

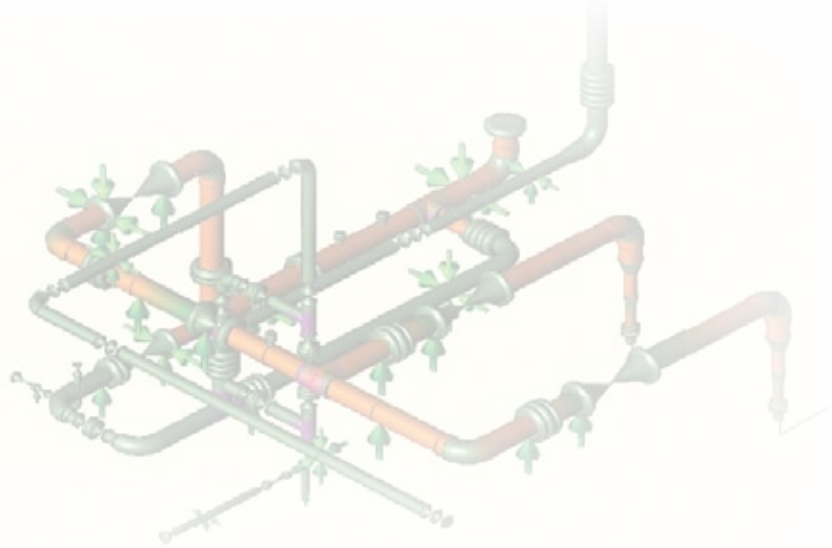


شركة صناعة الأنابيب المحدودة ش.م.م. Composite Pipes Industry L.L.C.

Stress Legend

Code Stress by Percent (%)

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Level 5	> Percent, %	80
	Color	128; 0; 0
Level 4	> Percent, %	60
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Level 3	> Percent, %	40
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Level 2	> Percent, %	20
	Color	255; 128; 0
Level 1		



TECHNICAL BROCHURE ENGINEERING



44 Years Experience

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INTRODUCTION

CPI is a leading manufacturer of Fiberglass Reinforced Plastics (GRP) systems with more than 44 years of experience (15 years in Oman) in supplying piping solutions globally.

Cutting edge technology of filament wound reinforced thermosetting resin piping systems was acquired from the former SEPMA Company of France. CPI supplies a fully engineered piping system with an integrated service such as design, stress analysis, prefabrication of spools, construction and field services. CPI corrosion resistant piping systems are used in a wide range of applications to both above ground and underground installations.

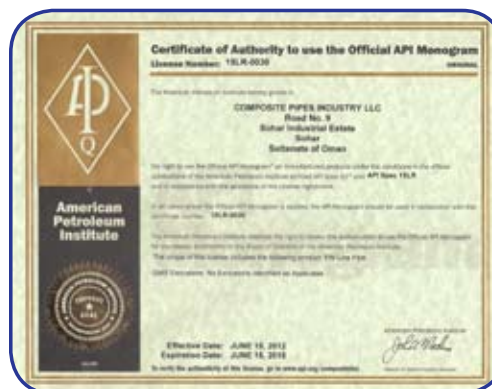
CERTIFICATION & ACCREDITATION

CPI is accredited by

- TUV Nord - ISO 9001 & ISO 14001
- FM 1614
- NSF/ANSI 61
- API 15 HR and API 15 LR

Client Approvals

PDO, BP, Saudi Aramco, KNPC, KOC, EIL and ONGC



PRODUCT FEATURE AND BENEFITS

CPI GRP pipes and fittings are bringing the product which provides low cost, long term piping corrosion solutions and light weight to the customer around the world.

Features	Benefits
<p>Corrosion resistant materials</p>	<ul style="list-style-type: none"> • Long effective Design Life. • No need for cathodic protection. • No need for extra cost for pipe coating, wrapping, lining, painting. • Low maintenance cost. • Hydraulic characteristics remain unchanged over period of time.
<p>Light weight: 1/4th weight of ductile iron and 1/10th of concrete pipe.</p>	<ul style="list-style-type: none"> • Easy to install. No need for expensive handling and installation equipment. • Low delivery cost.
<p>Extremely smooth bore</p>	<ul style="list-style-type: none"> • Less friction loss means less pumping energy needed. • Minimum slime build up can help lower cleaning costs.
<p>Dimensional stability</p>	<ul style="list-style-type: none"> • Pipe can maintain the critical tolerances required of the most demanding structural and piping applications. • The material meets the most stringent material stiffness, dimensional tolerance and weight.
<p>Pipe specifications meet or exceed worldwide standards</p>	<ul style="list-style-type: none"> • Assure high quality product specification.
<p>High technology pipe manufacturing system</p>	<ul style="list-style-type: none"> • Help ensure consistent product quality.

PRODUCT APPLICATION

GRP pipe is used in many industries, including:

- Chemical processes
- Desalination
- Ducting and vent piping
- Geothermal
- Industrial effluents
- Irrigation
- Oil and gas fields
- Potable water
- Power plant cooling and raw water
- Sanitary sewers
- Seawater intake and outfalls
- Slurry piping
- Storm sewers
- Water distribution, and
- Water transmission.

Typical applications services for the use of GRP pipe include:

Boiler feed water
Cooling water
Potable water
Drains
Water/oil mixtures
Glycol

Condensate (water & gas)
Brackish water
Process water
Sewer
Flow lines
Fresh water

Sea water
Produced water
Sour water
Hydrocarbon drains
Water injections
Fire water

APPLICABLE STANDARDS

Many organizations have published nationally recognized standards, test methods, specifications, and recommended practices on fiberglass piping systems and products.

These organizations include Shell Group, the American Society for Testing and Materials (ASTM), the American Petroleum Institute (API), the American Society of Mechanical Engineers (ASME), the American National Standards Institute (ANSI), and the International Organization for Standardization (ISO).

Following is a listing of fiberglass pipe standards and specifications that are commonly used in specifying, testing, and using fiberglass piping systems.

ISO14692 – 1: Vocabulary, symbols, applications and materials
(Petroleum and natural gas industries-Glass-Reinforced Plastics (GRP) piping)

ISO14692 – 2: Qualification and manufacture
(Petroleum and natural gas industries-Glass-Reinforced Plastics (GRP) piping)

ISO14692 – 3: System design
(Petroleum and natural gas industries-Glass-Reinforced Plastics (GRP) piping)

ISO14692 – 4: Fabrication, Installation and Operation
(Petroleum and natural gas industries-Glass-Reinforced Plastics (GRP) piping)

AWWA M45: Fiberglass Pipe Design

AWWA C950: Fiberglass Pressure Pipe

DEP31.40.10.19 Gen: Fiberglass reinforced plastic pipeline and piping systems

API 15LR: Specification for low pressure fiberglass line pipe

API 15HR: Specification for high pressure fiberglass line pressure

ASME B31.8: Gas transmission and distribution piping systems
(ASME code for pressure piping, B31)

ASME B31.3: Process piping (ASME code for pressure piping, B31)

ASME B16.5: Pipe flanges and flanged fittings NPS ½ through NPS 24 metric/inch standard

ASTM D696: Standard test method for coefficient of linear Thermal expansion of plastics between 30°C

ASTM D1598: Standard Test Method for Time to Failure of Plastic Pipe Under Constant Internal Pressure

ASTM D1599: Standard Test Method for Resistance to Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing and Fittings

ASTM D2105: Standard Test Method for Longitudinal Tensile Properties of “Fiberglass” (Fiberglass Reinforced Thermosetting-Resin) Pipe and Tube

ASTM D2412: Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading

ASTM D2924: Standard Test Method for External Pressure Resistance of “Fiberglass” (Fiberglass Reinforced Thermosetting-Resin) Pipe

ASTM D2925: Standard Test Method for Beam Deflection of “Fiberglass” (Fiberglass Reinforced Thermosetting-Resin) Pipe under Full Bore Flow

ASTM D2992: Standard Practice for Obtaining Hydrostatic or Pressure Design Basis for “Fiberglass” (Fiberglass Reinforced Thermosetting-Resin) Pipe and Fittings

ASTM D2996: Standard Specification for Filament-Wound “Fiberglass” (Fiberglass Reinforced Thermosetting-Resin) Pipe

ASTM D3567: Standard Practice for Determining Dimensions of “Fiberglass” (Fiberglass Reinforced Thermosetting-Resin) Pipe and Fittings

ASTM D3681: Standard Test Method for Chemical Resistance of “Fiberglass” (Fiberglass Reinforced Thermosetting-Resin) Pipe in a Deflected Condition

ASTM D4024: Standard Specification for Machine Made “Fiberglass” (Fiberglass Reinforced Thermosetting-Resin) Flanges (Applicable for 1/2 in. through 24 in).

ASTM D5365: Standard Test Method for Long-Term Ring-Bending Strain of “Fiberglass” (Fiberglass Reinforced Thermosetting-Resin) Pipe.

MATERIAL

General

The material selection process shall ensure that the material is compatible with the service fluids to which it is exposed over the full design temperature range so that the mechanical, physical and chemical properties of the GRP satisfies the design requirements throughout the intended lifetime. CPI shall provide the details of the raw materials and resin systems intended to be used for the project during the technical bid stage for the company review and acceptance. Fiberglass pipe is a composite material system produced from fiberglass reinforcements, thermosetting plastic resins, and additives. By selecting the right combination and amount of materials and the specific manufacturing process, CPI can create a product to meet the most demanding requirements.

The Material System

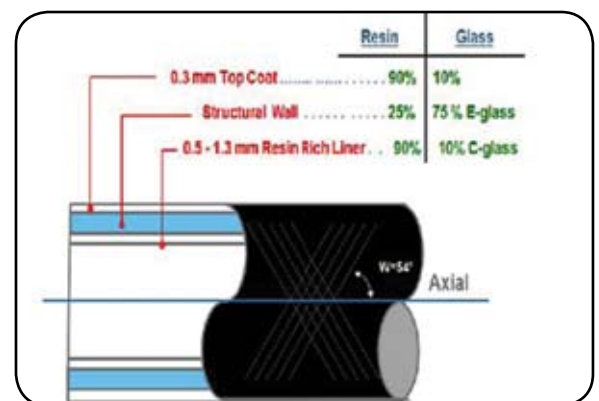
The principal reinforcement material of the component wall shall be fiberglass, e.g. continuous E-Glass and/or woven rovings. Fiberglass composites consist of fiberglass reinforcements, thermosetting resins and additives, which are designed and processed to meet specific functional performance criteria. The following is a list of raw material used in describing the material system.

Fiberglass reinforcement

The amount, type, location and orientation of fiberglass in the pipe that will provide the required mechanical strength. The fiberglass most commonly used in pipe are referred to as Types E, ECR, and C. Glass types ECR and C provide improved acid and chemical resistance. Type C fiberglass are generally only used to reinforce chemical-resistant liners.

Resins

The second major component of fiberglass pipe is the resin system. Manufacturers choose a resin system for chemical, mechanical and thermal properties and process ability. Fiberglass pipe, by definition, uses only thermosetting resin systems. Thermosets are polymeric resin systems cured by heat or chemical additives. Once cured, a thermoset is essentially infusible (cannot be remelted) and insoluble. The temperature range of different resins is shown in table.



TEMPERATURE LIMITATIONS FOR GRP

Type GRP	Design Temperature	Typical Tg value of fully cured resin
Fiberglass/epoxy (GRE)		
Aromatic-amine cured	100°C	130°C
Cyclo-aliphatic cured	100°C	130°C
Aliphatic-amine cured	85°C	115°C
Anhydride cured	85°C	115°C
Fiberglass/vinyl ester (GRV)		
Bisphenol A	90°C	120°C
Novolac	100°C	140°C
Fiberglass/polyester (GRP)		
Isophthalic	60°C	90°C

Epoxy Resin

Epoxy resins are used to a wide range of moderately strong acids and alkalis, conveying water, condensates, hydrocarbons and caustics. Fiberglass epoxy piping is used in oil fields at pressures up to several thousand per square inch (kilopascals). Epoxy resins cannot be categorized by resin type as easily as polyesters. The type of curing agent or hardener, is critical with epoxy resins because the agent influences the composite properties and performance.

For optimum chemical resistance, these mixtures usually require a heat cure and/or post cure. The cured resin has good chemical resistance, particularly in alkaline environments, and can have good temperature resistance. There are several types of base epoxy resins and associated curing agents. Curing agents typically used for epoxy resin are: • Cyclo aliphatic amine • Aliphatic amine • Aromatic amine • Anhydride.

Polyester Resin

Polyester resins are commonly used to produce large-diameter water and sewage piping. Polyesters have excellent water and chemical resistance and are noted for acid resistance. Polyester resins are cured by organic peroxide catalysts. The type and amount of catalyst will influence gel time, cure time, curing temperature and the degree of cure. Isophthalic polyester resin is typically used. Isophthalic polyester is a relatively low cost resin with limited chemical resistance.

Vinyl ester Resin

Compared to polyester, vinyl ester resin has very good chemical resistance, especially against acids, high temperature and chemical resistant vinyl ester based resins, e.g. Novolac vinyl ester, are also available.

Chemical resistance of GRP material

Fluid Type	GRE Aliphatic	GRE Aromatic	GRE Anhydride	GRV Vinyl ester	GRP Polyester
Acids	X	X	X	✓	X
Alkalis (Caustic)	✓	✓	X	✓	X
Solvents (BTX)	✓	✓	X	X	X
Water	✓	✓	✓	✓	✓
Sea/Brackish					

PRODUCT DESIGN

General

Pipeline and piping systems shall be designed so that mechanical integrity is maintained under all coincident loading conditions and process temperatures to which these systems can be exposed, and shall represent the most severe anticipated conditions experienced during installation and within the service life of the system.

GRP pipe systems are more sensitive to mechanical overloading, surge and water hammer effects than steel systems. This requires special care when designing GRP pipe systems.

CPI designer are actively involved throughout the entire project from start to finish, including late installation changes, system hydro testing and up to commissioning.

Jointing System

CPI is offering various types of bonded and mechanical joints for GRP piping system. These tend to be proprietary in nature but can generally be categorized into the following types:

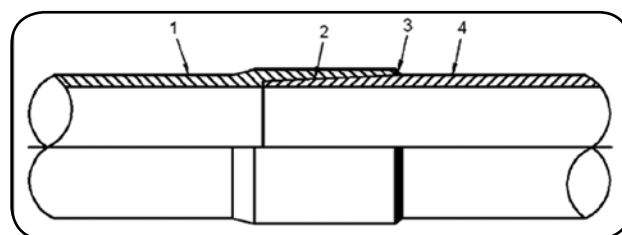
- Adhesive-bonded joints, (conical bell & spigot)
- Laminated joints (butt & wrap joint)
- Mechanical O-ring bell-and-spigot elastomeric seal joints (key – lock joint)
- Flanged joints
- Threaded joints
- Metallic/GRP interfaces.

Adhesive-bonded joints

The adhesive-bonded joint is a rigid type of joint, which consists of a slightly conical (tapered) bell end and a machined tapered spigot end. Adhesive joints have the lowest material cost of all joints and are structurally efficient when made up correctly. Make-up of the adhesive joint tends to become more difficult for larger sizes, particularly for pipe above 600 mm diameter. CPI recommend to use adhesive bonded joint up to 600 diameter and up to 65 bar design pressure.

Key

- pipe with integral socket end
- adhesive
- finishing fillet
- pipe with spigot end



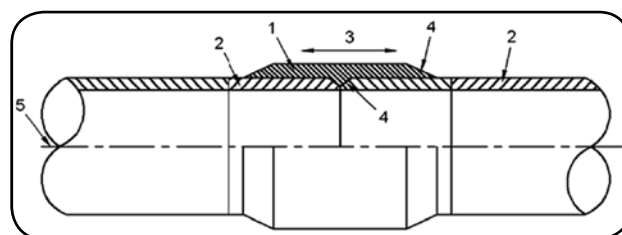
Typical adhesive-bonded joint

Laminated joints

The laminated joint consists of plain-ended pipe and fittings, prepared, aligned and laminated with reinforcing fibers and resin/hardener mixture as shown in Figure.

Key

- laminates overlay, 2 pipe laminate
- laminates length, 4 tapers not steeper than 1 in 6
- pipe centre line



Typical laminated joint

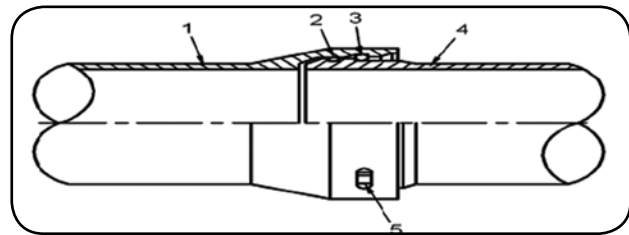
Mechanical O-ring elastomeric bell-and-spigot seal lock joints (Key-lock joint)

Elastomeric bell-and-spigot seal lock joints are made up of a spigot end and a socket end with O sealing rings. The socket will be an integrated part of the pipe. If a tensile-resistant joint is required, a locking strip can be incorporated as shown in Figure.

These are the simplest joints to assemble and they can be designed to enable a small amount of axial and angular movement within the joint. They are cheaper and generally structurally more efficiently than flanged joints, but more expensive than adhesive joints. They are bulkier than adhesive joints, but have the advantage that they can be quickly assembled in poor working conditions and are the preferred joint for concrete gravity-base system piping and ballast transfer piping in ships.

Key

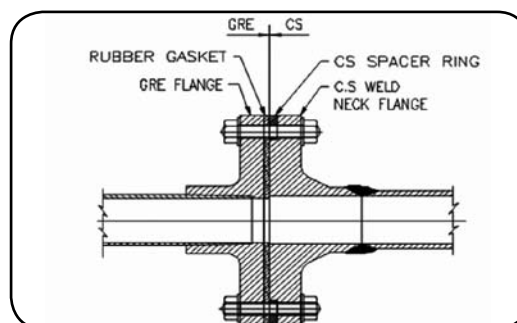
- 1 pipe with integral socket end
- 2 elastomeric ring
- 3 locking strip
- 4 pipe with spigot end
- 5 insert hole for locking strip



Typical elastomeric bell-and-spigot sealed joints (locking type)

Flanged joints

Flanged joints facilitate connections with steel piping and allow easy assembly and disassembly of piping systems. The outside diameter and hole spacing of flanges should meet the requirements of ASME B16.5/ASME B16.47. GRP flanges are always flat-faced and, accordingly, matching flanges should also be flat-faced in order to avoid the crack.



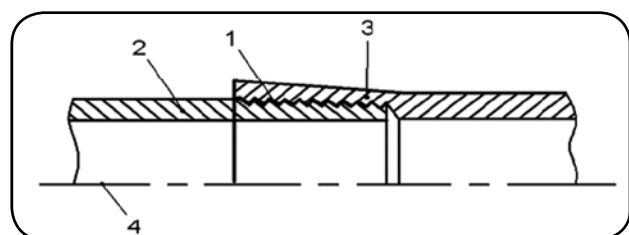
Typical Sketch of GRE Flange to CS Flange Connection using Gasket & Spacer Ring

Threaded connections

Thread joints are normally use for high pressure piping systems. Threaded end connections which conform to API standards should meet the requirements of API 15HR. Threaded end connections which are the design of the manufacturer should meet the specification. CPI recommend to use threaded joints for high design pressure (more than 70 bars).

Key

- 1 standard API threads
- 2 pipe body – male end
- 3 pipe body – female end
- 4 pipe center line



Threaded joint

Hydraulic Design

The aim of hydraulic design is to ensure that GRP piping systems are capable of transporting the specified fluid at the specified rate, pressure and temperature throughout their intended service life. The selection of nominal pipe diameter depends on the internal diameter required to attain the necessary fluid flow consistent with the fluid and hydraulic characteristics of the system. Fluid velocity, density of fluid, interior surface roughness of pipes and fittings, length of pipes, inside diameter of pipes, as well as resistance from valves and fittings shall be taken into account when estimating pressure losses. The smooth surface of the GRP may result in lower pressure losses compared to metal pipe.

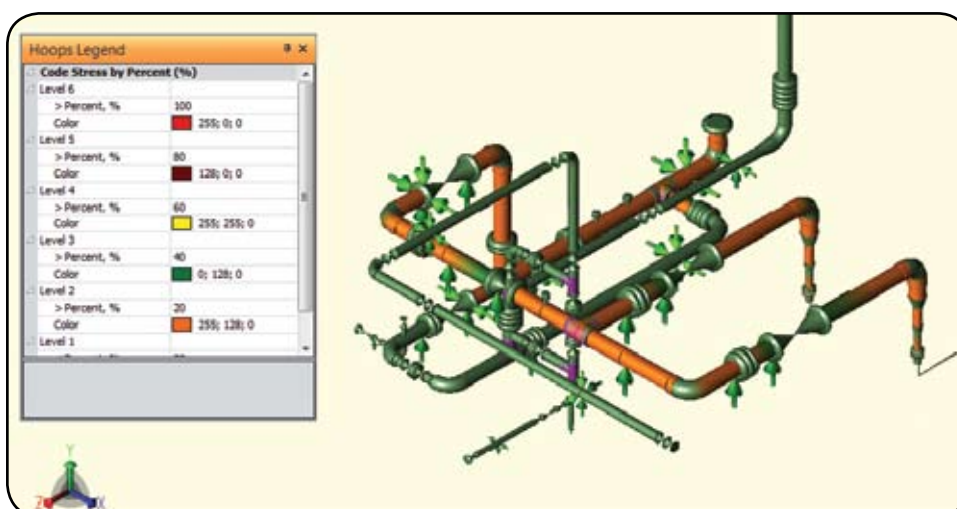


For typical GRP installations, the mean linear velocity for continuous service of liquids is shown in table:

Fluid Type	Normal Flow m/s	Maximum Intermittent Flow m/s
Liquid	1-5	10
Gas	1-10	20

System Design General

The aim of system design for GRP piping systems is to ensure that they shall perform satisfactorily and sustain all stresses and deformations during construction/installation throughout their service life. This clause identifies the service design criteria and the loads to which GRP may be subjected. In order to provide sufficient robustness during handling and installation, minimum reinforced wall thickness of any GRP pipe component shall not be less than 3mm. Minimum reinforced wall thickness of pipe is calculated based on Hoop stress or stiffness requirement and by using ISO 14692 loading conditions.

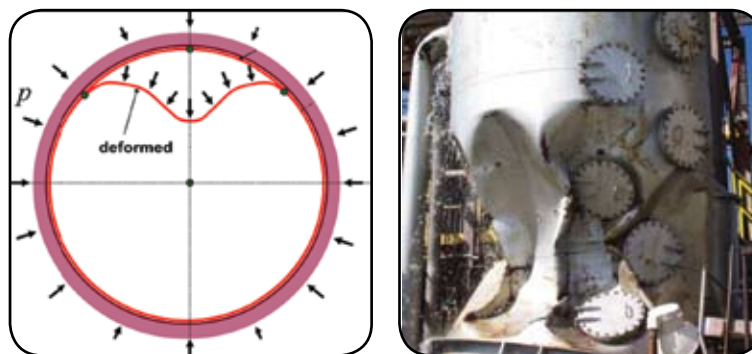


Design of Above ground Pipe



For above ground design, calculated wall thickness shall be checked for below loading conditions.

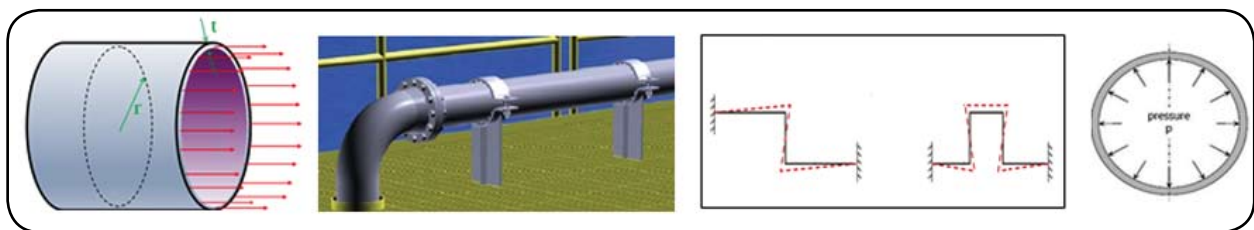
(i) External pressure/vacuum



Pipe and fittings shall have sufficient stiffness to resist vacuum and/or external pressure loads. The design engineer shall ensure where possible, that vacuum conditions can be sustained by the selected component.

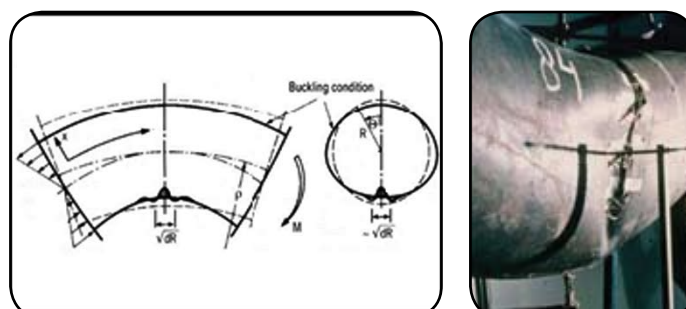
(ii) Axial Stress

Total axial stresses due to Internal Pressure, Self-mass and thermal Expansion are in compressive in nature then selected Pipe structural wall thickness needs to satisfy Shell and Euler buckling conditions as below.

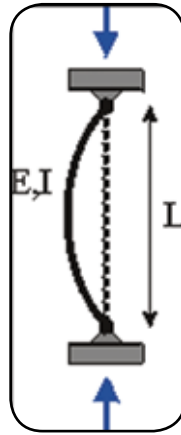


(iii) Shell buckling

The axial elastic buckling stress for a cylinder in pure bending. The ratio of the buckling stress to the maximum axial stress shall be greater than 3.



(iv) Euler buckling



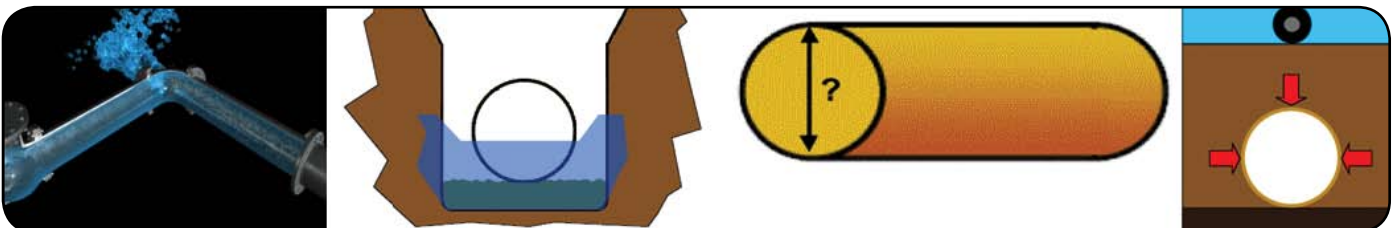
The ratio of buckling stress (due to constrained thermal expansion or vertical pipe runs with end compressive loads and a given length of unsupported pipe) to maximum axial stress shall be greater than 3.

Design of Underground Pipe

Structural design of GRE not only involves establishing design conditions, selecting Pipe classes and corresponding Pipe properties also requires selecting Installation Parameters. It needs to withstand Soil as well as traffic loads as defined in AWWA M45.

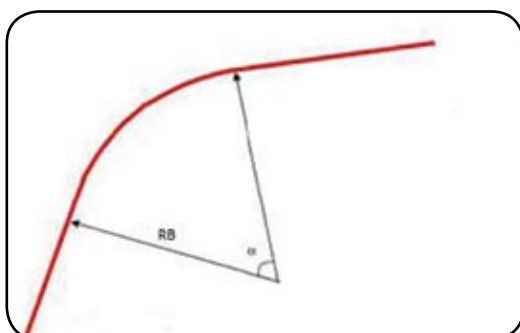
Under Ground Design Procedure involves following steps:

- Calculating Pressure class, checking working and surge Pressure
- Calculating allowable deflection from ring bending
- Checking deflection prediction ($\Delta y/D$)
- Checking buckling
- Buoyancy Calculations



Elastic Bending Radius

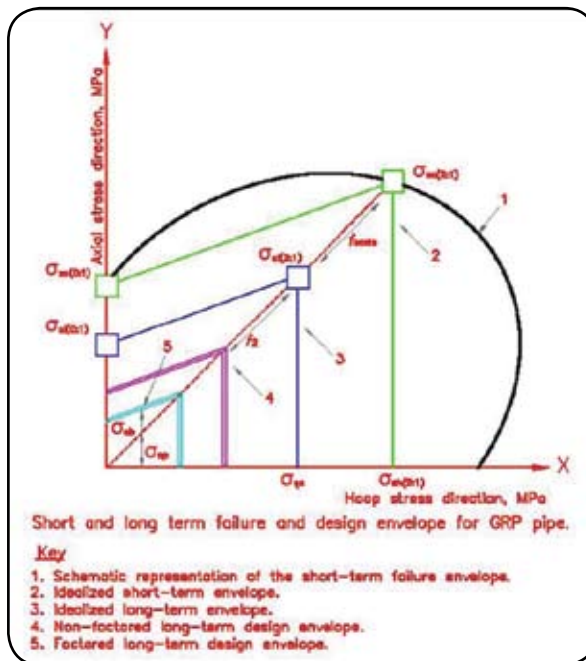
Since GRP pipes are more flexible than steel pipe so, elastic bending radius of GRP pipe are very critical during installation. A careful calculation is required as per standards which reduces bends required for pipeline and it can accommodate any movements in trench profile.



Design Envelope

With Isotropic materials (properties of a material are identical in all direction) such as steel, the effect of combined stresses (pressure and non-pressure induced) are greatly simplified as hoop and axial strength are identical. This result gives a significant margin in allowable strength to accommodate this extra axial stress as the pressure induced. Axial stress (load) is exactly one half of hoop stress. Whereas, for anisotropic material (properties of a material are different in all direction) such as filament wound GRP pipes, hoop and axial strength are significantly different. Axial stress is not exactly half of hoop stress. Therefore hoop strength is significantly greater than the axial strength.

If the effective hoop and axial stresses, σ_{heff} , and σ_{aeff} , lie inside the factored long-term design envelope, then the GRP pipes and fittings designed within the acceptable limits. If the stresses lie outside this envelope, then high-rated GRP pipes and fittings, i.e. a thicker walled pipes and fittings shall be chosen and repeat the same stress calculation until it lies within the acceptable limits of factored long-term design envelope.



Thrust Block Design

Unbalanced thrust forces occur in pressure pipelines at changes in direction (i.e., elbows, wyes, tees, etc.), at changes in cross-sectional area (i.e., reducers), or at pipeline terminations (i.e., bulkheads). These forces, if not adequately restrained, may cause pipeline movement resulting in separated joints and/or pipe damage.

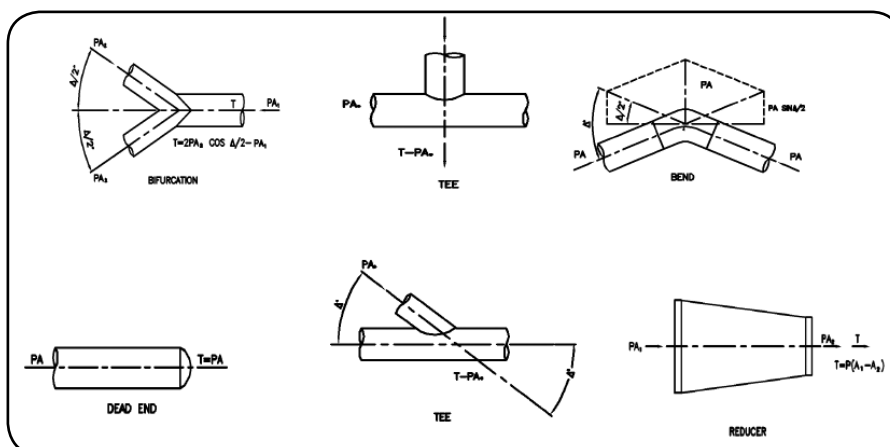
Thrust forces are:

- (1) hydrostatic thrust due to internal pressure of the pipeline and
- (2) hydro-dynamic thrust due to changing momentum of flowing fluid.

Since most pressure lines operate at relatively low velocities, the hydrodynamic force is very small and is usually ignored.

Typical examples of hydrostatic thrust are shown in below Figure. The thrust in dead ends, tees, laterals, and reducers is a function of internal pressure P and cross-sectional area A at the pipe joint.

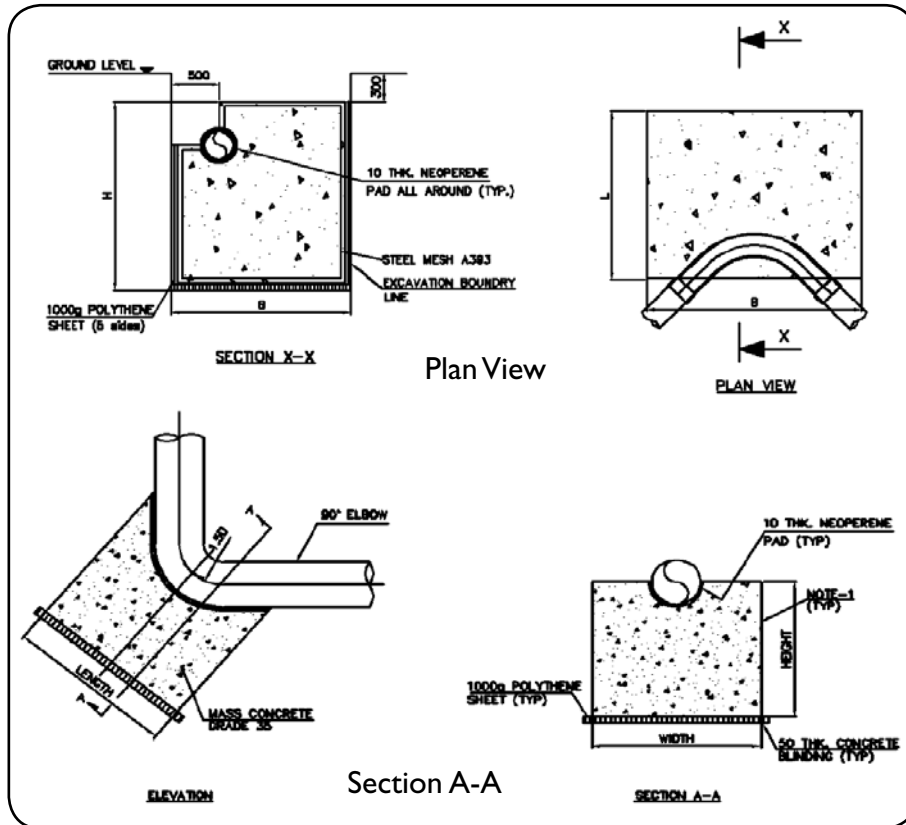
Thrust Force Definitions



Thrust Block

Concrete thrust blocks increase the ability of fittings to resist movement by increasing the bearing area and the dead weight of the fitting. Typical thrust blocking of a horizontal bend (elbow) and vertical bend (elbow) is shown in Figure:

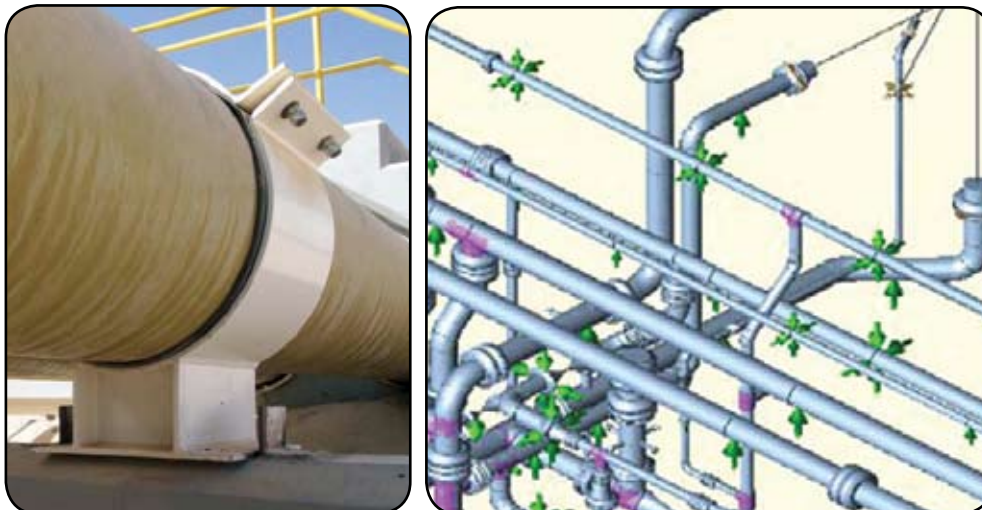
Thrust block of a bend



Support Design

GRP piping systems can be supported using the same principles as those for metallic piping systems.

However, due to the proprietary nature of piping systems, standard-size supports will not necessarily match the pipe outside diameters. The use of elastomeric pads may allow the use of standard-size supports.



The following requirements and recommendations apply to the use of system supports.

- a) Supports shall be spaced to avoid sag (excessive displacement over time) and/or excessive vibration for the design life of the piping system.
- b) In all cases, support design should be in accordance with the CPI guidelines. CPI will provide the support design for above ground pipe system.
- c) Valves or other heavy attached equipment shall be independently supported.
- d) GRP piping should be adequately supported to ensure that the attachment of hoses at locations such as utility or loading stations does not result in the pipe being pulled in a manner that could overstress material.

Guidance for span lengths

Pipe nominal diameter mm	Span m
25	2.0
40	2.4
50	2.6
80	2.9
100	3.1
150	3.5
200	3.7
250	4.0
300	4.2
350	4.8
400	4.8
450	4.8
500	5.5
600 \geq	6.0

Above mentioned span length table is only for reference. However CPI design engineers will recommend the span distance and type of support after performing the stress analysis and will provide the design of support drawing accordingly.

Type of Pipe supports can be categorized into those that permit movement and those that anchor the pipe.

MECHANICAL PROPERTIES

Mechanical and physical properties of CPI GRE product has conducted as per ASTM and other related testing standard. Mechanical properties of CPI GRE items are as per below table.

Mechanical Properties

Sr. No.	Property	Ref. Standard	Value
1.	Hydrostatic Design Basis (HDB)	ASTM D 2992	132 MPa
2.	Axial Tensile Strength	ASTM D 2105	51 MPa
3.	Axial Tensile Elastic Modulus	ASTM D 2105	12117 MPa
4.	Poisson's Ratio for an Axial Tensile Load and resulting axial expansion	ASTM D 2105	0.41
5.	Axial Bending Modulus	ASTM D 2105	12000 MPa
6.	Hoop Tensile Modulus	API 15HR Appendix D	23609 MPa
7.	Poisson's Ratio for Hoop's tensile load and resulting axial expansion	API 15HR Appendix D	0.6
8.	Thermal co-efficient of expansion in axial direction	ASTM D 696	18×10^{-6} mm / mm ^{°C}
9.	Thermal conductivity of Component	ASTM C 177	0.244 W/mk
10.	Hoop Bending Modulus (Ring Flexural modulus of elasticity)	ASTM D 2412	12531 Mpa
11.	Long term ring bending strain	ASTM D 2992	2%

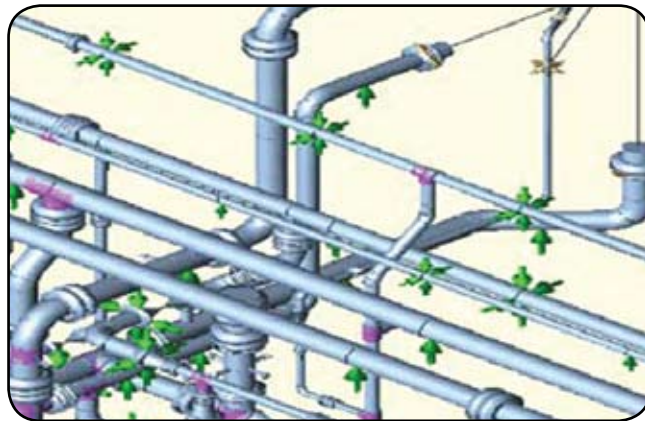
Physical properties

Property	Ref. Standard		
Coefficient of linear thermal expansion	ASTM D 696	18×10^{-6}	mm/mm.°C
Thermal conductivity		0.244	W/mK
Specific heat		921	J/Kg. K
Barcol hardness		40	
Surface resistance	ASTM D 2583	10×10^6	m
Density	ASTM D 792	1.905	g/cc

CPI PRODUCT RANGE

CPI Recommended Product Range

Inside Diameter (mm)	Design Pressure (bar)	Pipe Laying Length (m)	Type of Joint
15	65	2	Adhesive
20	65	2	
25	65	2	
40	65	2	
50	65	6	
80	65	6	
100	65	9	
150	65	9	
200	65	12	
250	65	12	
300	50	12	
350	50	12	
400	50	12	
450	40	12	
500	40	12	
600	40	12	
700	25	9	Lamination
800	25	9	
900	20	9	
1000	20	9	
1100	18	9	
1200	10	9	
1400	10	9	
50	120	6	Threaded
80	120	6	
100	120	9	
150	100	9	
200	100	9	
100	25	9	Key lock
150	25	9	
200	25	12	
250	20	12	
300	20	12	



www.cpioman.com



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