

DESIGN OF RPS "AA" SERIES ABSORBER SPRAY PIPING

1. General

Most FRP pressure piping is designed to optimize pressure-retaining capability. This is done by manufacturing the pipe with reinforcing fibers aligned at 55° to the pipe axis. The 55° winding angle results in a hoop strength in the pipe which is twice that of its axial strength. These strengths exactly match the 2:1 hoop stress to axial stress in a cylinder exposed to pressure, thus resulting in an optimum design for pressure.

Absorber spray piping is not normally exposed to high internal pressures, but usually is exposed to significant axial loads resulting from the weight of the pipe and its contents. RPS therefore designs absorber spray piping by addressing this axial load-carrying requirement as the primary requirement.

2. Design Basis

Design pressures in Absorber spray piping vary from system to system but are usually in the range of 15 psi to 25 psi. Theoretically, the piping could be designed for this magnitude of pressure rating, but the resulting wall thicknesses would be inadequate to safely carry other axial loads. RPS's approach has been to design the spray pipes to provide the same axial load-carrying capability as 150 psi filament wound pipe. This approach has proven over the years to yield a robust design at a reasonable cost.

RPS manufactures spray pipes by the contact molding process wherein layers of chopped strand glass and woven roving are applied to a male mold until the desired number of layers have been applied. This manufacturing process is employed as it allows the branch connections between the main headers and spray branches, and between the spray branches and spray nozzle outlets, to be integrally molded with a smooth radius. The branch connections are not stub-in or saddle type branches, so there is no abrupt discontinuity at the junction. The integrally molded branches provide a stronger construction, and most importantly for this type of service, they minimize turbulence, thereby maximizing erosion resistance.

2. Design Basis (cont'd)

The filament winding manufacturing method results in an orthotropic material, with an Ultimate Tensile Strength (UTS) in the hoop direction of 40,000 psi, and a UTS in the axial direction of 20,000 psi. The axial load-carrying capability of the filament wound pipe is the axial UTS of 20,000 psi, multiplied by the cross-sectional area of the pipe wall. For convenience, the load-carrying capability of the pipe is expressed per unit length of circumference. This "unit strength" is equal to the UTS of 20,000 psi multiplied by the pipe thickness.

The contact molding manufacturing method results in an essentially isotropic material with the hoop strength of the pipe being the same as the axial strength. The magnitude of this strength depends upon the proportions of chopped strand glass and woven roving in the laminate. For laminates composed of only chopped strand glass, laminate strength is typically about 16,000 psi. For laminates composed of high proportions of woven roving, laminates strengths can be as high as 24,000 psi.

The spray pipes are designed by ensuring the laminate unit strength of the spray pipe meets or exceeds the axial unit strength of the 150 psi filament wound pipe of the same size.

Example: The structural thickness of a 24" diameter 150 psi filament wound pipe is 0.45". The axial unit strength of this pipe is $20,000 \text{ psi} \times 0.45" = 9,000 \text{ lb/in.}$ The standard design for a 24" diameter spray pipe consists of 7 layers of chopped strand glass and 4 layers of woven roving. This construction will result in a laminate strength of approx. 22,300 psi and a thickness of 0.412", for a unit strength of $22,300 \text{ psi} \times 0.412" = 9,200 \text{ lb/in.}$, i.e. $> 9,000 \text{ lb/in.}$

3. Laminate Properties

Laminate properties, including strength and modulus, will depend upon the proportions of chopped strand glass and woven roving in the laminate. The higher the proportion of woven roving, the higher will be the strength and the modulus. To facilitate analysis of the various combinations of chopped strand and woven roving throughout the pipe size range, the properties are determined by considering the contribution of each individual layer. For example, a layer of chopped strand glass (at 1.5 oz/ft^2) contributes a unit strength of approx. 600 lb/in. (i.e. 16,000 psi UTS, times the per layer thickness of 0.0375"). A layer of woven roving (at 24 oz/yd^2) contributes a unit strength of approx. 1250 lb/in. (i.e. 33,300 psi UTS, times the per layer thickness of 0.0375"). The unit strength of a laminate is determined as the total of all the layers.

3. Laminate Properties (cont'd)

Example: For the 24" diameter spray pipe with 7 layers of chopped strand and 4 layers of woven roving, the total unit strength would be:

$$\text{Laminate unit strength} = 7 \times 600 + 4 \times 1250 = 9200 \text{ lb/in.}$$

The laminate thickness would be:

$$\text{Laminate thickness} = 7 \times 0.0375'' + 4 \times 0.0375'' = 0.412''$$

And the laminate UTS would be:

$$\text{Laminate UTS} = 9200 / 0.412 = 22,300 \text{ psi.}$$

The modulus of the laminate is determined in a similar manner with the values of 1.2E6 psi for the chopped strand glass, 2.5E6 psi for the woven roving, and 1.0E6 psi for the liners. These strength and modulus values are consistent with those predicted using lamination theory, and they have been verified in numerous tensile tests carried out by RPS over many years.

Laminate properties, including thicknesses, for all sizes of spray pipes are listed in the table below. Note: The fracture strain of the erosion-resistant liner is approximately 75% of that for the structural layers. The lower fracture strain has been taken into account in the calculation for the strength of the structural laminate, and the strength values listed have been adjusted accordingly.

4. Allowable Stress and Pressure Rating

The allowable stress for the spray pipes is calculated from the laminate strengths using a Design Factor of 6, and is based upon the structural layers only. No credit to strength is given to the erosion/corrosion-resistant liner. The Design Factor of 6 is in accordance with ASTM D6041 Standard Specification for Contact-Molded "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Corrosion Resistant Pipe and Fittings. The allowable stress varies from 2600 psi to approx. 3400 psi depending upon laminate strength. For convenience, an allowable stress of 3000 psi can be used for all pipe sizes other than 4", for which a value of 2600 psi should be used.

The pressure rating of the spray pipes is a consequence of the design philosophy. It does not drive the design as would be the case in pressure piping. For the RPS standard wall thicknesses, the pressure rating in all pipe sizes is no less than 100 psi based upon the structural wall laminate and the Design Factor of 6.

5. Pipe Stress Analysis

Pipe stress analysis of spray pipes is somewhat special compared with typical pipe stress analyses in that most of the weight supports cannot be assumed to be rigid.

The deflection of the supports (usually beams) should be incorporated in the analysis to permit accurate distribution of the loads within the piping.

As with any analysis of FRP piping, an expansion stress range is not applicable.

The operating stresses (including thermal and other displacement-induced loads) should be compared to the allowable stresses defined in Section 4.

The modulus value for the total laminate (including the internal and external liners) should be used in the analysis to permit accurate distribution of loads within the piping.

A “corrosion” allowance equal to the combined thickness of the internal and external liners should be included in the stress calculations for all load cases.

RPS “AA” Series Spray Pipe Properties *

Nom. Size (in.)	I.D. (in.)	Thickness (in.)			O.D. (in.)	Strength		Modulus (Msi)
		Liner	Structure	Total		(lb/in)	(psi)	
4	4.00	0.110	0.150	0.370	4.74	3050	20333	1.21
6	6.00	0.110	0.150	0.370	6.74	3050	20333	1.21
8	8.00	0.110	0.225	0.445	8.89	4900	21778	1.32
10	10.00	0.110	0.225	0.445	10.89	4900	21778	1.32
12	12.00	0.110	0.263	0.483	12.97	5500	20952	1.31
14	14.00	0.110	0.263	0.483	14.97	5500	20952	1.31
16	16.00	0.110	0.300	0.520	17.04	6750	22500	1.40
18	18.00	0.110	0.300	0.520	19.04	6750	22500	1.40
20	20.00	0.110	0.375	0.595	21.19	8600	22933	1.45
24	24.00	0.110	0.413	0.633	25.27	9200	22303	1.44
30	30.00	0.110	0.488	0.708	31.42	11050	22667	1.48
36	36.00	0.110	0.600	0.820	37.64	13500	22500	1.50
42	42.00	0.110	0.713	0.933	43.87	16600	23298	1.57
48	48.00	0.110	0.788	1.008	50.02	17800	22603	1.54

* The listed thicknesses and O.D.’s apply to RPS’s standard structural wall thicknesses with 0.11” internal and external liners. These are by no means the only thicknesses that can be supplied. Each spray header system is treated as a custom design and in many cases thinner structural walls may be appropriate when the applied loads are low as a result of favorable support conditions. Also, additional local reinforcement can easily be added in areas of high stresses, as can additional liner thickness in areas of potentially higher erosion rates.