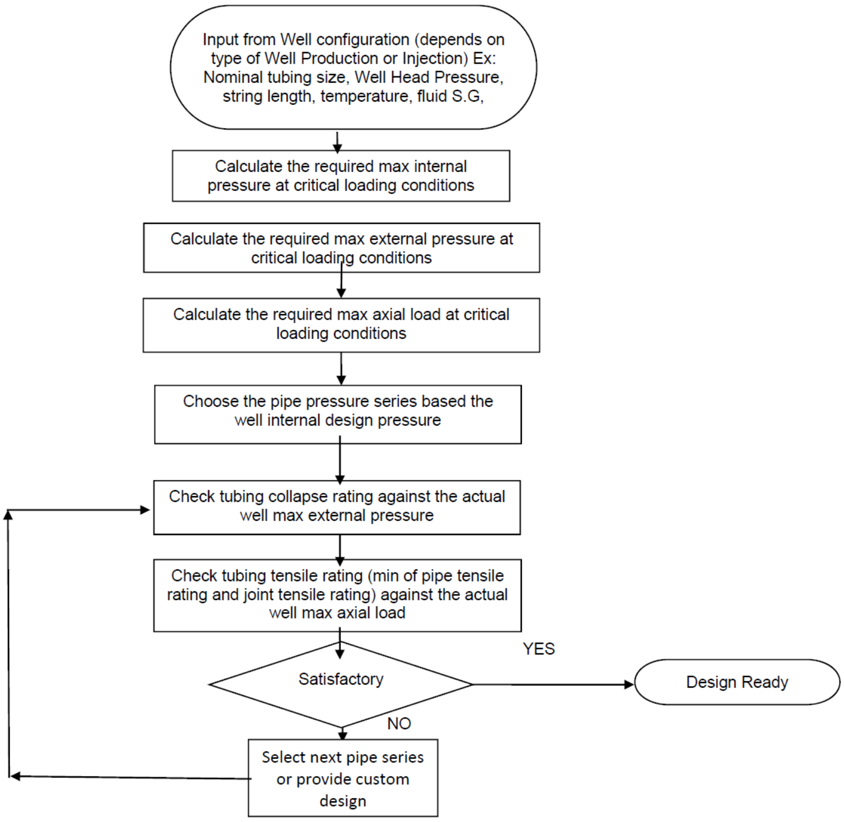


Figure3. *Design Workflow for Fiberglass Casing, courtesy of Future Pipe Industries*

3. Fiberglass in the Field

The conventional, well-established advantages of fiberglass tubing in oilfield applications are well documented. Although much laboratory research on the material exists, the ultimate test for any product is when it is employed in the field for an extended period of time. Fiberglass is unique with respect to its application, it has been selectively adopted, with some operators using it in operations for more than 50 years, whilst other companies hold reservations on the material even today (Al-Yaarubi 2015). Operators voice a number of concerns, or reasons against employing fiberglass tubulars downhole, some of which will be addressed in the subsequent section. The categories are arranged in order of significance and proportional to the number of times a specific issue or complaint is reported in literature. The end of each section is concluded with a look towards the future of the issue and its' application or impact in the field.

3.1. Corrosion, Limiations and Failure

The primary reason to employ fiberglass casing and tubing in the field is its ability to resist corrosion. The success of fiberglass both as a corrosion-resistant material and scale formation-retardant downhole is well documented (Hawkins 2008). Published research indicates the successes of fiberglass tubulars in Brunei, Malaysia, North and South America, the Gulf of Mexico, Alaska, the Arabian Gulf, Russia and Eastern Europe (Oswald 1996).Some case histories have reported fiberglass tubulars with operative lives of up to 35 years (Sharif et al. 2012). This results in direct cost savings not only in the form of reduced maintenance, workovers and corrosion control, but also with respect to replacement costs such as with steel (Rookus 2010). There is no dispute on the corrosion-resistant properties of fiberglass tubulars, however the lack of universal adoption of fiberglass tubulars is dependant on the temperature tolerance and tubing size of the fiberglass (Cowley and Hatfield 2004), which are directly correlated to the field and reservoir type. The current limitation of the performance of fiberglass tubulars is temperature, as beyond a certain limit, the epoxy resin in the tubular fails to support the glass rovings and the pipe fails (Barrere-Tricca et al. 2002). (**Fig.4**) illustrates the diminishing storage modulus of three resins with varying properties.

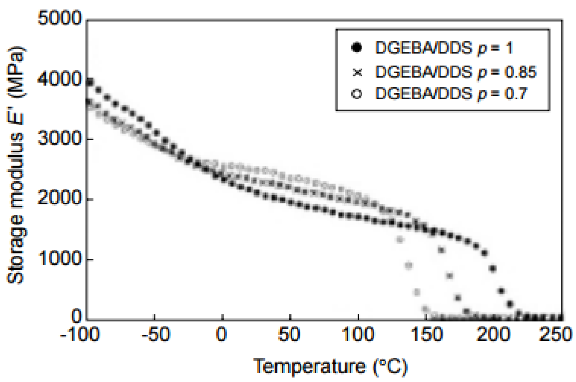


Figure4. *Storage Modulus versus Temperature for Three Epoxy Resins used in Fiberglass Tubulars*

As the resin begins to fail at elevated temperatures, the resin's stress tolerance decreases, leading to pipe failure. An important field-experience advantage to note at this point is regarding the failure method of fiberglass tubulars. Compared to failure methods of steel pipe such as collapse and burst, fiberglass piping fails with weepage. This is a relatively benign method of failure that is a lower risk than bursting and explosions as in the case of failing steel piping (Williams 1988).Tanigushi *et al.* (1991) observed that the weepage pressure of fiberglass pipes is proportional to the failure strain of the resin. This is evidence of the correlation between increased temperature and fiberglass failure (weepage). Thus, because of the resins' thermal limiations, steel is still favoured in high temperature environments (Schmit 2011). Another type of field where fiberglass has still not replaced steel is in high flow-rate fields where large diameter tubing is required. This is mainly because of the current manufacturing methodologies of fiberglass tubulars, as the diameter of the required fiberglass tubular increases, the cost difference between it and its steel counterpart decreases (Cowley and Hatfield 2004). Advances in creating a higher temperature tolerance for fiberglass tubing, especially through advances in epoxy formulation, and novel manufacturing methods to include larger diameter tubing will certainly increase the adoption of fiberglass tubulars in the place of steel.

3.2. Logging

Interviews conducted with local drilling operators have suggested that logging is their primary concern with fiberglass casing. Reportedly, certain logs cannot be run as efficiently as with carbon steel. This claim is especially crucial since the Arabian Gulf region has an underlying aquifer that causes severe corrosion problems in steel surface and intermediate casings, which necessitates a non-corroding replacement (Abdul Rauf 2015). Another issue cited by operators in literature are problems with cement bond logs with fiberglass casing.

Research reveals however, that employing fiberglass casing and tubing in fact increases the number of logs available to run in the wellbore. Fiberglass casing is actually used when a more complex logging suite is required (Edwards et al. 2014). Most conventional logs may be run in fiberglass, with the exception of cement bond logs, and it is most often a simple case of calibrating detectors in logs to account for absorbing components in the epoxy resin of the fiberglass tubular (Bowers et al. 1972). The primary reason behind the additional number of logs is that fiberglass material is non-conductive as opposed to carbon steel. When the casing material is non-conductive, additional measurements such as induction resistivity, cross-well resisitivity, surface to borehole resisitivity, and Nuclear Magnetic Resonance are available (Al-Yaarubi 2015). Another mechanism, in addition to the non-conductivity of the fiberglass, is the material's better trasmissivity; ultrasonic energy travels better through fiberglass than in carbon steel, rendering many log readings more accurate in fiberglass tubulars. In fact, fiberglass casing coupled with NMR logging is an effective method for quantitative monitoring of the remaining oil saturation throughout the course of an EOR flood (Al-Yaarubi 2015).

With respect to cement-bond and time-based logs, there are several methods in place to allow calibration and measurement of cement bond logs with fiberglass casing (Edwards et. al 2014).One example is a method developed by Maki et al. using a specially configured Pulse Echo Tool as early as 1988 (**Fig.5**) (Maki et al. 1988). However, issues arise with the variation of fiberglass-manufacturer methods. For example, in Enhanced Oil Recovery processes, it is essential to know whether hydraulic isolation of the casing exists or not, as this is a crucial factor influencing the interpretation of time-based logs (Edwards et al. 2014). To account for this, acoustic impedance values of fiberglass tubulars are required. However, the value of this parameter varies according to the type of resin, winding, liner, and surface finish the manufacturer has employed. Therefore, more research and development of standards is needed. Standardizers such as the American Petroleum Institute have extensive specifications for the fiberglass tubulars, such as API 15TR, but need to start including specifications on the manufacturing method of these tubulars (Sharif et al. 2012), as opposed to being limited to physical parameters like diameter, density and pressure ratings.

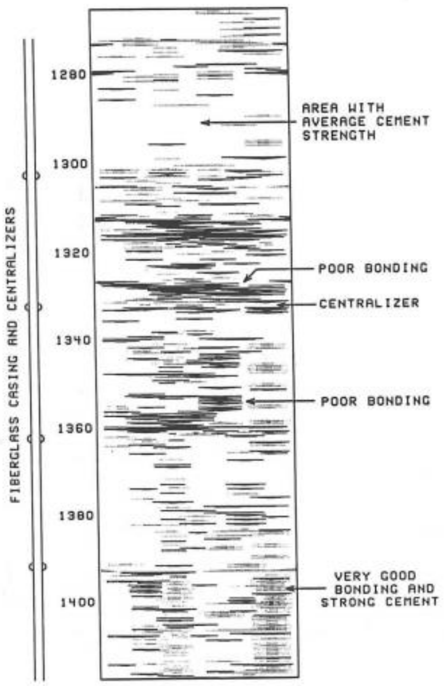
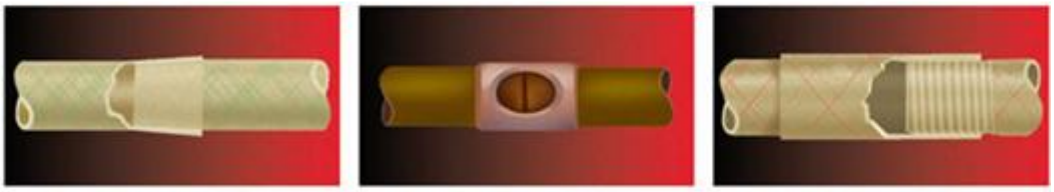


Figure5. *Results of a Cement Bond Log (Modified Pulse Echo Tool) run with Fiberglas Casing*

3.3. Joints and Standards

One of the most common complaints concerning fiberglass piping is leakage at joints (Williams 1987). As joints have been identified as a problem area with fiberglass tubulars as early as 1987, much research has been conducted in this area (Mouring et al. 2012). All fiberglass tubulars that are adopted for use in the field are pressure and temperature rated, and meet the required burst, collapse and tensile stress requirements. However, regardless of how strong and withstanding the tubular itself is, the joints are often reported to fail. At depths where fiberglass cannot meet the required pressure and temperature values, but where it's resistance to corrosion and other advantages are required, it is used in conjunction with steel. The joints or connections between steel piping and the fiberglass tubular have been reported to have had the most failures (Hawkins 2008).Fiberglass piping joints can be categorized as mechanical, bonded, threaded and flanged (Williams 1987) and any of these categories can apply to fiberglass-fiberglass joints and fiberglass-steel joints. O-ring seals between the two materials, and bonded joints have had reported leakages.

Manufacturers now provide a large number of solutions to these problems, with high performance flanges and new curing methods (**Fig. 6**). In addition, industry standards for fiberglass joining technology have been developed, such as EUE 8RD, OD 8RD and API 5B. Despite several standards and benchmarks being available for joints, there seems to be a discrepancy amongst standards for employing fiberglass tubular-joints as a whole. In the 1980's several complaints of the absence of standards and certifications were voiced (Williams 1988). Almost three decades later, several codes, benchmarks and standards have been developed but there seems to be an inadequacy on the industry's part with respect to having adopted these standards in a uniform manner. Research on numerous manufacturers of fiberglass reveals that almost all marketers prove to hold one form of certification/standard or another, yet these standards are by no means common as different suppliers adhere to different standards. Additionally, an operator has the freedom to choose what type of fiberglass to employ, and in which application. Each pipe design adheres to, or is certified by, a different institution or agency. As a result, the rules and standards for fiberglass casing and tubing can be very confusing and ambiguous, and fail to address the unique properties of fiberglass in terms of downhole performance. This underscores the need to update installation and testing guidelines for fiberglass (Hawkins 2006), in order to provide an industry-wide best practice and uniform implementation standard.ISO14692 aims to provide an international standard for fiberglass manufacturers but only has sparse references to field application and joints. In terms of universal acceptance,independent researchers have attempted to develop standardized methodologies to help provide a means to judge the image and perceptions of companies and products in the fiberglass-tubular industry (Holtzclaw 1998). Rookus (2010) presents an extensive review of standards and guidelines for fiberglass tubulars and notes that these standards are heavily dependant on operators' experiences in the field, and shall become more reliable and effective with increased use of fiberglass tubulars downhole. It is therefore a case where a young industry trend needs to mature with an accumulation of field experiences in order to replace older, steel technologies.



Bell & Spigot FRP Pipe Joining
A matched-taper joint secured with epoxy adhesive. Stronger than the fiberglass piping itself, in both internal-pressure and axial-tension capability. Resists movement, facilitating joining long runs of fiberglass pipe **without waiting for the adhesive to cure**. Fiberglass bell and spigot joining can be used with 1 inch to 24-inch frp pipe diameters.
[Bell and Spigot Fiberglass Pipe]

Socket FRP Pipe Joining
Positive stop lands simplify precise makeup of complex piping configurations. For pipe diameters of 1 inch to 14 inches.
[Socket Fiberglass Pipe]

T.A.B.™ FRP Pipe Joining - Threaded and Bonded
The ultra-reliable FGS threaded and bonded joining system. Double-lead threading ensures an extra secure adhesive connection during threaded fiberglass pipe installation. Available for 2-inch through 6-inch frp pipe diameters (larger sizes available by special quotation).
[Threaded Fiberglass Pipe]

Figure6. *Type of Joints available for Fiberglass Tubulars from a Manufacturer*

In addition to extensive developments in specific types of joining methods, independent researchers have innovated entirely new methods of steel-fiberglass joining methods. An example is the Comeld hybrid joining technique (**Fig.7**) developed by Imperial College and the U.S. Naval Academy (USNA), which are reported to be 87% stronger than plain bonded joints, in addition to having the characterisitic of redistributing stress along the joined region, as opposed to concentrated areas of stress with conventional joints (Mouring et al. 2012).

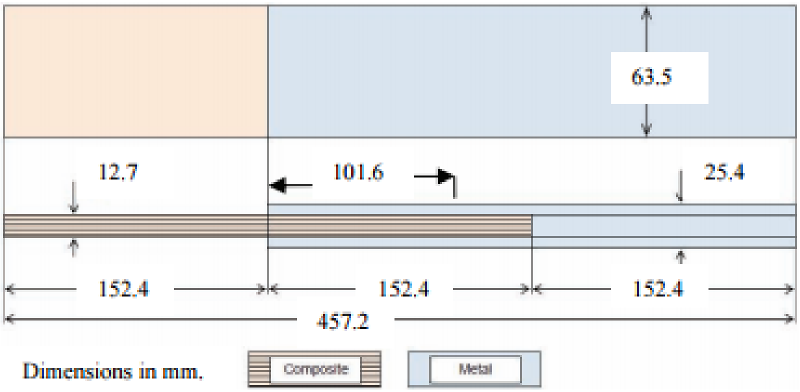


Figure7. *Comeld Hybrid Steel-to-Composite Joining Tecchnique by Imerial College and United States Naval Academy*

3.4. Fire Safety and Erosion

Due to the fact that fiberglass tubulars have epoxy resin as one of their main chemical constituents, fire safety comes into question as these resins are often flammable. Fire safety issues with fiberglass tubulars have been reported offshore and onshore in as early as 1988 (Williams 1988). Important to note here is that this issue is dependant on the type of resin used, the choice of which depends greatly on the application for which the fiberglass tubular will be used. A certain type of flammable resin may be used in a chemical application for its specific electrical, mechanical or chemical properties, despite the material's extra flammability when compared to other resins. Thus, chemical and processing applications for fiberglass tubulars are more susceptible to fire safety issues, compared to donwhole applications (Bochicchio 2011).

Another factor to consider here is the fact that fiberglass tubulars have a smooth inner surface. This is often considered a favourable advantage as it reduces friction pressure losses and aids artificial lift, injection and disposal operations in the field (Sharif et al. 2012). However, the same smooth surface can be the cause of static charge building up on the inside of the tubing, which may lead to sparks that eventually ignite a fire (Williams 1988). This is especially crucial if the fluid being transported by the tubular is flammable, in this case, a fire may not only ignite the tubular but lead to catastrophic fire hazards. The majority of offshore platforms use fiberglass in the construction of their platforms (Dutta 1995), if such a fire were to break out on one of these platforms, the possibility of the tubulars, the fluid, and the whole platform being consumed in a fire exists.

This issue has been sufficiently addressed and remedied in the past two decades. Perhaps the most crucial step towards achieving this end was to develop fire testing codes, standards and procedures and making them a benchmark-standard for fiberglass manufacturers. ASTM E-84 Tunnel Test, Flame Spread Index (FSI), and Smoke Developed Index (SDI) are just some examples. To meet these standards, manufacturers have developed several fire protection coatings that are wound on the fiberglass tubular in the manufacturing process (Cowley 2005). There are also a multitude of fire-retardent coatings available post-manufacture of the tubular, and can easily be lined on the inside or outside of the tubulars, both through a curing or winding process. Advances in fiberglass linings are not limited to fire-proof coatings, linings that provide protection against erosion and ultraviolet degradation have curtailed complaints against these issues that were common in the 1980's (Cowley and McCauley 2005). With current technology, the use of even high-density proppants has no noticeable eroding effect on fiberglass casing (Romera et al. 2008). Additionally, a variety of intumescent paints, mastic coatings, and lightweight ceramic coatings (Williams 1988) for specific fire-retardant or erosion-protection purposes are available with the majority of fiberglass manufacturers (Sharif et al. 2015). As explained in the *Corrosion, Limiations and Failure* section, temperature is a limiting factor fiberglass tubulars. Fire safety is therefore the most crucial issue to be addressed in our review. Preventative measures aside, several types of fire-retardant resins have also been developed that do not affect the desired property (e.g. corrosion resistance, flexibility etc.) of the material (Stevens 2001). (**Table 1**) shows the fire retardancy of three such resins, all three of which have good corrosion and acid resistance properties, have enhanced chemical performance in their respective, specialized applications (Stevens 2001). As can be seen from **Table 1**, adding antimony trioxide to the resins greatly reduces the Flame Spread Index of the fiberglass tubular.

Table1. *Fire Retardant Properties of Vinyl-Ester Resins*

Resin	Standard Br. VE		High Performance Br. VE	Styrene Free Br. VE
Styrene Level, %	40		35	0
Antimony Trioxide	0	3	0	3
ASTM E-84 FSI	40	15	25	20

To reduce effects of static charge building up in chemical storage tanks and tubulars, water inlets have been designed and palced at the bottom of water tankers. Isolated metal parts within completions and surface facilities have been grounded to earth and isolated with insulation. In the case of using fiberglass tubulars to inject and dispose of seawater, static charge build-up risk is negligible, as the ions in seawater help bleed off static charge (Williams 1988). Another methodology used for tubulars handling non-ionized fluid is to wind a layer of electrically conductive steel or copper in the filament-winding process during manufacture (**Fig. 2**). This will ensure conductivity of the tubular and bleed off any charge buildup within the tubular. This tubular can then be grounded to an earth plate from a surface contact (Cowley 2005).

3.5. Equipment and Handling

A common concern voiced by operators is the need for fiberglass tubulars to be handled by special equipment. Not all equipment used for steel is directly suitable for use with fiberglass tubulars. More damage of fiberglass pipe has been reported pre-operation due to damage from handling/equipment than during operation (Sharif et al. 2012).

The solutions to this issue have been effectuated with two types of methods: either the equipment to handle fiberglass has been modified to be able to handle the tubulars, or the fiberglass has been adapted to be able to withstand conventional steel-suited equipment. Abrasion and erosion resistant linings for fiberglass tubulars (see *Fire Safety* section) have been developed by manufacturers and are widely available for use in the field. Such tubulars have been effectively installed in Argentina, Oman, and Brunei with no reported complications (Romera et al. 2008).

The second category of solutions is to adopt steel-suited tools to handle the fiberglass tubulars, and to take special care while handling the fiberglass. Several observations have been made in this regard. With regards to handling the fiberglass tubulars before it is inserted into the well, numerous operators have advised the use of soft slings and capped ends, and to inspect metal components like swedges, SSD's, locator-seal assemblies, side pocket mandrels and tubing hangers for rough edges and burrs that may damage the fiberglass (McLaughlin 1986).

Two common problem areas were identified, namely packers and perforations. Packers were often reported to have shifted during operation or to have damaged the fiberglass tubular. Drilling out drillable squeeze packers has also been reported to have caused damaged to fiberglass casing (McLaughlin 1986). One identified reason is that slip grips on most conventional equipment are designed to be anchored to steel, however the high density of these threads causes sticking when set on fiberglass. Slip grips with lower thread densities are therefore required (Peralta et al. 2006).

Perforations using shallow penetration guns have had no reported complications. However, deep penetration charges and capsule-type guns cause damage to the fiberglass tubulars, creating a rough hole which leaves debris on the tubular (**Fig.8**). This debris can then cause further problems for other equipment like gauging instruments and packers. These issues are either remedied by using strictly shallow-penetration charges, hollow carrier guns, or using weight bars on baskets for gauging operations, so as to prevent them from getting stuck in perforation debris (Romera et al. 2008). In addition to capsule-type perforation guns, other equipment unsuitable for fiberglass tubulars has also been identified. These include slip-type casing elevators, power tongs, and button-type slips as these all cause damage to the fiberglass tubular. Instead, normal serrated slips, soft slings, strap wrenches (**Fig.9**), and equipment from the pipe manufacturer have have been advised (Romera et al. 2008).

Figure8. *Results of Perforation of Fiberglass Casing*

Figure9. *Use of Strap Wrenches with Fiberglass Casing, courtesy of Future Pipe Industries*

Other operational precautions that have been found include: using a packer to isolate a cross-over between steel and fiberglass in hybrid strings to prevent corrosion, avoiding heavy fishing equipment in the hole, employing specific packers specified by manufacturers, and anchoring fiberglass casing to the formation prior to cementing (Peralta et al. 2006). Anchoring is required because the low density of fiberglass can lead to buoyancy/flotation issues during cementing, an alternative would be to use a lower-density cement slurry. The lower density also requires metal collars to be added to the end of fiberglass tubulars to add weight when pushing downhole (Romera et al. 2008), however this would require special precautions as cited in the *Joints and Standards* section. When these collars are added, the crossover between fiberglass to steel material should be isolated as in the case of hybrid strings. All of the above, as with standards and guidelines, will become standardized and more effective with increased use of fiberglass tubulars in the field.

4. CONCLUSIONS

The days of corrosion issues with steel tubulars down hole are slowly but surely coming to an end. Alternatives like fiberglass casing have made significant advances and accumulated sufficient field experience in order to become a viable replacement for conventional carbon steel. All field issues that currently exist with fiberglass tubulars have multiple avenues of resolution, provided users are proactive and progressive. Logging, fire safety, joints, and standards have all been addressed either through experience or innovation. What remains is a basic yet careful approach to the handling and use of this material, as with all crucial equipment in the oilfield.

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