

Fiberglass Pipe Product Guide

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THOMPSON[™]
PIPE GROUP

ABOUT THOMPSON PIPE GROUP AND TPG FRPM



Since 1987 Thompson Pipe Group has supplied engineered products to customers throughout North America. Founded by a contractor the company designs and manufactures a full range of products for drainage/sewer, pressure and trenchless applications.

Thompson Pipe Group Fiberglass Reinforced Polymer Mortar (TPG FRPM) products provide corrosion-resistant solutions. The FRPM division of this family-owned company is the exclusive North American provider of Flowtite® fiberglass pipe. Additionally, this family-owned U.S. based company offers non-round rehabilitation fiberglass products in a broad range of sizes, stiffness and pressure classes.

Thompson Pipe Group offers technical support, project management and field services to assist owners, engineer and contractors with turn-key solutions in water, wastewater, rehabilitation and trenchless markets.

TPG FRPM products are lightweight, long-lasting, and inherently corrosion resistant. Diameters range from 12" to 156" and are produced in pressure classes up to 450 psi. Available joint systems include jacking, slipline, pressure coupling, and the key-lock restrained joint. TPG FRPM is a reliable, cost-effective solution for municipal, industrial and hydropower applications.

TPG FRPM BENEFITS AT A GLANCE



RELIABILITY

All of our products are produced in a controlled environment and rigorously tested. From concrete to steel to FRPM we know how to engineer, manufacture and support water and waste water projects.

LOW TOTAL COST

Owners save money on pipe, pumping, maintenance, delivery, and installation. Fiberglass products are lightweight and do not require cathodic protection. Pipe lengths can be adjusted based on project needs.

SUSTAINABILITY

FRPM products have an estimated lifetime 150 years or more.

DELIVERY

Since 1971, FRPM products have revolutionized the global water and wastewater pipe industry. FRPM pipes are lighter and designed with specific lengths based on project requirements.

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FRPM PIPES FOR YOUR EVERY NEED

TYPE/USE	PICTURE	DESCRIPTION
<p>PRESSURE</p> <p>FRPM pipes produced with main reinforcement in the hoop direction. Used in applications without pressure end thrust, for example penstocks and pressure mains.</p>		<ul style="list-style-type: none">▶ Diameter range (DN): 12 - 156 in▶ Pressure (PN): up to 450 psi▶ Standard lengths: 10 - 40 ft▶ Stiffness (SN): 18, 36, 46 and 72 psi
<p>BIAXIAL PIPES</p> <p>FRPM pipe reinforced in the hoop and axial directions resists pressure end thrust and bending loads. Common uses are cooling water and desalination and similar above ground applications.</p>		<ul style="list-style-type: none">▶ Diameter range (DN): 12 - 156 in▶ Pressure (PN): Up to 250 psi▶ Lengths: 10 - 40 ft▶ Stiffness (SN): 18, 36, 46 and 72 psi
<p>JACKING PIPES</p> <p>FRPM designed to withstand high jacking forces. Typically used for jacking under structures like roads and railways.</p>		<ul style="list-style-type: none">▶ Diameter range (DN): 12 - 84 in▶ Pressure (PN): Gravity▶ Standard lengths: 10 - 40 ft▶ Stiffness (SN): 200+ psi

FRPM PROPERTIES

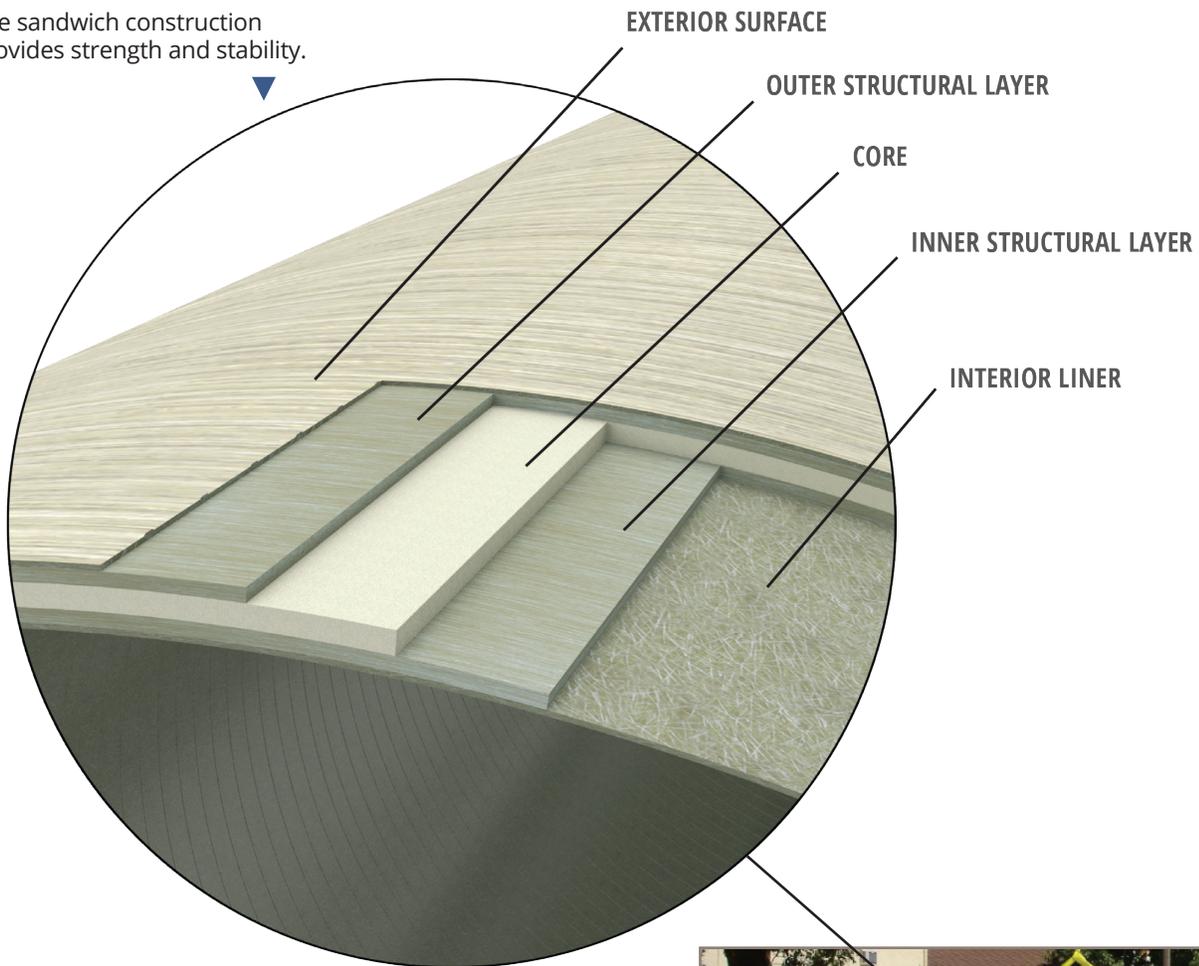
TECHNICAL DATA FRPM PIPES	
Main materials	Resin, fiberglass, sand
Operating temperatures	-58°F - +158°F
Standard lengths	10 - 40 ft
Diameter range	DN 12 - DN 156 in
Pressure range	PN 50 - PN 450 psi
Estimated lifetime	More than 150 years
Corrosion protection	None needed
Hydraulic roughness	$k = 9.5 \times 10^{-5} \text{ ft}$ / $C = 150$ (Hazen-Williams)/ $n=0.009$ (Manning)
Assessment of conformity	CEN TS 14632



PIPE WALL CONSTRUCTION

The pipe wall is built as a structural sandwich, using the continuous filament winding technology. The high strength continuous glass fibers resist the hoop stresses from internal pressure, while the chopped fibers provide excellent resistance to axial stresses, impact and handling loads. The structural laminate consists of heavily reinforced skins, separated by a compact, reinforced silica-filled core to provide optimal bending stiffness. Together with the protective layers, this construction provides capacity to resist high internal pressures and maintains excellent long-term stiffness.

The sandwich construction provides strength and stability.





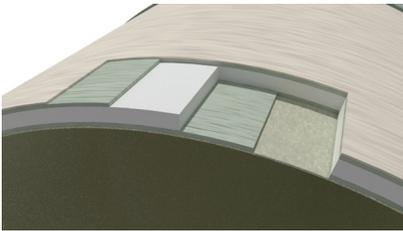
STANDARD STIFFNESS CLASSES

Pressure and sewer pipes are manufactured in four standard stiffness classes.

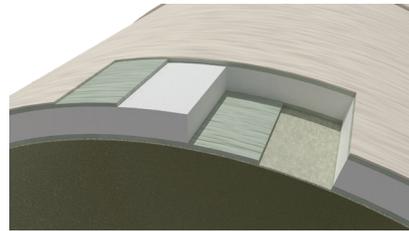
STANDARD PRESSURE RANGE

Pipes are manufactured in pressure classes ranging from PN 50 to PN 450.

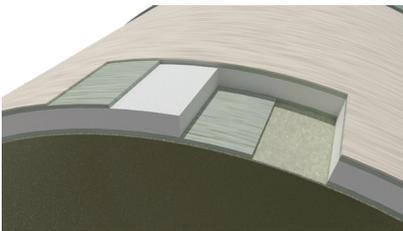
SN 18



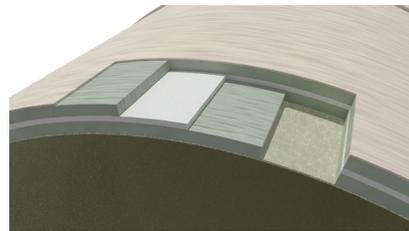
PN 50



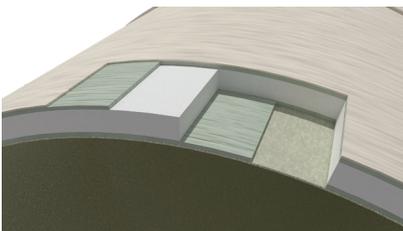
SN 36



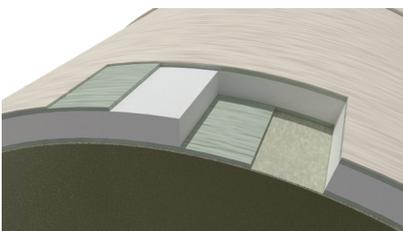
PN 450



SN 46



SN 72



POISSON'S RATIO

- Poisson's ratio is influenced by the pipe construction. For FRPM pipes the ratio for hoop (circumferential) loads and axial response ranges from 0.22" to 0.29."

THERMAL COEFFICIENT

- The thermal coefficient of axial expansion and contraction for FRPM pipes is 13 to 17x10⁻⁶ in/in/°F.

WHY ENGINEERS CHOOSE TPG FRPM PRODUCTS



NO CORROSION

FRPM products do not require coating or anti-corrosion treatment and are manufactured with inherently corrosion resistant materials, outperforming steel, ductile iron and steel-reinforced pipes that require corrosion protection.

UV RESISTANCE

FRPM pipes are resistant to UV light. For pipes installed above ground, the outside surface might change color, but this has no impact on the long-term performance of the pipes.

FRPM pipes have extraordinary acid and chemical resistance. The unique resistance is ensured by careful consideration of all materials, pipe designs and waters in desalination plants. FRPM pipes resist sulfuric acid in sewers, actions of ground salts and salty waters in desalination plants. FRPM pipes may also be used in other chemically demanding applications. See the chemical resistance table in the technical data section (page 36).

LIGHT WEIGHT

FRPM pipes are lighter than ductile iron, steel, concrete and non-reinforced plastic pipes. Transportation is less expensive. These lightweight pipes can be transported and handled in remote and inaccessible areas. For traditional installations FRPM pipes are often nested, smaller pipes are inserted into larger pipes; nesting reduces transportation costs. Additionally, installation requires less-expensive equipment.

COUPLINGS AND JOINTS

MORE THAN SIX MILLION FRPM DOUBLE BELL COUPLINGS ARE IN SERVICE WORLDWIDE.

The majority of buried FRPM pipelines are assembled with the trusted Double Bell Coupling. Since 1979, these couplings have been used on all continents.



The expected lifetime of these couplings is more than 150 years. The Double Bell Coupling is a preferred couple for FRPM installations and is available in three different versions:

- ▶ **Pressure**
- ▶ **Biaxial lock joint**
- ▶ **Angled coupling**

TECHNICAL DATA FRPM DOUBLE BELL COUPLING

Operating pressure: Up to 450 psi*

Main materials: Resin, fiberglass, sand

Estimated lifetime: More than 150 years

External waterhead: 462 ft

Operating temperature: 58°F, - + 158° years

Estimated gasket lifetime: More than 150 years

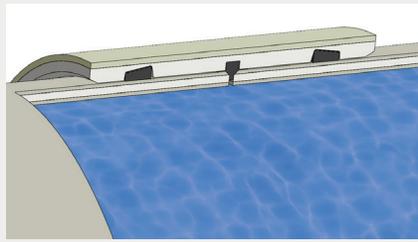
Gasket: EPDM, Reka

*The coupling has been tested successfully to 1400 psi

DOUBLE BELL COUPLINGS

PRESSURE COUPLING

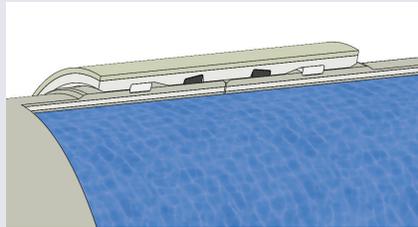
Commonly used for penstocks, water supply, irrigation and pressure sewer applications.



- Diameter range (DN) : 12 - 156 in
- Pressure (PN): up to 450 psi

BIAXIAL LOCK JOINT

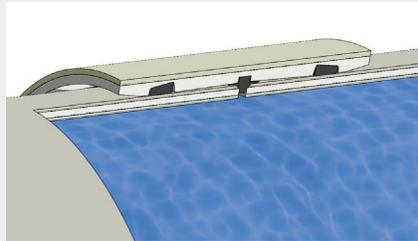
Used for applications where transfer of load between pipes is required. Commonly used on desalination and cooling applications.



- Diameter range (DN): 12 - 78 in
- Pressure (PN): 50 - 250 psi

ANGLED COUPLING

FRPM coupling for increased angular deflections up to 3 degrees.

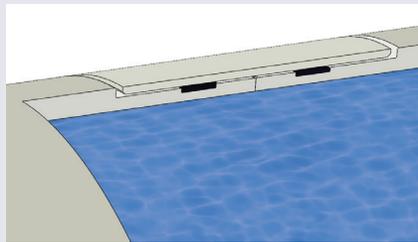


- Diameter range (DN): up to 156 in
- Pressure (PN): up to 250 psi

JACKING AND SLIPLINE JOINTS

GR JOINT

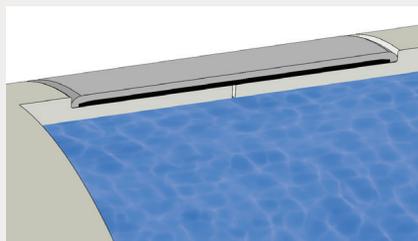
This joint is used for jacking and sliplining applications and includes an FRP sleeve with EPDM rubber seals fitted into grooves in the pipe spigot.



- Diameter range (DN) : 12 - 96 in
- Pressure (PN): up to 100 psi

SE JOINT

This joint is used for jacking and sliplining applications and includes a Gr.316 stainless steel band with an integral EPDM elastomeric seal.



- Diameter range (DN) : 12 - 96 in
- Pressure (PN): up to 150 psi

PATENTED BUTT WRAPS

Patented butt-wrap joints install quickly and are cost efficient. FRPM pipes may be jointed with fiberglass reinforcement and resin. Butt-wrap joints are common in applications with axial thrust.



FLANGES

TPG produces flanges in various designs, standards and requirements. When connecting FRPM flanges, the standard bolt pattern is ANSI B16.5/ AWWA C207. Other bolting dimension systems including ISO, DIN, and JIS can be supplied.



Steel flanges connected to FRPM flanges.

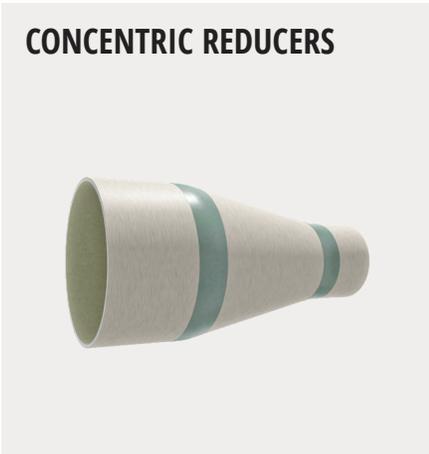
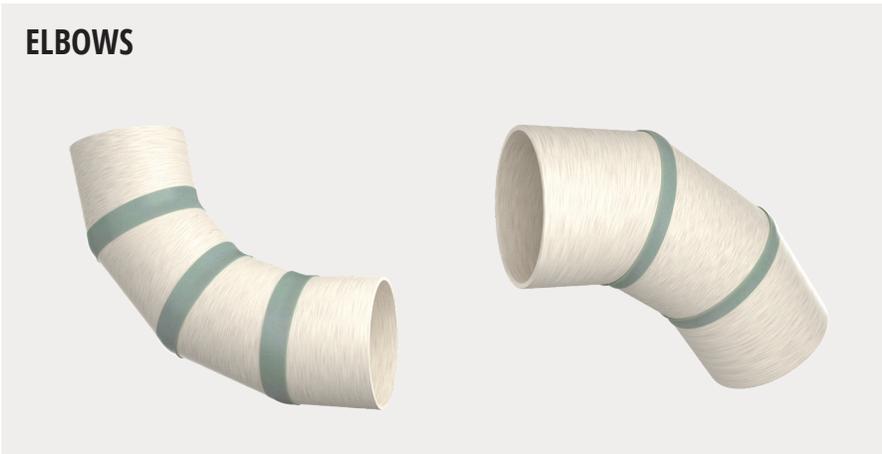
USING STEEL COUPLINGS TO JOIN FRPM PIPES



Our FRPM pipes can be joined using steel couplings. Examples of steel couplings are the tangential bolt couplings of Straub, Tee-Jay and Arpol, and the axial bolt couplings Viking Johnson, Heiden, Klamflex, Romac and Smith-Blair.

COMMON FITTINGS

Fittings are designed based on an extensive research program and patented concepts. Researchers have analyzed critical strains in bends, tees and elbows. Fittings are molded or fabricated using the same materials in fiberglass pipes.



CONSIDERATIONS FOR THE ENGINEER



FLOW CALCULATIONS

The most economical flow velocity in pipes is usually 6-10 ft/s. This is the case for FRPM pipes. The maximum recommended flow velocity is 16 ft/s. FRPM pipelines sustain velocities of up to 25 ft/s if the water is clean and contains no abrasive material.



Due to the larger inner diameter the headloss in FRPM pipes is less than most other pipe materials.

SURGE AND WATER HAMMER

The most important factors influencing the water hammer pressure in a pipe system are the stiffness of the pipe in the hoop direction, the change in velocity of the fluid, the rate of change of the velocity (valve closing time), compressibility of the fluid, and physical layout of the pipe system. The maximum water hammer pressure expected for FRPM pipes is approximately 50% of that for steel and ductile iron pipes in similar conditions.

$$\Delta H = \frac{w \cdot \Delta V}{g}$$

Where:

ΔH = change in pressure ft

w = surge wave celerity (ft/s)

ΔV = change in water velocity $\left(\frac{\text{ft}}{\text{s}}\right)$

g = acceleration due to gravity (ft/s²)

ANGULAR DEFLECTION ON JOINTS

The maximum angular deflection (turn) at each coupling joint, taking the combined vertical and horizontal deflection into consideration, and measured as the change in adjacent pipe center lines, shall not exceed 3 degrees. The pipes shall be joined in straight alignment and thereafter deflected angularly as required.

The table is valid for angled coupling up to PN 250. For all other joints, contact your Thompson Pipe Group representative.

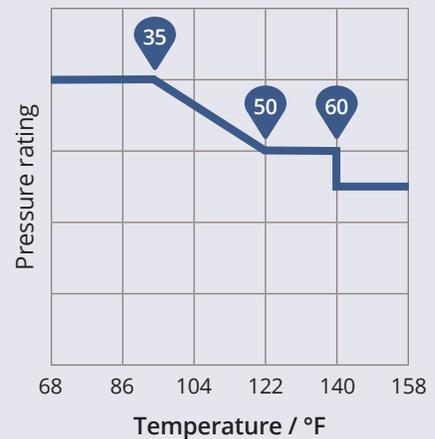


Minimum Radius of Curvature

Angle of Deflection	Pipe Length		
	10 ft	20 ft	40 ft
3	190 ft	383 ft	763 ft

OPERATING TEMPERATURE

FRPM pipes may be used with operating temperatures between -58° and 105° F. Requirements in the international pipe standards require a consideration for pressure rerating above 95° F. At temperatures above 122° F, vinyl ester resins are often recommended. FRPM pipes may be used up to operating temperatures of 158° F with appropriate consideration to pipe design, materials usage and gasket materials.



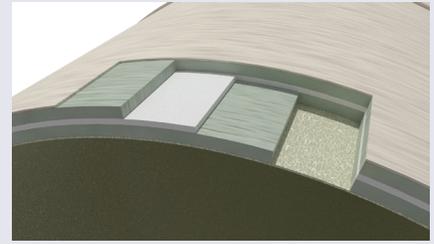
TRAFFIC LOADS

All backfill to grade should be compacted when continuous traffic loads are present. Minimum cover restrictions may be reduced with special installations such as concrete encasement, concrete cover slabs or casings.



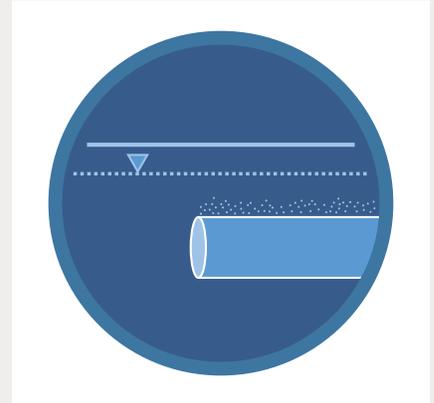
NEGATIVE PRESSURE (VACUUM)

Negative pressure, or vacuum, may occur in pipelines. In this case a stiffer FRPM pipe is recommended where high negative pressure is expected.



HIGH GROUND WATER TABLE

A minimum of .75 times the diameter of earth cover with minimum dry soil bulk density of 120 lb/ft³ is required to prevent an empty submerged pipe from floating. Alternatively, the installation may proceed by anchoring the pipes.



HIGH PRESSURE

High pressure (>250 psi) may require a deeper bury to prevent uplift and movement. The minimum burial should be 4 ft for pipes DN 12 and larger.



CHEMICAL EXPOSURE

Standard FRPM pipes sustain excellent properties in contact with clean and dirty water, including sea water. However, re-rating and material selection must be considered if the pipe is to be used in contact with chemicals, process water or contaminated ground waters, with and without elevated operating and design temperatures. Special pipe design options are available for most chemicals, including process water from pulp and paper.



INSTALLATION

**LIGHT AND LESS EXPENSIVE EQUIPMENT
CAN BE USED INSTALLING TPG FRPM PIPES.**



Installation of buried flexible pipes takes advantage of the pipe and soil properties for optimal performance in terms of time and cost. The design and installation procedures are based on guidelines in international standards.

The resulting installation procedures do not require any special considerations, just good contractor practice and workmanship, to ensure excellent long-term performance of the pipeline.

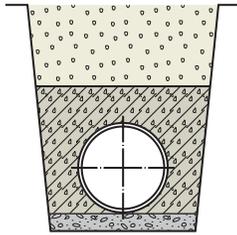
BURIED INSTALLATION

Below is a partial review of installation procedures. More information can be found in our TPG FRPM Installation Guide.

Two installation types are most common: Type 1 for deep burials or heavy traffic loads, and type 2 for less demanding installations, where less expensive backfill materials can be used.

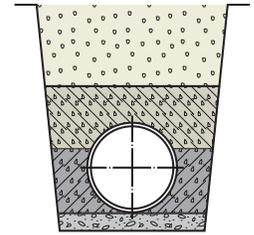
INSTALLATION TYPE 1

- ▶ Backfill the pipe zone to 12 in over the pipe crown with the specified backfill material compacted to the required relative composition level.



INSTALLATION TYPE 2

- ▶ Backfill to 60% of pipe diameter with the specified backfill material compacted to the required relative compaction level.
- ▶ Backfill from 60% of diameter to 12 in over the pipe crown with a relative compaction necessary to achieve a minimum soil modulus 200 psi.



INSTALLATION KEY POINTS

BEDDING

The trench bed should provide a uniform and continuous support for the pipe. Most granular soils are suited as bedding. The bed must be over-excavated at each joint location to ensure continuous support for the pipe.

BACKFILLING

For optimum pipe-soil interaction the prescribed backfill material for the installation type must be used. Care should be taken to ensure that the material does not include rocks, soil clumps, debris, frozen or other organic material.

CHECKING THE INSTALLED PIPE

After the installation of each pipe the maximum diametrical vertical deflection shall be checked. Installation is fast and easy. For typical installations the initial deflection will be 1 – 2%, and should be compared with the predicted value. The maximum allowable initial deflection is 3% and the maximum allowable long-term deflection is 5%.

RESTRAINED JOINT INSTALLATIONS

Thrust-bearing pipe systems carry the fluid pressure and are able to transfer longitudinal forces or bending moments resulting from end thrust. Both the pipe and the joints have axial load-bearing capacity. Unbalanced thrust can thereby be resisted by the piping system and thrust blocks are not necessary; correct location of support will ensure that the axial stress is under allowable limits. Thrust-bearing piping systems require a detailed three-dimensional structural analysis. The piping engineer uses specialized computer

software to determine all stresses and displacements, as well as support forces. Due to the inherent flexibility of FRPM pipes, the force on components is usually considerably lower than in steel installations.



ABOVE GROUND INSTALLATIONS

Pipes are installed on supports or cradles and fastened with straps to ensure stability. The supports are usually concrete or steel; the fastening straps are made of steel. Non-thrust bearing pipes systems carry fluid pressure, but are not designed to transfer thrust forces and therefore require thrust blocks or other supports to resist unbalanced thrust.

JACKING AND SLIPLINING INSTALLATIONS



With their high strength, FRPM pipes are well suited for sliplining and jacking. In sliplining applications, the pipe can be jointed outside the existing pipe, culvert or borehole and pushed in. Alternatively, the pipes can be brought in pipe by pipe, and jointed inside. Low flows can be permitted during installation.



FRPM pipe design for jacking and microtunneling takes advantage of non-corrodible materials. The smooth external surface and water repellency gives low friction during jacking.



SUBAQUEOUS INSTALLATIONS

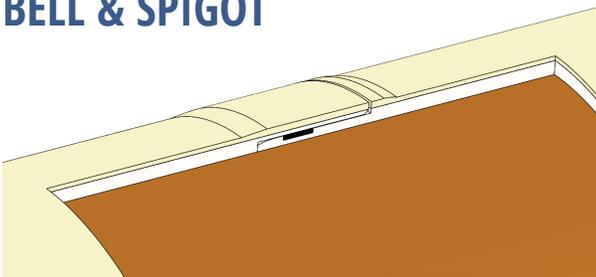
FRPM pipes are excellent for subaqueous installations. Dimensions up to 13 ft in diameter are common in this application. FRPM pipes do not float.

NON-ROUND FRP



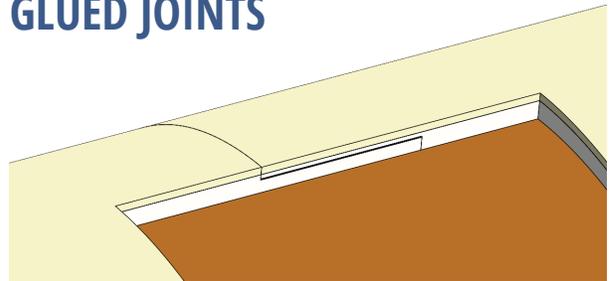
JOINTING SYSTEMS

BELL & SPIGOT



Pipes are joined with the use of a bell and spigot connection with an installed elastomeric gasket.

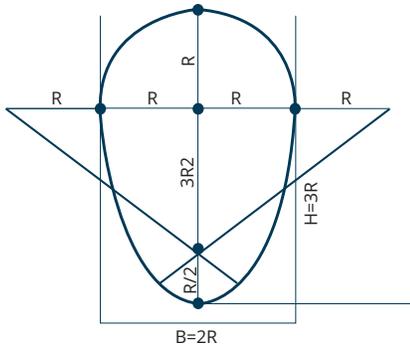
GLUED JOINTS



Depending on the project requirements and installation conditions, where the use of the elastomeric gasket is not applicable, the glued joints are commonly preferred.

PIPE SHAPES

EGG SHAPE



Nominal Length:

Up to 9.8 ft

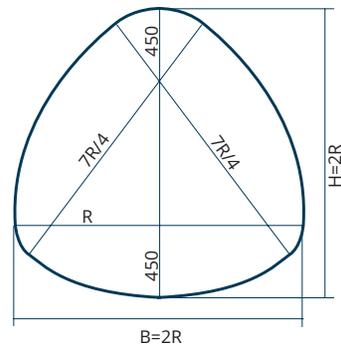
Nominal Height (H):

Up to 156 inch

Nominal Breadth (B):

Up to 156 inch

MOUTH SHAPE



Nominal Length:

Up to 9.8 ft

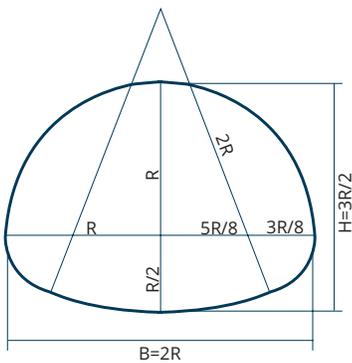
Nominal Height (H):

Up to 156 inch

Nominal Breadth (B):

Up to 156 inch

ARCH SHAPE



Nominal Length:

Up to 9.8 ft

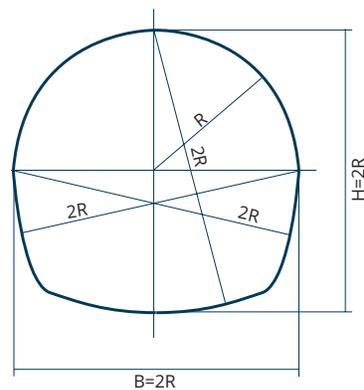
Nominal Height (H):

Up to 156 inch

Nominal Breadth (B):

Up to 156 inch

HORSESHOE SHAPE



Nominal Length:

Up to 9.8 ft

Nominal Height (H):

Up to 156 inch

Nominal Breadth (B):

Up to 156 inch

CUSTOMIZED SHAPE

Apart from the commonly used ones as mentioned above, Thompson Pipe Group can also produce other profiles on request with dry weather channel or extraordinary profile shapes.

MATERIAL EFFICIENCY

An independent study conducted at the Norwegian University of Life Sciences in 2012 concludes that FRPM pipes have minimal negative impact compared to other pipe materials. The main reason is for the material efficiency.

RECYCLABLE

Fiberglass pipes are recyclable. The Federation of Reinforced Plastics in Germany recommends that FRPM pipes may be used in cement production.



TRANSPORTATION EFFICIENCY

TPG FRPM pipes can be nested during transportation, which means lower carbon emissions from pipe transportation.

LOW ENERGY PRODUCTION

TPG FRPM pipes can be nested during transportation, which means lower carbon emissions from pipe transportation.

EXCELLENT HYDRAULICS

The smooth bore and good flow characteristics of TPG FRPM pipes reduce the amount of energy used for pumping, in penstocks, it increased the energy outtake.



A third-party verified lifecycle assessment has been conducted on TPG FRPM pipes according to ISO 14040. The information may be provided upon request.

PERFORMANCE STANDARDS



ALL PIPES ARE SUBJECT TO CONTROL CHECKS:

- ▶ Visual inspection
- ▶ Barcol hardness
- ▶ Wall thickness
- ▶ Section length
- ▶ Diameter
- ▶ Hydropstatic leak tightness test to twice the rated pressure for all pressure pipes

CONTROL CHECKS PERFORMED ON SAMPLES:

- ▶ Pipe stiffness
- ▶ Deflection without damage or structural failure
- ▶ Axial and circumferential tensile load capacity
- ▶ Material composition analysis

ISO CERTIFICATION

Thompson Pipe Group's aim is offer the highest quality product as well as meet the needs of our customers with a strong focus customer satisfaction. As part of this goal, our FRPM products or offered from ISO 9001 manufacturing facilities to ensure consistent quality of products that we provide.

FLOWTITE PIPE HAS BEEN RIGOROUSLY TESTED TO VERIFY CONFORMANCE TO THE FOLLOWING INTERNATIONAL PERFORMANCE STANDARDS:

STANDARD	PURPOSE
AWWA C950	Water supply
AWWA M45	Design manual
ISO 10639	Water supply
ISO 10467	Sewer and drainage
EN 1796	Water supply
EN 14364	Sewer and drainage
ASTM D3262	Sewer
ASTM D3517	Water supply
ASTM D3754	Pressure sewer

QUALIFICATION TESTS

STRAIN CORROSION TESTING

To develop the world's best sewer pipes, engineers have continuously subjected FRPM pipes to strain corrosion tests since 1978. Sewer pipes are exposed to sulfuric acid, which causes corrosion and eventually sewer leakage. ASTM D3681 therefore demands that pipes are chemically tested while under strain. FRPM pipes with extreme chemical resistance are the result of decades of continuous testing.



◀ Strain corrosion testing is done in accordance with ASTM D3681. This standard requires a minimum of 18 ring samples of the pipe to be deflected to various levels and held constant.

HYDROSTATIC DESIGN BASIS

Since the 1970's, engineers have performed hydrostatic design testing (HDB) on FRPM pipe. These tests have enabled reliable pipes for penstocks, drinking water and other pressure applications.

HDB testing verifies a pipe can perform at 1.8 times the rated pressure during its certified lifetime.



◀ HDB tests are completed in accordance with ASTM D2992 Procedure B. The standard requires hydrostatic pressure testing of many pipe samples for failure (leakage) at a variety of high constant pressure levels.

LONG-TERM RING BENDING

FRPM pipes are designed to tolerate loads from traffic, landfills and buildings. To ensure long term sustainability, TPG FRPM pipes are rigorously tested under AWWA C950 and ASTM D565. After AWWA C950 tests are complete, the resulting 50-year predicted value is used in the pipe design. TPG FRPM pipes are tested under the ASTM D565 long-term ring bending strain of fiberglass pipe and meets both requirements.



JOINT TESTING

TPG FRPM has an extensive testing program to verify that couplings will remain sealed and perform consistently under severe conditions. Joint prototypes for elastomeric gasket-sealed couplings are in accordance with ASTM D4161. This standard incorporates some of the most stringent joint performance requirements in the piping industry for pipe of any material within the pressure and size ranges of TPG FRPM. ASTM D4161 requires these flexible joints to withstand hydrostatic testing in configurations that simulate very severe in-use conditions. The pressures used are twice those rated. Joint configurations include straight alignment, maximum angular rotation and differential shear loading. A partial vacuum test and cyclical pressure tests are included.



ABRASION RESISTANCE

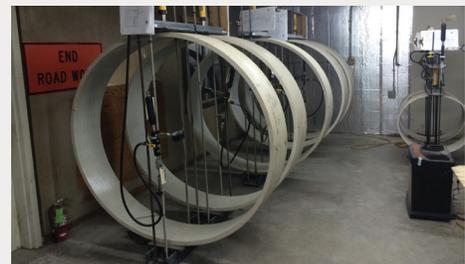
FRPM pipes are in penstocks and other applications where substances such as gravel impact the inner surface of the pipe. While there is no widely standardized testing procedure or ranking method, TPG FRPM abrasion resistance has been evaluated using the Darmstadt Rocker method. Using gravel obtained from the same source as that used at Darmstadt University, the average abrasion loss of TPG FRPM pipe is 0.013 inches per 10,000 cycles. More abrasion resistance liners are available. Please contact your TPG representative for more information.



▲ A section of water-filled pipe with gravel trapped inside is continuously rocked.

LONG-TERM STIFFNESS

The long-term stiffness of TPG FRPM pipes is considerably higher than most other plastic pipes. Creep tests according to ISO 10468 lasting more than 10,000 hours, have demonstrated a 50-year stiffness between 60% and 75% of the initial.



TECHNICAL DATA

The numbers in these tables are approximate, nominal values, and are subject to change without notice. For current, accurate values, please contact your Thompson Pipe Group business development manager.

STIFFNESS CLASS 18

18 PSI		ID MIN (INCHES)									WEIGHT SPAN U.S. Pound/Feet	
DN	DOS max	PN 50	PN 100	PN 150	PN 200	PN 250	PN 300	PN 350	PN 400	PN 450	from	to
12	13.19	12.75	12.75	12.76	12.81	12.81	12.85	12.83	12.81	12.78	5	6
14	15.33	14.84	14.84	14.85	14.91	14.91	14.95	14.93	14.91	14.88	7	9
16	17.40	16.86	16.86	16.88	16.94	16.94	16.98	16.97	16.94	16.90	8	11
18	19.49	18.89	18.90	18.93	18.99	18.99	19.03	19.02	18.98	18.94	11	14
20	21.61	20.96	20.98	21.01	21.07	21.07	21.11	21.11	21.07	21.02	13	17
24	25.79	25.02	25.06	25.09	25.16	25.17	25.21	25.20	25.15	25.09	18	26
30	32.01	31.10	31.14	31.19	31.26	31.28	31.31	31.31	31.24	31.14	28	39
36	38.31	37.26	37.30	37.36	37.44	37.46	37.50	37.50	37.38	37.26	39	55
42	44.49	43.29	43.34	43.41	43.51	43.52	43.57	43.56	43.44	43.31	53	73
48	50.79	49.45	49.50	49.59	49.69	49.70	49.75	49.74	49.59	49.44	69	95
54	57.56	56.07	56.11	56.22	56.33	56.35	56.40	56.40	56.27	56.11	87	121
60	61.61	60.03	60.08	60.20	60.31	60.33	60.38	60.36	60.18	60.00	101	138
63	64.45	62.80	62.85	62.98	63.09	63.11	63.16	63.13	62.98	62.79	111	151
66	68.46	66.72	66.78	66.92	67.03	67.06	67.10	67.09	66.96	66.77	124	170
72	72.48	70.65	70.70	70.85	70.97	71.00	71.04	70.98	70.83	70.63	140	190
75	76.50	74.56	74.63	74.79	74.91	74.94	74.98	74.96			155	212
78	80.51	78.49	78.56	78.72	78.85	78.88	78.93	78.93			169	234
81	84.53	82.42	82.49	82.66	82.79	82.82	82.87	82.87			186	257
84	88.54	86.34	86.41	86.60	86.73	86.76	86.81	86.81			203	282
90	92.56	90.26	90.34	90.53	90.67	90.70	90.75	90.75			222	308
96	96.57	94.19	94.26	94.47	94.61	94.65	94.69	94.70			242	334
99	100.59	98.11	98.20	98.41	98.55	98.59	98.64				266	362
102	104.61	102.04	102.12	102.34	102.49	102.53	102.58				287	391
108	112.64	109.89	109.97	110.21	110.37	110.41	110.46				332	452
120	120.67	117.73	117.82	118.09	118.25	118.29	118.35				381	518
120	120.67	117.73	117.82	118.09	118.25	118.29	118.35				381	518
126	128.70	125.58	125.96	126.13							459	609
132	136.73	133.43	133.53	133.83	134.01						516	688
138	140.75	137.35	137.46	137.77							658	728
144	144.76	141.28	141.39	141.70							696	768
150	152.80	149.13	149.24	149.57							774	855
156	160.83	156.98	157.09	157.44							857	948

STIFFNESS CLASS 36

36 PSI		ID MIN (INCHES)									WEIGHT SPAN U.S. Pound/Feet	
DN	DOS max	PN 50	PN 100	PN 150	PN 200	PN 250	PN 300	PN 350	PN 400	PN 450	from	to
12	13.19	12.67	12.67	12.68	12.74	12.74	12.79	12.79	12.78	12.78	6	8
14	15.33	14.74	14.74	14.76	14.83	14.83	14.88	14.87	14.87	14.87	8	11
16	17.40	16.74	16.74	16.78	16.84	16.85	16.89	16.90	16.90	16.90	10	14
18	19.49	18.76	18.76	18.81	18.88	18.89	18.93	18.93	18.94	18.93	13	18
20	21.61	20.82	20.82	20.87	20.95	20.96	21.01	21.01	21.01	21.01	16	22
24	25.79	24.88	24.88	24.94	25.02	25.04	25.08	25.09	25.09	25.09	23	31
30	32.01	30.91	30.91	30.98	31.08	31.11	31.16	31.16	31.17	31.14	35	48
36	38.31	37.03	37.03	37.12	37.22	37.26	37.31	37.31	37.32	37.26	49	68
42	44.49	43.04	43.04	43.13	43.26	43.29	43.35	43.35	43.35	43.31	66	90
48	50.79	49.16	49.16	49.26	49.40	49.44	49.50	49.50	49.51	49.44	86	117
54	57.56	55.72	55.72	55.86	56.00	56.05	56.11	56.12	56.12	56.11	110	151
60	61.61	59.66	59.66	59.81	59.96	60.01	60.07	60.08	60.09	60.00	125	172
63	64.45	62.42	62.42	62.57	62.72	62.77	62.84	62.85	62.85	62.79	137	188
66	68.46	66.32	66.32	66.47	66.64	66.69	66.76	66.77	66.78	66.77	153	211
72	72.48	70.22	70.22	70.39	70.56	70.61	70.68	70.69	70.70	70.63	172	237
75	76.50	74.12	74.12	74.29	74.47	74.53	74.60	74.62			196	263
78	80.51	78.02	78.02	78.20	78.39	78.45	78.52	78.54			217	290
81	84.53	81.92	81.92	82.11	82.30	82.37	82.44	82.46			238	320
84	88.54	85.82	85.82	86.02	86.22	86.29	86.37	86.39			261	350
90	92.56	89.72	89.72	89.93	90.14	90.21	90.29	90.31			286	382
96	96.57	93.63	93.63	93.84	94.06	94.13	94.21	94.23			310	415
99	100.59	97.53	97.53	97.75	97.97	98.05	98.13				343	450
102	104.61	101.43	101.43	101.66	101.89	101.97	102.06				371	486
108	112.64	109.23	109.23	109.48	109.72	109.81	109.90				429	563
120	120.67	117.03	117.03	117.30	117.55	117.65	117.74				493	645
126	128.70	124.83	124.83	125.11	125.39						605	759
132	136.73	132.64	132.64	132.93	133.72						682	856
138	140.75	136.54	136.54	136.85							851	907
144	144.76	140.44	140.44	140.76							900	958
150	152.80	148.24	148.24	148.57							1002	1067

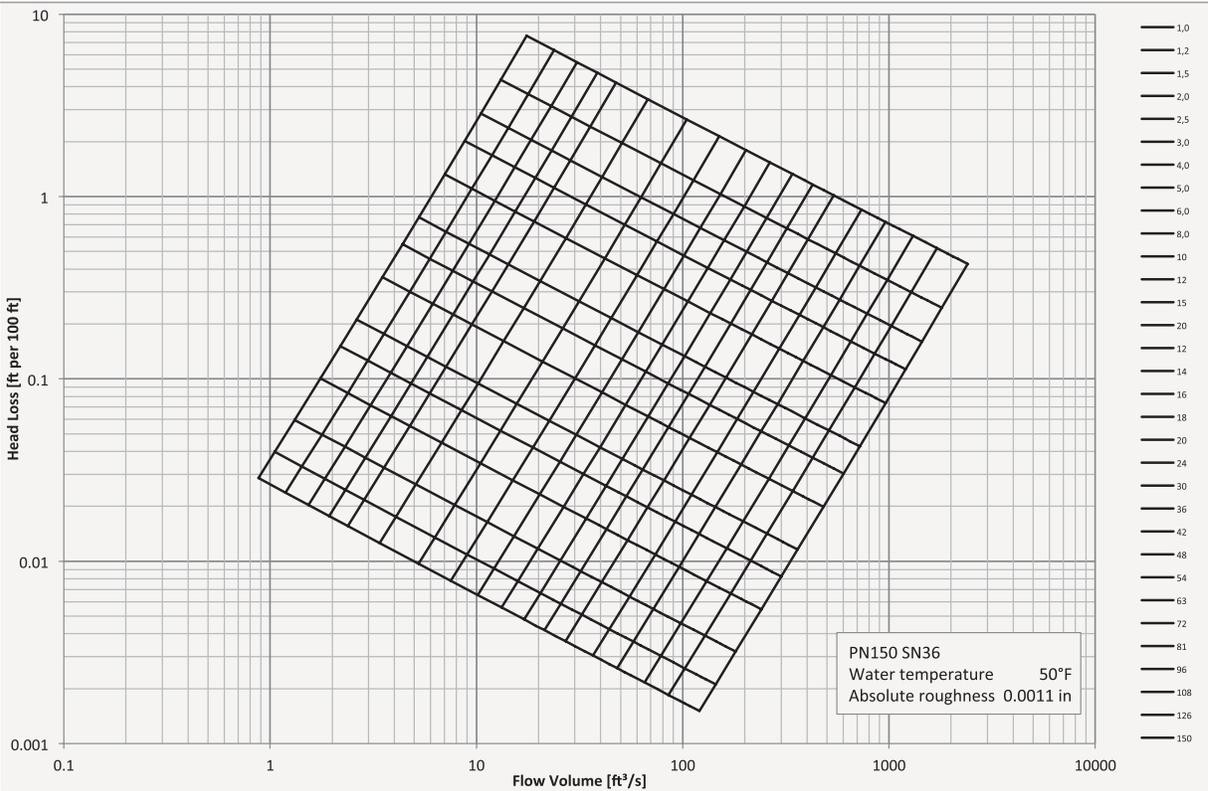
STIFFNESS CLASS 46

46 PSI		ID MIN (INCHES)									WEIGHT SPAN U.S. Pound/Feet	
DN	DOS max	PN 50	PN 100	PN 150	PN 200	PN 250	PN 300	PN 350	PN 400	PN 450	from	to
12	13.19	12.63	12.63	12.64	12.70	12.71	12.76	12.76	12.76	12.76	6	9
14	15.33	14.70	14.70	14.72	14.79	14.80	14.84	14.84	14.84	14.85	9	12
16	17.40	16.70	16.70	16.73	16.80	16.81	16.85	16.86	16.86	16.86	11	15
18	19.49	18.71	18.71	18.75	18.83	18.84	18.89	18.89	18.90	18.90	14	20
20	21.61	20.77	20.77	20.81	20.90	20.91	20.96	20.96	20.97	20.97	17	24
24	25.79	24.81	24.81	24.87	24.95	24.98	25.03	25.03	25.04	25.04	24	34
30	32.01	30.84	30.84	30.91	31.00	31.03	31.09	31.09	31.10	31.10	37	51
36	38.31	36.94	36.94	37.00	37.13	37.17	37.22	37.24	37.24	37.24	53	73
42	44.49	42.93	42.93	43.01	43.14	43.19	43.25	43.26	43.27	43.27	71	97
48	50.79	49.03	49.03	49.12	49.27	49.32	49.39	49.40	49.41	49.41	92	127
54	57.56	55.59	55.59	55.69	55.86	55.91	55.98	56.00	56.01	56.01	118	162
60	61.61	59.52	59.52	59.63	59.80	59.86	59.94	59.95	59.96	59.97	134	185
63	64.45	62.27	62.27	62.38	62.56	62.62	62.70	62.72	62.72	62.73	147	202
66	68.46	66.16	66.16	66.28	66.46	66.54	66.61	66.63	66.64	66.65	166	228
72	72.48	70.05	70.05	70.17	70.37	70.44	70.52	70.54	70.56	70.56	185	255
75	76.50	73.94	73.94	74.07	74.28	74.35	74.44	74.46			215	283
78	80.51	77.83	77.83	77.97	78.18	78.26	78.35	78.37			237	313
81	84.53	81.72	81.72	81.87	82.09	82.18	82.26	82.29			261	345
84	88.54	85.62	85.62	85.76	86.00	86.09	86.18	86.20			287	377
90	92.56	89.51	89.51	89.67	89.90	90.00	90.09	90.11			312	412
96	96.57	93.39	93.39	93.56	93.81	93.91	94.00	94.03			340	448
99	100.59	97.28	97.28	97.46	97.71	97.82	97.91				377	486
102	104.61	101.18	101.18	101.36	101.62	101.73	101.83				407	525
108	112.64	108.96	108.96	109.15	109.43	109.55	109.65				471	608
120	120.67	116.74	116.74	116.95	117.24	117.37	117.48				540	696
126	128.70	124.52	124.52	124.74	125.06						669	822
132	136.73	132.31	132.31	132.54							884	925
138	140.75	136.20	136.20	136.43							938	980
144	144.76	140.09	140.09	140.33							991	1036

STIFFNESS CLASS 72

72 PSI		ID MIN (INCHES)									WEIGHT SPAN U.S. Pound/Feet	
DN	DOS max	PN 50	PN 100	PN 150	PN 200	PN 250	PN 300	PN 350	PN 400	PN 450	from	to
12	13.19	12.61	12.61	12.60	12.64	12.65	12.70	12.70	12.70	12.70	8	10
14	15.33	14.66	14.66	14.67	14.70	14.72	14.77	14.78	14.78	14.78	10	14
16	17.40	16.66	16.66	16.67	16.71	16.73	16.78	16.78	16.79	16.79	13	18
18	19.49	18.66	18.66	18.69	18.72	18.74	18.80	18.81	18.81	18.81	17	22
20	21.61	20.72	20.72	20.73	20.78	20.80	20.86	20.87	20.88	20.88	20	27
24	25.79	24.74	24.74	24.75	24.81	24.85	24.91	24.92	24.93	24.93	29	39
30	32.01	30.74	30.74	30.75	30.82	30.87	30.94	30.95	30.96	30.97	44	59
36	38.31	36.81	36.81	36.82	36.92	36.97	37.05	37.07	37.08	37.09	62	83
42	44.49	42.76	42.76	42.77	42.89	42.96	43.04	43.06	43.08	43.09	84	113
48	50.79	48.83	48.83	48.84	48.99	49.06	49.15	49.17	49.19	49.20	108	146
54	57.56	55.36	55.36	55.37	55.53	55.62	55.71	55.74	55.76	55.78	140	186
60	61.61	59.28	59.28	59.28	59.45	59.55	59.65	59.68	59.70	59.72	159	213
63	64.45	62.00	62.00	62.01	62.19	62.30	62.39	62.43	62.45	62.47	174	232
66	68.46	65.88	65.88	65.88	66.08	66.19	66.29	66.33	66.35	66.36	197	262
72	72.48	69.75	69.75	69.75	69.96	70.07	70.18	70.22	70.24	70.26	219	293
75	76.50	73.62	73.62	73.63	73.85	73.96	74.07	74.12			254	326
78	80.51	77.50	77.50	77.50	77.73	77.85	77.97	78.02			281	360
81	84.53	81.36	81.36	81.37	81.61	81.75	81.86	81.91			310	397
84	88.54	85.24	85.24	85.24	85.50	85.63	85.76	85.81			340	435
90	92.56	89.11	89.11	89.11	89.38	89.53	89.65	89.70			371	475
96	96.57	92.98	92.98	92.98	93.26	93.42	93.54	93.60			403	515
99	100.59	96.85	96.85	96.85	97.15	97.31	97.44				450	560
102	104.61	100.72	100.72	100.72	101.03	101.20	101.33				486	604
108	112.64	108.47	108.47	108.47	108.80	108.98	109.12				563	699
120	120.67	116.21	116.21	116.21	116.56	116.76	116.91				645	802
126	128.70	123.96	123.96	123.96	124.33						810	945
132	136.73	131.69	131.69	131.69	132.09						915	1006

HEAD LOSS



SURGE WAVE CELERITY

DN	12	16	20	24	36	48	72	120
SN18								
PN50	1400	1280	1200	1160	1140	1120	1120	1100
PN100	1400	1300	1280	1240	1200	1200	1160	1140
PN150	1500	1480	1440	1420	1400	1380	1360	1340
PN200	1580	1550	1550	1530	1510	1500	1490	1480
PN250	1700	1690	1660	1650	1630	1630	1620	1610
PN300	1820	1780	1770	1750	1740	1730	1720	1720
PN350	1880	1870	1850	1840	1840	1840	1870	
PN400	1960	1940	1930	1920	1960	1960	1950	
PN450	2020	2010	2000	2020	2080	2070	2050	

DN	12	16	20	24	36	48	72	120
SN36								
PN50	1440	1340	1280	1280	1260	1240	1240	1240
PN100	1440	1340	1280	1280	1260	1240	1240	1240
PN150	1520	1500	1460	1440	1400	1380	1380	1360
PN200	1590	1560	1560	1540	1520	1510	1500	1490
PN250	1710	1690	1670	1660	1640	1630	1620	1620
PN300	1800	1780	1770	1760	1740	1740	1730	1720
PN350	1890	1870	1850	1850	1840	1830	1820	
PN400	1950	1940	1930	1920	1950	1940	1930	
PN450	2020	2020	2020	2030	2080	2070	2050	

- ▶ Celerity values are in ft/s calculated for non-restrained pipes using the Korteweg formulation. A modulus of compressibility of water of 300,000 psi and FRPM pipe design properties are assumed.
- ▶ The values above are rounded. Contact us if more precise values are required for transient analysis. For pipe DN's not listed, the values can be interpolated. For DN's larger than listed, use the value for the largest DN listed.
- ▶ The values above are valid for pipe with joints every 40 feet. The effect of other pipe structures like surrounding soils, fittings, thrust blocks etc. has to be evaluated separately.

SURGE WAVE CELERITY

DN	12	16	20	24	36	48	72	120
SN46								
PN50	1460	1360	1320	1320	1300	1300	1280	1280
PN100	1460	1360	1320	1320	1300	1300	1280	1280
PN150	1540	1500	1460	1440	1420	1400	1380	1360
PN200	1590	1570	1550	1550	1530	1520	1510	1500
PN250	1700	1690	1670	1660	1650	1640	1630	1620
PN300	1800	1780	1770	1760	1750	1740	1730	1730
PN350	1900	1860	1850	1850	1840	1830	1820	
PN400	1950	1940	1930	1930	1910	1910	1900	
PN450	2030	2010	2000	2000	2070	2060	2050	

DN	12	16	20	24	36	48	72	120
SN72								
PN50	1500	1420	1420	1400	1400	1380	1380	1360
PN100	1500	1420	1420	1400	1400	1380	1380	1360
PN150	1540	1500	1480	1460	1420	1400	1380	1380
PN200	1600	1570	1560	1550	1530	1520	1510	1510
PN250	1710	1690	1670	1670	1650	1640	1630	1630
PN300	1800	1790	1770	1770	1760	1740	1740	1730
PN350	1880	1870	1860	1860	1840	1830	1830	
PN400	1960	1950	1930	1930	1910	1910	1900	
PN450	2030	2010	2000	2000	2040	2030	2010	

- ▶ Celerity values are in ft/s calculated for non-restrained pipes using the Korteweg formulation. A modulus of compressibility of water of 300,000 psi and FRPM pipe design properties are assumed.
- ▶ The values above are rounded. Contact us if more precise values are required for transient analysis. For pipe DN's not listed, the values can be interpolated. For DN's larger than listed, use the value for the largest DN listed.
- ▶ The values above are valid for pipe with joints every 40 feet. The effect of other pipe structures like surrounding soils, fittings, thrust blocks etc. has to be evaluated separately.

GUIDELINES FOR PIPE STIFFNESS SELECTION

TYPE 1 TRAFFIC LOAD AASHTO HS 20 – NO INTERNAL VACUUM – GROUND WATER TO LEVEL																									
DN ≥ 12																									
Backfill	Standard Trench. Bd/D = 1.8												Wide Trench. Bd/D = 3.0												
	CL I			CL II			CL III			CL IV			CL I			CL II			CL III			CL IV			Native Soil
Burial Depth ft	18	36	72	18	36	72	18	36	72	18	36	72	18	36	72	18	36	72	18	36	72	18	36	72	
3.3	D	D	D	85	85	85	90	85	85		95	95	D	D	D	85	85	85	90	90	85			95	1
4.9	D	D	D	85	85	85	85	85	85	95	95	95	D	D	D	85	85	85	90	85	85			95	
6.6	D	D	D	85	85	85	85	85	85	95	95	95	D	D	D	85	85	85	90	90	85			95	
9.9	D	D	D	85	85	85	90	85	85			95	D	D	D	85	85	85	90	90	90				
16.4	D	D	D	85	85	85	90	90	90				D	D	D	90	90	85	95	95	95				
26.2	D	D	D	90	90	90	95	95	95				D	D	D	90	90	90	95	95	95				
39.4	D	D	D	90	90	90	95	95	95				D	D	D	90	90	90							
65.6	D	D	D	95	90	90							D	D	D	95	95	95							
98.4	C	D	D	100	95	95							C	D	D	100	95	95							
3.3	D	D	D	85	85	85	90	85	85			95	D	D	D	85	85	85	90	90	85			95	4
4.9	D	D	D	85	85	85	85	85	85	95	95	95	D	D	D	85	85	85	90	90	85			95	
6.6	D	D	D	85	85	85	85	85	85	95	95	95	D	D	D	85	85	85	90	90	90			95	
9.9	D	D	D	85	85	85	90	90	85			95	D	D	D	85	85	85	90	90	90				
16.4	D	D	D	90	90	85	95	95	95				D	D	D	90	90	90	95	95	95				
26.2	D	D	D	95	95	90							D	D	D	90	90	90							
39.4	C	C	C	100	100	100							D	D	D	95	95	95							
65.6													C	D	D	100	95	95							
98.4														C	C		100	100							
3.3	D	D	D	95	95	90							D	D	D	90	90	85	95	95	90				6
4.9	D	D	D	95	90	90			95				D	D	D	90	85	85	95	95	90				
6.6	D	D	D	95	95	90			95				D	D	D	90	90	85	95	95	90				
9.9	D	D	D	95	95	95							D	D	D	90	90	85	95	95	95				
16.4			C			100							D	D	D	90	90	90			95				
26.2													D	D	D	95	95	95							
39.4													D	D	D	95	95	95							
65.6														C	C		100	100							
98.4																									

NATIVE SOIL CLASSIFICATION ACCORDING TO M45

NATIVE IN SITU SOILS					
Granular			Cohesive		
			q _u		
Group	Blows/ft* (0.3 m)	Description	ton/sf	kPa	Description
1	>15	compact - very dense	2.0 -> 6.0	200 -> 600	very stiff - very hard
2	8-15	slightly compact	1.0-2.0	100-200	stiff
3	4-8	loose	0.50-1.0	50-100	medium
4	2-4		0.25-0.50	25-50	soft
5	1-2	very loose	0.125-0.25	13-25	very soft
6	>0-1	very, very loose	>0-0.125	0-13	very, very soft

*Standard penetration test per ASTM D1586 according to M45.

BACKFILL SOIL CLASSIFICATION ACCORDING TO M45

Soil Classes	Unified Soil Classification System Soil Groups*
CL I	Crushed rock: \leq 15% sand, maximum 25% passing the 3/8-in. sieve and maximum 5% passing No. 200 sieve
CL II	Clean, coarse-grained soils: SW, SP, GW, GP or any soil beginning with one of these symbols with 12% or less passing No. 200 sieve
CL III	Coarse-grained soils with fines: GM, GC, SM, SC or any soil beginning with one of these symbols with more than 12% fines
	Sandy or gravelly fine-grained soils: CL ML (or CL-ML, CL/ML, ML/CL) with 30% or less retained on a No. 200 sieve
CL IV	Fine-grained soils: CL, ML (CL-ML, CL/ML, ML/CL) with 30% or less retained on a No. 200 sieve

*ASTM D2487, Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System)

CHEMICAL RESISTANCE TABLE

	Standard Pipe Resin or Vinyl Ester	Vinyl Ester Only
Acetic Acid < 20%*		X
Adipic Acid*		X
Alum (Aluminum Potassium Sulfate) (113°F)	X	
Aluminum Chloride, Aqueous (104°F)	X	
Ammonia, Aqueous < 20%		X
Ammonium Chloride, Aqueous (104°F)	X	
Aniline Hydrochloride		X
Beet Sugar Liquor		X
Benzene Sulfonic Acid (10%)*		X
Benzoic Acid*		X
Black Liquor (Paper)		X
Borax (104°F)	X	
Boric Acid		X
Calcium Bisulfite*		X
Calcium Carbonate		X
Calcium Chlorate, Aqueous (104°F)*	X	
Calcium Chloride (Saturated) (104°F)	X	
Calcium Hydroxide, 100%		X
Calcium Hypochlorite		X
Calcium Nitrate (104°F)	X	
Calcium Sulfate NL AOC (104°F)	X	
Cane Sugar Liquors		X
Carbon Dioxide, Aqueous (104°F)	X	
Casein	X	
Caustic Potash (KOH) (104°F)		X
Chlorine, Dry Gas*		X
Chlorine, Water*		X
Chlorine, Wet Gas*		X
Citric Acid, Aqueous		X
Copper Acetate, Aqueous (104°F)	X	
Copper Nitrate, Aqueous (104°F)	X	
Copper Sulfate, Aqueous (104°F)	X	
Crude Oil (Sour) (86°F)*	X	
Crude Oil (Sweet) (86°F)*	X	
Crude Oil, Salt Water (77°F)*		X
Cyclohexane (104°F)*		X

CHEMICAL RESISTANCE TABLE *(continued)*

	Standard Pipe Resin or Vinyl Ester	Vinyl Ester Only
Cyclohexanol (86°F)*		X
Fuel Oil (77°F)*	X	
Gasoline, Ethyl*		X
Glycerine		X
Green Liquor, Paper		X
Kerosene*		X
Lactic Acid, 10% (86°F)	X	
Lead Acetate, Aqueous (77°F)	X	
Lead Nitrate, Aqueous (77°F)	X	
Linseed Oil*	X	
Lithium Chloride, Aqueous (104°F)*	X	
Magnesium Bicarbonate, Aqueous (86°F)*	X	
Magnesium Carbonate (104°F)*		X
Mineral Oils*	X	
n-Heptane (77°F)*	X	
Naphthalene (86°F)*	X	
Naptha*		X
Oleic Acid (104°F)	X	
Oxalic Acid, Aqueous		X
Paraffin (86°F)*	X	
Perchloric Acid (77°F)		X
Petroleum, Refined & Sour*		X
Phosphoric Acid		X
Potassium Nitrate, Aqueous (104°F)	X	
Potassium Sulfate (104°F)	X	
Propylene Glycol (86°F)	X	
Sea Water (104°F)	X	
Sewage (122°F)	X	
Silicone Oil (104°F)	X	
Silver Nitrate, Aqueous (104°F)	X	
Sodium Hydroxide 10%		X
Sodium Mono-Phosphate		X
Sodium Nitrate, Aqueous (104°F)	X	
Sodium Nitrite, Aqueous (104°F)*	X	
Sodium Silicate		X
Stannous Chloride, Aqueous (104°F)	X	

CHEMICAL RESISTANCE TABLE *(continued)*

	Standard Pipe Resin or Vinyl Ester	Vinyl Ester Only
Stearic Acid (104°F)*	X	
Sulfuric Acid, < 25% (77°F)*	X	
Tannic Acid, Aqueous (95°F)	X	
Tartaric Acid (86°F)	X	
Triethylamine (104°F)*		X
Turpentine*		X
Urea, Aqueous (86°F)*	X	
Vinegar (77°F)	X	
Water, Distilled (104°F)	X	
Water, Tap (104°F)	X	
Zinc Chloride, Aqueous (104°F)	X	

* Current EPDM type gasket can not be used. Use of NBR type gasket is recommended, or consult your local gasket supplier.