UPDATE ON API ACTIVITIES FOR FIBERGLASS PIPE AND DOWNHOLE TUBING AND CASING

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ABSTRACT

More and more interest is generated for fiberglass tubulars because of their excellent corrosion resistance and mechanical strength.

The major obstacle for more extensive use of fiberglass has been the lack of recognized engineering standards that would allow the field engineer to specify fiberglass with confidence for a particular application.

Recognizing this need, several API committees are at work with unusual speed and efficiency to develop product specifications for fiberglass tubulars.

Specifications for low-pressure line pipe were issued in 1986. Specifications for high-pressure line pipe followed in 1988. A specification for fiberglass downhole tubing is expected to be issued next year, in 1991. Finally, a specification for fiberglass casing is planned to be issued in 1992.

This paper summarizes these API activities and details API fiberglass product specifications, both those issued and those still in committee.

BACKGROUND

Fiberglass-reinforced epoxy is one of the many space age materials that was developed by the government at great R & D expense for the rocket program and was then left for private industry to use it if it could.

The rocket people liked fiberglass because it was very strong -- stronger than steel and very light in weight -- perfect for rocket motor cases where every pound of weight saved allowed a pound of nuclear material to be carried in the warhead.

Fiberglass is still the primary material of construction for solid fuel motor cases for the Polaris and Minuteman class rockets and for the pair of solid booster motors for the space shuttle.

When private industry looked at this material, it became obvious that the premium in price could not be justified by saving weight alone. Lighter products were appreciated as some savings could indeed be realized by reduced crew size and handling equipment. Unfortunately, these cost savings due to weight reduction (to one-fourth to one-tenth) of steel weight, were not sufficient to offset the price premium of fiberglass.

It was at this point in time that engineers discovered that this material was not only strong and lightweight but also was extremely resistant to most corrosion. It makes sense; corrosion is an electrical action that breaks down metallic materials on the molecular level -- fiberglass is entirely nonmetallic and thus, nonconductive. This realization of the corrosion-free property of fiberglass is what gave birth to a new industry: fiberglass as an engineering material became a reality.

At first, simple fiberglass structural elements were introduced. Then as design engineers became more familiar and more comfortable with the new material, more sophisticated parts appeared made of filament-wound fiberglass, among them piping.

Corrosion was always a problem in the oilfields. Saltwater, sour crude, and H_2S were not kind to steel. For this reason, oilfield piping was one of the first applications for fiberglass, back as far as the late 1950s. Fiberglass solved the corrosion problem, had sufficient mechanical strength but was new and different. Early products were crude by today's standards and had to be assembled by the then unfamiliar method of epoxy adhesives.

Acceptance was fast because of the strong technical need for a corrosion-resistant engineering material for oilfield piping. With progress came problems, headaches, but progress nonetheless. By the end of the 60s, low-pressure fiberglass pipe was an accepted piping material for such applications as flowlines, gathering lines, etc. High-pressure fiberglass pipe, for operating pressures over 1000 psi, appeared in the late 60s for use in secondary recovery, waterflood applications. Last to be developed was fiberglass downhole tubing in the early 70s and fiberglass casing in the late 70s.

Overall usage of fiberglass tubulars in the oilfields is still small compared to the total pipe used. Given the excellent engineering properties, the technical need and the readily available supply of prime quality fiberglass tubulars, why then is its usage limited?

The most probably reason, in this writer's opinion, is that even now, field engineers are still somewhat hesitant to consider fiberglass except where no conventional material might do the job -- not because engineers are scared of new materials; they explore new ideas every day! More likely it is because of the absence of recognized engineering standards, handbooks, and reference libraries for fiberglass.

When designing for steel tubulars, engineers can go to textbooks, reference books, and AIP specifications for reliable, accepted technical information. Compare this to fiberglass: no textbooks, no reference books, and until recently, no accepted API specifications. The only source of information seemed to be the sometimes limited data presented in each manufacturer's technical literature, and of course, the salesmen, who while sincere in their efforts to promote their particular brand of product, always seemed to have to get answers to technical questions from the home office.

Finally, it became obvious that something had to be done. Oil companies wanted to use fiberglass because of what it could do for them, if they could only understand it better and be able to specify the proper grade and performance ratings with a good degree of confidence. Parallel to this, naturally, fiberglass tubular manufacturers with their vested interest in selling more product, wanted to break down barriers to fiberglass' use in the field. The result was a refreshingly cooperative effort between users and manufacturers and even between rival manufacturers.

The best avenue was the standardization efforts of the American Petroleum Institute (API). This paper summarizes the status of this work accomplished within the API framework. It describes in detail the standards already published and those still under preparation by API committees.

LOW-PRESSURE LINE PIPE
(Working pressure under 1000 psi - working temperature up to 200°F)

API Specification 15LR is the latest in a series of standards covering low-pressure fiberglass pipe in sizes 2" through 16" diameter. It was reissued in its current form in October, 1986.

Because of the nature of the intended application, the pipe and fittings are rated based on their performance in cyclic pressure service. The test method is ASTM D2992, Procedure A, which is described in Figure 1. In essence, the method projects the life of the product under cyclic pressure exposure to 100,000 hours or 150,000,000 cycles.

Pipe can be manufactured by filament winding or by centrifugal casting, and can be made of fiberglass-reinforced epoxy, polyester or vinylester. The primary connection is a bell-and-spigot glued joint or one of several proprietary, mechanical joints.

In addition to requiring determination and publishing of certain basic material properties, the standard also requires additional tests to verify design validity: namely, short-term failure pressure at 4 times rating, cyclic pressure performance at design level at 750 cycles and resistance to impact loads.

Minimum level quality control tests are prescribed, covering dimensional check, hydrostatic mill pressure test at 1.5 times rated pressure, burst pressure, degree of resin cure, and visual inspection. Visual standards are shown in Figure 4.

There is an accompanying care-and-use standard - API 5L4, which is planned to be updated and reissued sometime next year.

HIGH-PRESSURE LINE PIPE
(Working pressure above 1000 psi - working temperature up to 200°F)

API Specification 15HR was issued in late 1988 as a new specification. It reflects the latest thinking of both user and manufacturing members of the API committee. The specification covers high-pressure fiberglass pipe in sizes 2" through 8" diameter. It is worth noting that as of the time of the writing of this presentation, none of the producer companies have completed all the required testing for API monogram rights. Some producers expect to obtain the API monogram in 1990.

The pipe and fittings are rated based on their performance in static pressure service. The test method is ASTM D2992, Procedure B, which is described in Figure 2. In essence, the method projects the service life of the product under static pressure exposure to 20 years with a service factor of 0.5 (safety factor of 2:1).

Pipe is manufactured by the filament winding method and can be made of fiberglass reinforced epoxy or vinylester. The primary connection is 8 Round EUE threaded joint, up to 4" size, with integral joint or threaded-and-coupled. Above 4" size, the standard thread is 8 Round casing long thread.

In addition to requiring determination and publishing of certain basic material properties, the standard also requires additional tests to verify design validity: namely, short-term failure pressure, cyclic pressure performance, 5,000 cycles at 0-to-1.5 times rated full-amplitude pressure and static pressure performance for 10,000 hours at 2 times pressure rating.

Minimum level quality control tests are prescribed, covering dimensional check including threads, hydrostatic mill pressure test at 1.5 times rating, optional acoustic emission monitoring, degree of resin cure, burst pressure, glass content, and visual inspection. Visual standards are shown in Figure 4.

The care-and-use standard, API 5L4, which is planned to be updated and reissued sometime next year, will include provisions for high-pressure as well as low-pressure fiberglass pipe.

DOWNHOLE TUBING

(Performance limits not yet determined)

API published a fiberglass tubing specification, API 5AR, back in the early 80s that unfortunately was completely unrepresentative of any of the commercially available products. It was generally ignored by users and manufacturers alike, and none of the manufacturers ever attempted to qualify under this specification. In 1987, when API realigned its specification numbers, it reissued this specification as API 15AR. Again, as before, none of the manufacturers qualified under it.

Recognizing that there is a definite technical need for a corrosion-free, high-strength tubing material and an API specification covering it, a special subcommittee was assigned to prepare a document which will eventually replace API 15AR. It will be designated API 15TR.

Currently, the subcommittee has completed the first draft of the proposed API 15TR tubing specification. It covers fiberglass downhole tubing in sizes 2-3/8" through 9-5/8". Tubing will be filament wound and made of fiberglass-reinforced epoxy or vinylester. Primary connection will be 8 Round EUE thread up to 4-1/2" size and 8 Round casing long thread on larger sizes, integral joint or threaded-and-coupled.

Fiberglass tubing will be rated on the basis of its tensile rating. This is a departure from previous versions of piping specifications, where pipe is rated on the basis of internal pressure. The design criteria will be based on a combined axial tension, internal and/or external pressure loading. In effect, a failure envelope will be drawn and, by the application of appropriate service factors, a rating diagram will be developed -- probably as shown on Figure 3.

A considerable amount of work is required to complete this specification. While the subcommittee is forging ahead at full speed, completion and API specification status are not anticipated until 1991. An accompanying care-and-use standard, API 5A4, is currently available but requires extensive updating. This updating is planned to be accomplished immediately after completion of the tubing specification.

Meanwhile, fiberglass tubing is used more and more, to depths as deep as 10,000 feet. Hopefully, standardization work will catch up with field usage.

CASING

(Performance limits not yet determined)

Fiberglass casing has been used with good success for the past five or so years. It is commercially available in sizes of 4-1/2" through 9-5/8" with tensile rating of up to 150,000 pounds, internal pressure rating up to 3,000 psi and collapse pressure rating of up to 6,700 psi.

Presently, there is no work done within API to prepare a fiberglass casing specification. Plans call for commencing work on a casing specification immediately upon completion of the tubing specification and care-and-use standard (by the same API subcommittee). Completion date is estimated to be sometime in 1992, at best.

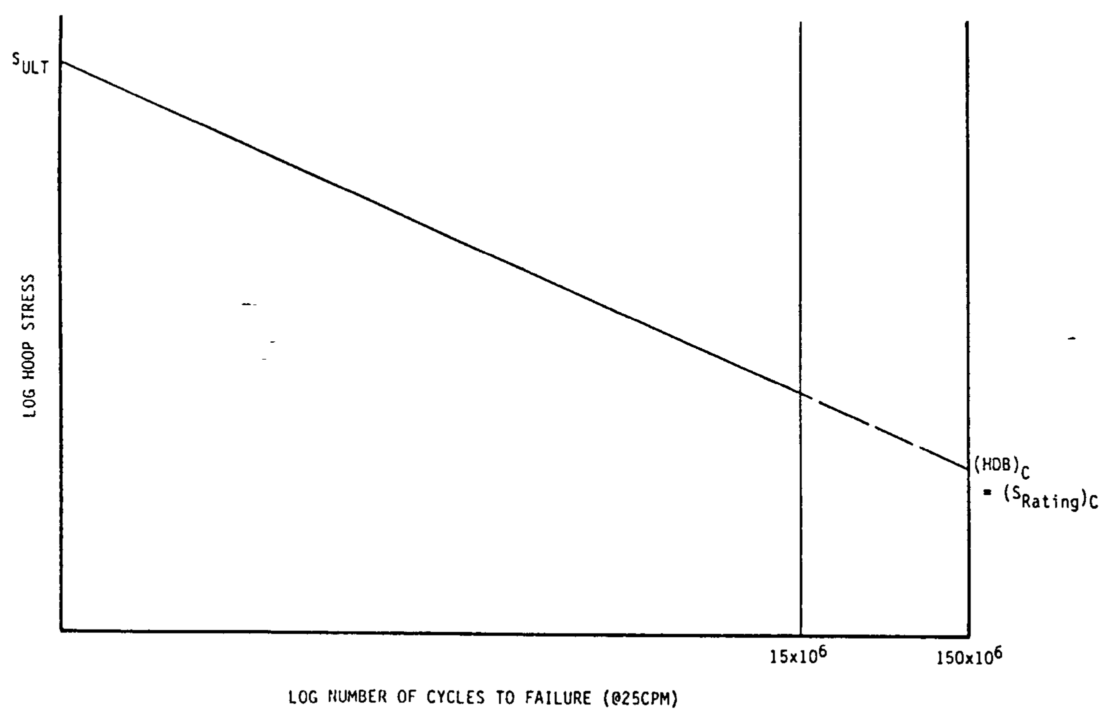


Figure 1 — Cyclic pressure performance test for low-pressure fiberglass pipe (ASTM D2992, Procedure A)

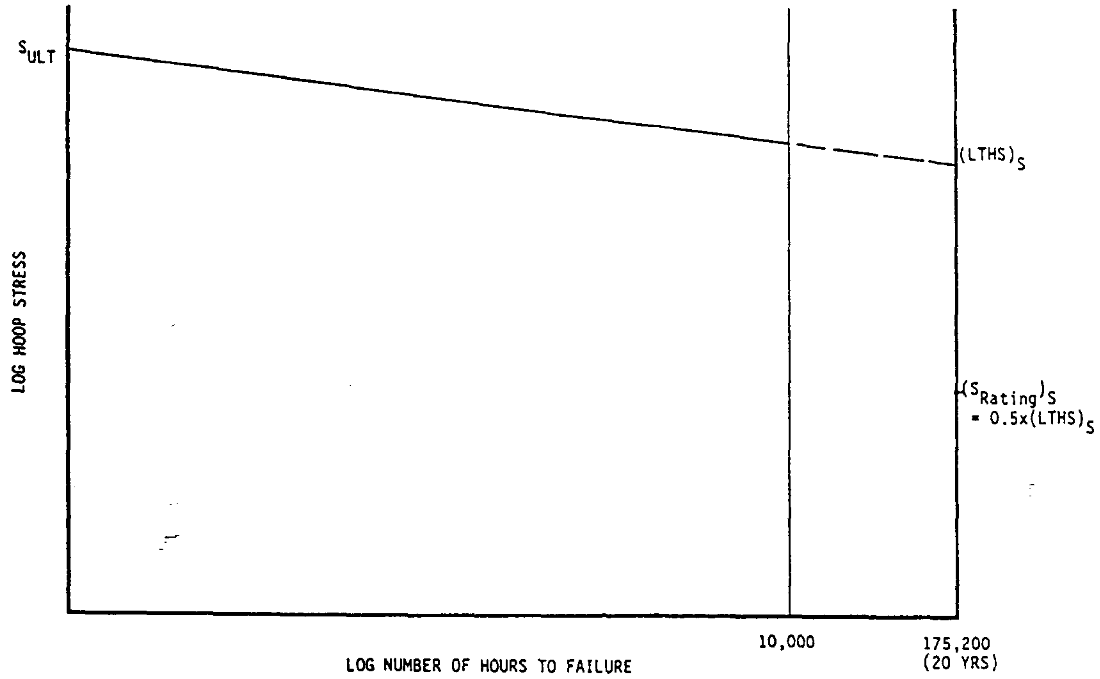


Figure 2 — Static pressure performance test for high-pressure fiberglass pipe (ASTM D2992, Procedure B)

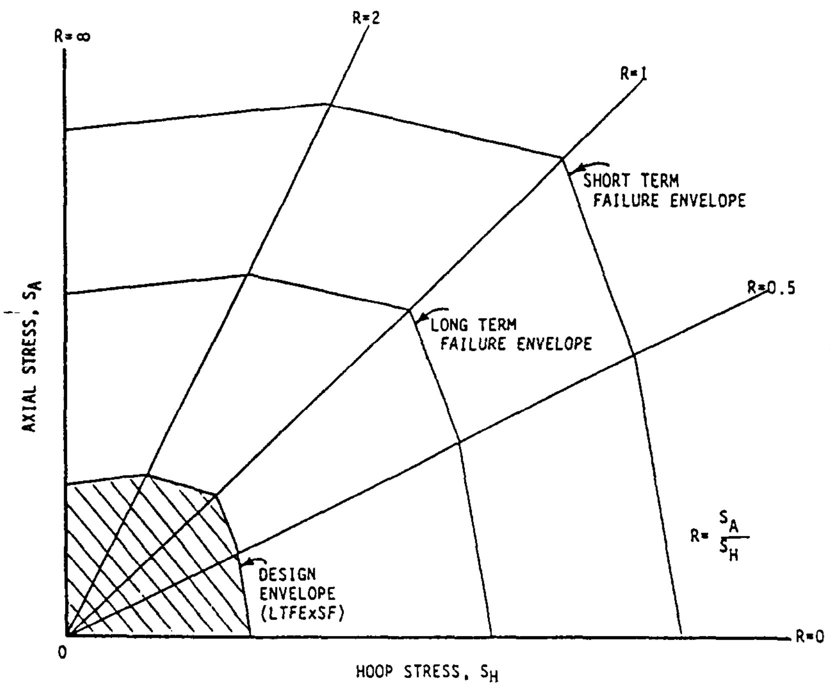


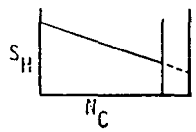
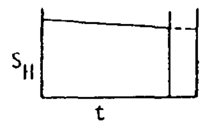
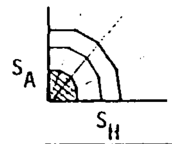
Figure 3 — Combined tension and pressure *for fiberglass downhole tubing*

TABLE 5.1
VISUAL STANDARDS

Defect	Description	Maximum Size
Tube Body and Coupling		
Burn	thermal decomposition evidenced by distortion or discoloration of the surface	20% area-lightly blemished, 5% area-moderate burn of outer resin layer structural roving
Chip	small piece broken from edge or surface	permitted if laminate has not been fractured
Crazing	fine cracks at or under the surface as seen by the unaided eye	none permitted
Cut Roving	broken or cut outer rovings due to scraping or scuffing or manufacturing process	maximum 3 per pipe with one square inch maximum size such that the wall thickness is not reduced below minimum
Dry Spot	area where reinforcement was not thoroughly wet with resin	none permitted
Fracture	Rupture of laminate without complete penetration. Visible as lighter colored area of interlaminar separation	none permitted
Pits (pinholes)	small craters in the surface	maximum 1/16" deep, no limit on number
Resin Drip	resin protrusion	maximum 1/8" high, no limit on number
Restriction	any restriction: paste, epoxy or wax, lump, foreign matter in I.D. of pipe	none permitted
Scratch	shallow mark caused by improper handling	no limit on number if reinforcement is not exposed
Threads		
Air Bubbles	small bubbles at crest of threads	maximum size 1/8", one permitted. Maximum size 1/16", 10 permitted.
Broken Thread	light patch at the root of the thread	maximum size 1/8" in any direction and one allowed per pin
Chips	areas where over 10% of thread height is removed	maximum 3/8" long in one thread per connection, none permitted in LC area
Cracks	in direction of thread axis	none permitted
Flat Thread	area where top of thread is broken or ground off	maximum 3/8" long in one thread per connection not to exceed 10% of the thread height, none permitted in LC area
Squareness	angle perpendicular to pipe axis	maximum 1/16" variation in end
Finish	finish cut end	no sharp edges. No exposed loose fiber. No protrusions. No impact areas.

Figure 4 — API Specification 15HR for high-pressure fiberglass line pipe

STATUS OF STANDARDIZATION EFFORT OF API FOR FIBERGLASS PIPE, DOWNHOLE TUBING AND CASING

PRODUCT	LOW PRESSURE LINE PIPE LESS THAN 1000 PSI	HIGH PRESSURE LINE PIPE ABOVE 1000 PSI	DOWNHOLE TUBING/CASING
SPECIFI-CATION	API 15LR (10/15/86)	API 15HR (9/15/88)	API 15TR (1991)
MFG. PROCESS	FILAMENT WINDING CENTRIFUGAL CASTING	FILAMENT WINDING	FILAMENT WINDING
MATERIAL	FIBERGLASS REINFORCED EPOXY OR POLYESTER OR VINYLESTER	FIBERGLASS REINFORCED EPOXY OR VINYLESTER	FIBERGLASS REINFORCED EPOXY OR VINYLESTER
PRIMARY CONNECTION	TAPERED BxS, EPOXY BONDED	8RD THREADED (T&C OR IJ)	8RD THREADED (T&C OR IJ)
BASIC DESIGN CRITERIA	CYCLIC PRESSURE TEST ASTM D2992, PROC. A.  See FIG. 1.	STATIC PRESSURE TEST ASTM D2992, PROC. B.  See FIG. 2.	ACROSS JOINT TENSILE PLUS INTERNAL/EXTERNAL PRESSURE TEST  See FIG. 3.
DESIGN VERFICATION TEST	- SHORT TERM FAILURE @400% - CYCLIC PRESSURE, 750 CYCLES - IMPACT RESISTANCE	- SHORT TERM FAILURE PRESSURE - CYCLIC PRESSURE 5,000 CYCLES @150% - STATIC PRESSURE, 10,000 HRS. @200%	? (IN COMMITTEE)
QUALITY CONTROL TEST	- DIMENSIONAL - HYDROSTATIC MILL TEST @150% - SHORT TERM FAILURE PRESSURE - DEGREE OF CURE OR PERCENT EXTRACTABLES - VISUAL	- DIMENSIONAL, INCLUDING THREAD - HYDROSTATIC MILL TEST @150% - ACOUSTIC EMISSION (OPTIONAL) - DEGREE OF CURE - SHORT TERM FAILURE PRESSURE - GLASS CONTENT - VISUAL	? (IN COMMITTEE)