GRP pipe: custom or commodity?

GRP pipe can be categorized as commodity pipe and custom pipe, but which is best? Alfred L. Newberry of FEMech Engineering explains the difference.

Glass reinforced plastic (GRP) piping is the material of choice for handling corrosive fluids and is especially suitable when corrosive external conditions exist.

Corrosive external conditions are typically caused by corrosive soils or by chemical fumes. In some cases, corrosive external conditions govern the selection of materials.

GRP pipe was used for a recent project requiring many kilometres of large diameter pipe because of the very corrosive soil conditions. The conveyed fluid for this project was fresh water, which is only mildly corrosive, but the external soil conditions were highly corrosive. GRP pipe was the clear choice in terms of external corrosion resistance, weight, ease of installation and price.

GRP pipe can be generally categorized as commodity pipe and custom pipe. Both types of pipe have relative merits and fit into different niches within the GRP pipe market.

Commodity versus custom

Commodity pipe is produced en masse and the properties are typically fixed in terms of the reinforcement schemes, the liner thickness, the structural thickness and the resin system. Commodity pipe is designed to suit the mass production process and issues such as resin type and liner thickness are selected to satisfy the commodity market.

Commodity pipe is generally lower in cost than custom pipe due to mass production and commodity pipe is often an ‘off the shelf’ product, resulting in shorter lead times.

Custom pipe is custom engineered and custom fabricated for the particular corrosive environment and mechanical and thermal loading. Essential design variables considered during the design of custom pipe are:

- pressure;
- vacuum;
- peak temperature;
- differential temperature;
- coefficients of expansion;
- support span;
- burial conditions (underground pipe);
- liner thickness; and
- resin system(s).

By tailoring these parameters to the particular job, the custom fabricator is able to provide a more reliable and longer life pipe, due to superior properties, higher design factors and higher corrosion resistance.

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The author recently visited a large power plant in the southern part of the USA which some years ago suffered a multi-million dollar loss because commodity GRP pipe had been used without proper attention to the essential design variables listed above. Properly engineered and fabricated custom GRP pipe would have performed very well in this service. In this particular power plant, GRP pipe has been ‘blacklisted’, which is unfortunate for the GRP industry as a whole. The engineers at the power plant understand that the failures were not due to the use of GRP but to the use of the incorrect GRP product. However, the company management issued a ‘blanket ban’ against GRP pipe because of the large monetary losses, preventing the engineering department from specifying GRP pipe of any type. The power plant engineers expressed regret that this had occurred and said it will take years to get the ban lifted. They fully understand that custom engineered pipe would have performed successfully for many years.

Manufacturing process

Commodity pipe is typically manufactured either by filament winding or centrifugal casting. In the case of centrifugal casting, glass fibres are chopped and mixed by various means with resin, and
centrifugal force is used to keep the pipe against the inside of the mould until the resin cures.

For buried pipe, some manufacturers mix sand into the matrix. Sand is a low cost material which ‘bulks up’ the pipe thickness.

Centrifugally cast pipe properties are highly resin dependent due to the short fibre lengths, so the long term properties are significantly lower than long term properties of custom engineered pipe. In addition, the strength and stiffness of short-fibre pipe is more sensitive to temperature. The wall thickness is relatively high because the material strength is relatively low. In the case of sand-filled pipe, mechanical strength is very low but wall thickness high because pipe stiffness is proportional to thickness cubed and linear with modulus.

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It is important to note there are many ways to do filament winding and the resultant properties can vary greatly. Commodity pipe is typically wound at 55° (as measured from the pipe axis). Many have been led to believe 55° is the optimum wind angle for GRP pipe, but this assertion is a ‘half truth’. An angle of 55° is optimum only for pipe subjected to biaxial pressure and manufactured only with single angle helical filament winding reinforcement. (O-ring joint pipe with thrust blocks is subjected only to hoop pressure while locked joint capped pipe is subjected to biaxial pressure loading.)

Other winding methods and reinforcement schemes will result in pipe with significantly improved properties over 55° filament wound pipe. However, for commodity pipe, these

superior winding techniques are not practical for mass production. The hoop and axial strengths of 55° pipe are dependent to a large degree on the shear strength of the resin. This explains the large ratio of short term to long term strengths. Long term burst is typically an order of one third the short term burst pressure because of the resin dependent properties.

Another consideration is that winding at 55° is difficult for larger pipe and relatively slow. The carriage speed required for 55° is about four times faster than required for typical custom engineered pipe. When the carriage speeds become high, the mandrel speed and material application speeds have to be reduced. Turn-around-zones on larger pipe are problematic at 55° in terms of band slippage and the large thickness.

In a recent discussion with the chief engineer of UK’s oldest GRP pipe company, the issue of turn-around-zone waste versus wind angle was discussed. Pipe wound at 55° as compared to 65° will result in 4.5% (of the total material weight) extra waste and 25-30% extra winding time. When pipe is wound at high angles, the reduction in waste and improvements in wind time become even more significant.

Corrosion liner

The corrosion liner in commodity pipe is typically fixed and relatively thin as compared to custom pipe.

The corrosion liner of commodity pipe is typically 1.25 mm or less. The corrosion liner of custom pipe is determined by the corrosive environment and is typically 2.5 mm or more.

In some cases commodity pipe has no corrosion barrier at all.

Sizes

Commodity pipe is made in select sizes up to about 48 inch (but normally 36 inch is the limit).

Custom engineered pipe can be made in virtually any size. Pipe 12 ft in diameter is not uncommon.

Resin systems

With some exception, commodity pipe is made with epoxy resin. Epoxy, while having good properties for mechanical strength and for the commodity manufacturing environment, is inferior to vinyl ester in terms of corrosion resistance.

Custom engineered pipe can be made with a wide range of resins, including fire retardant vinyl esters, epoxy vinyl esters, isophthalic polyesters, halogenated polyesters, etc. This allows custom pipe to handle a wide range of chemical services at competitive prices.

Dual resin systems are possible with custom pipe but not possible for commodity pipe. For example, vinyl ester can be used for the corrosion liner and a fire retardant vinyl ester can be used for the structure. This optimizes the performance of the pipe.

Mechanical properties

The best mechanical properties are found in properly engineered custom
Higher design factors result in pipe with greater tolerance of upset conditions and pipe with a longer mechanical service life. Combined with the typically greater liner thicknesses, custom engineered pipe can be expected to have a much longer and more reliable service life.

**Glass dependent versus resin dependent properties**

As has been mentioned, the mechanical properties of centrifugally moulded pipe and 55° filament wound pipe are much more resin dependent than typical custom engineered pipe.

In the case of centrifugally cast pipe, the tensile properties are very resin dependent because the fibres are chopped into relatively short lengths. Resin is a polymer and subject to creep and time-loss of mechanical properties. Also resin properties drop radically with temperature especially near the glass transition temperature.

In the case of 55° filament wound pipe, the mechanical properties are a function of the shear strength and stiffness of the resin. The small angles with respect to the axis create a 'scissor' action between the layers which puts the resin in shear. Like tensile properties, resin shear properties are subject to creep and a loss of strength and stiffness at elevated temperatures.

The properties of well-designed custom pipe are much more glass dependent than resin dependent. Glass fibres are not subject to creep and, for temperatures up to 200°C (the upper limit for GRP pipe), glass fibres do not lose strength or stiffness.

**Support spans**

By custom designing the pipe laminate, superior axial strength and stiffness can be achieved. This can be used to advantage to increase support spans thus reducing costs associated with pipe supports.

Custom engineered pipe can also be designed to be more tolerant of the localized stresses caused by pipe supports.

This can be accomplished by the design of the laminate and by the addition of special reinforcements in support regions.

**Stiffeners**

Stiffeners are often a very cost effective way to handle load conditions which cause the pipe to buckle and collapse. Examples are vacuum loading, soil loading and traffic loading.

Commodity pipe can rarely, if ever, be purchased with stiffeners. However, custom engineered pipe can be designed and fabricated with stiffeners, taking advantage of the cost savings and better performance which can be realized with stiffeners. The stiffener laminate, the stiffener size and the stiffener spacing can all be 'fine tuned' for the most efficient and cost effective design.

**The right choice**

Typically, the only advantages of commodity pipe over custom engineered pipe are cost savings and off-the-shelf availability. In some cases, the cost savings are realized with custom engineered and fabricated pipe.

For mildly corrosive applications where mechanical loading is not severe, commodity pipe is a good choice. However, for corrosion applications where chemical environment, temperature, temperature differential, coefficient of expansion, resin compatibility, available sizes, etc. are important factors, custom engineered and fabricated pipe is the appropriate choice. It is fair to state that other than price and warehouse stock, custom engineered pipe is superior to commodity pipe in virtually every way.

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