The Complete HOBAS Guide

HOBAS®

Centrifugally Cast, Fiberglass-Reinforced, Polymer Mortar Pipe

30

THIRTY YEARS & COUNTING

Why Pick HOBAS?

The HOBAS name on the pipe says you've chosen the leader in pipe technology: first choice for virtually every application and method of installation:

- **Sliplining**
- **Two-Pass Tunneling**
- **Jacking or Microtunneling**
- **Above Ground**
- **Direct Bury**

It's the Best Pipe Investment You Can Make:
Centrifugal Casting Is the Difference.

Every step of the HOBAS manufacturing process is carefully controlled and verified. In the Quality Control lab, samples taken from the production line are checked for adherence to the standards and specifications.

What Do You Want in Your Pipeline?
Here's What HOBAS Delivers:

Easy To Specify, Lower Project Cost, Superior Engineering and Customer Support

HOBAS Defined

HOBAS pipes are unique – centrifugally cast, fiberglass reinforced, polymer mortar (CCFRPM). They are strong and light with consistent dimensions, smooth surfaces and high stiffness.

Longest Service Life

HOBAS pipe is inherently corrosion resistant because of the materials that go into it. Design service life is up to 100 years and more.

Table of Contents

Introduction

Manufacturing

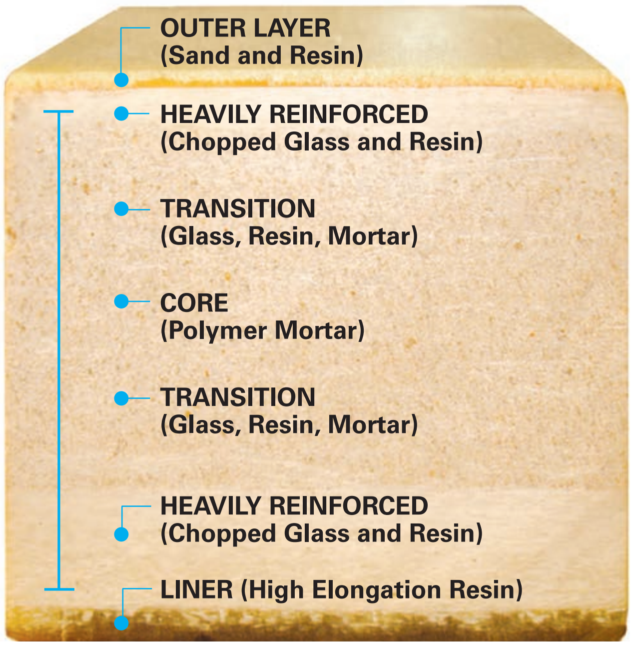
Sophisticated HOBAS manufacturing means you get real value, the lowest life cycle cost in the industry for both new installations and rehabilitation.

ASTM

HOBAS meets or exceeds ASTM standards as measured in sewer pipe accelerated aging tests. Results project that HOBAS pipe will last many thousands of years – unequaled by any other pipe needs.

Wall Construction:

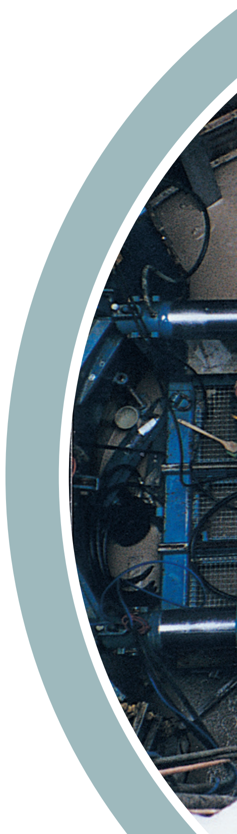
I-Beam Principle



Getting Technical

In the most scientific terms, HOBAS pipe is a glass-fiber-reinforced, aggregate-fortified, thermosetting-resin tubular product manufactured by a centrifugal casting process.

High strength, high stiffness and inherent corrosion resistance make HOBAS pipes ideal for many applications such as this sanitary sewer aerial crossing.



The Product

Consistent Quality and Performance

Most U.S. municipalities have HOBAS pipe in their systems and the use of HOBAS pipe in the USA is expanding faster than ever after more than 25 years of reliable performance. More than 40,000 miles of HOBAS pipe has been installed around the world.

Versatile

HOBAS pipes can be economically designed for non-pressure and pressure service by varying the quantity, placement and orientation of the glass-fiber reinforcements.

Smoother Surfaces, High Flow Capacity

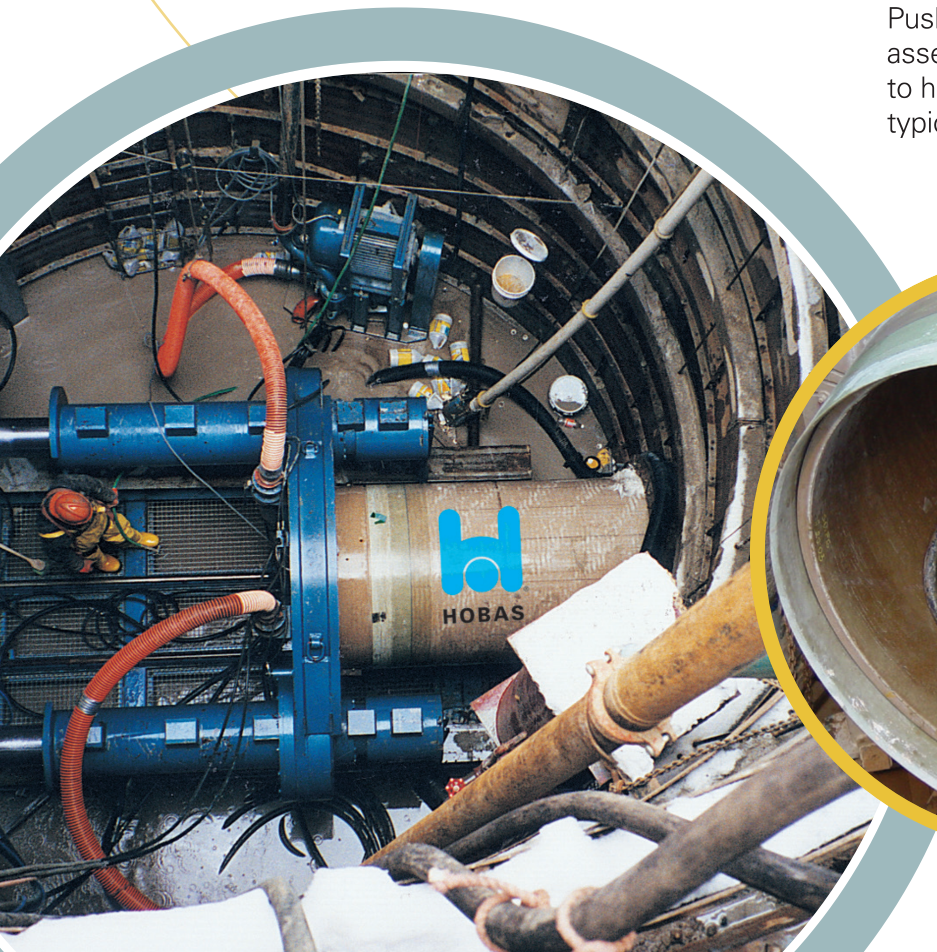
HOBAS Pipe is manufactured with a unique, precise, computer-controlled, centrifugal casting process that no other method can deliver. This produces very consistent, high-density pipe with a mold-smooth exterior surface and a glass-smooth nonporous liner that is resilient and abrasion resistant. In addition to superior hydraulics, thin-wall construction produces an oversized I.D. for the highest flow capacity available.

Leak-Free Joints

Another HOBAS advantage is push-together joints for a leak-free pipeline that preserves the streets above and reduces treatment costs.

Straightforward Installation

Installation is quick and easy with predictable, reliable pipe performance by every method. Push-together joints are simple and fast to assemble. Lightweight pipes are safe and easy to handle, often with the smaller equipment typically on the site.



HOBAS Worldwide

A Little History

In the mid-fifties, a textile manufacturer, seeking a replacement for the traditional wooden rollers, tried to produce cylinders with a smooth surface using polyester resin reinforced with glass fiber.

They tried the widely used filament winding process, but found that it was unsuitable because the outside surface it produced was not smooth enough. The idea of manufacturing the cylinders by centrifugal casting was born. HOBAS pipe is a direct descendant of that invention.

Shortly after, the first piping application appeared. Engineers needed a durable, corrosion resistant pipe with smooth interior surface. Centrifugal casting was adapted to meet the specifications and production quickly expanded. Soon after, pipes were installed in Europe.

Today HOBAS pipe is manufactured and used around the world. From Seattle to Key West, New York to Los Angeles, most U.S. municipalities have HOBAS pipe in their systems. After more than 45 years of reliable service, the use of HOBAS pipe is expanding faster than ever.

Currently, in addition to the USA, HOBAS has factories in Austria, Japan, Germany, China, Thailand, United Arab Emirates, Spain, Poland, Turkey, Uzbekistan, Czech Republic, Kazakhstan, Romania and Egypt. The group of companies has provided more than 40,000 miles of pipe. Over 6.5 million feet have been installed in the USA.

Versatile Solution

HOBAS centrifugally cast fiberglass reinforced polymer mortar pipes are ideally suited for nearly all large diameter corrosive piping applications. Listed below are the most common environments, installations and services in which the pipe has been used.

84-inch diameter Hydro-Electric Penstock in New Hampshire

Environments

- Gravity sanitary sewers
- Sewer force mains
- Raw water
- Sea water
- Industrial effluents
- Irrigation
- Geo-thermal piping
- Wastewater collection systems
- Storm water and sewer water segregation systems
- Odor control piping
- WWTP piping
- Potable water
- Contaminated water
- Cooling water
- Foul air

Installation and Service Operation

Installation	Service Operation Non-Pressure	Pressure
Direct Bury	•	•
Relining (Sliplining)	•	•
Jacking & Microtunneling	•	•
Above Ground	•	•
Tunnel Waterway Carrier	•	•
Pipe Bursting	•	•

Note: Products available for sustained temperatures over 150 ° F. See Corrosion Resistance Guide in Appendix F.

Direct bury installation at DFW Airport

84-inch diameter jacking pipe for the City of Los Angeles.

30-inch diameter sanitary sewer vent line.

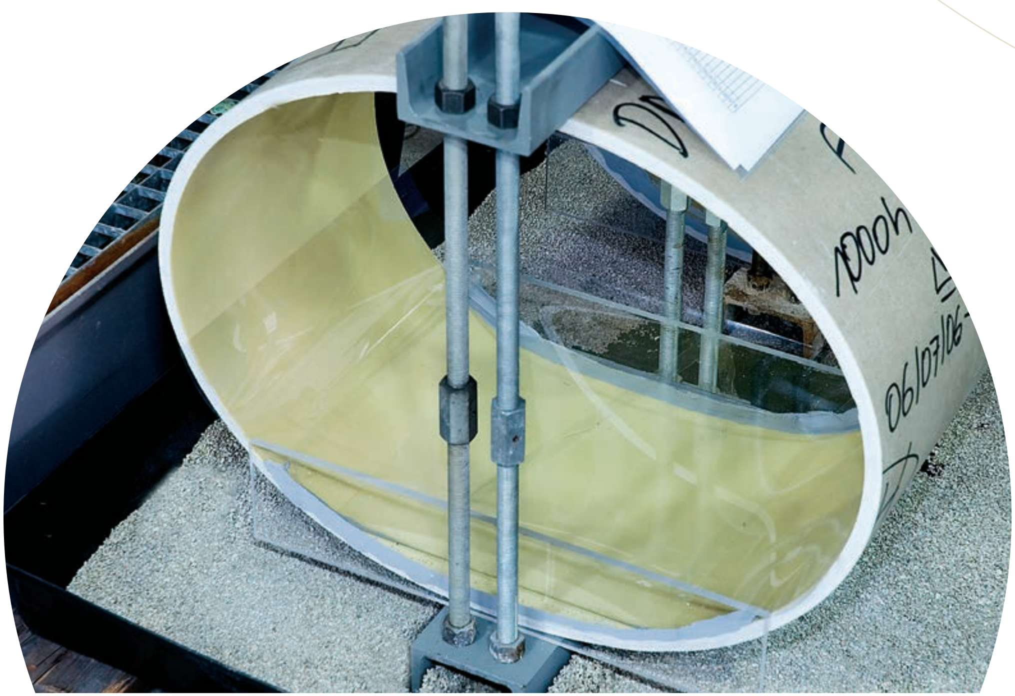
60-inch CMP storm culvert rehabilitation with 54-inch HOBAS.

60-inch diameter, 100 psi sewer force main in a two-pass system.

Better by Design

HOBAS centrifugally cast fiberglass reinforced polymer mortar pipes have many outstanding features that provide numerous cost saving benefits. Listed below are some of the key features and resulting benefits.

Features	Benefits
Inherent corrosion resistance	• Long, maintenance-free service life.
	• No costly add-on linings or coatings to damage, repair, inspect or maintain.
	• No need for expensive cathodic protection or polybags to install and monitor.
	• Ideal pipe for economical relining of corroded pipelines.
	• Hydraulic characteristics are virtually unchanged with time.
High stiffness design	• Easy to bury using methods routinely specified for traditional pipes.
	• Performance is predictable and reliable.
	• Deep covers handled with ease.
	• Pipes are rugged and durable.
	• Easy to grout annulus on sliplining and tunnel lining applications.



Inherent corrosion resistance of HOBAS pipes is proven by testing in acid under high stress.

Features	Benefits
Smooth interior surface & oversize ID's	• Deliver more fluid than any corrosion resistant pipe.
	• Permits greatest recovery of flow in rehabilitated pipelines.
	• Significant energy savings in pumped systems.
Bottle-tight joints	• Zero infiltration/exfiltration.
	• No extra treatment costs.
	• No pollution of ground waters.
	• Full delivery of pumped fluids.
	• No wasted time & expense trying to find and seal leaking joints to pass acceptance tests.
	• No undermining of above structures and infrastructure.

High stiffness pipes perform reliably even at deep covers such as this installation in Baltimore.

Reflection smooth interior surface and oversize ID's of HOBAS pipes provide outstanding long-term flow characteristics.

Features	Benefits
Lightweight/20 ft. sections	• Lighter, less expensive equipment needed for handling.
	• Fewer joints to assemble.
Push-on coupling joints with angular rotation capability	• "Fool-proof," fast assembly.
	• Requires no secondary treatments, diapers, bonding agents or other chemicals in the field.
	• Lower joining costs.
	• Radius curves possible without the need for fittings.
Smooth Constant OD	• Pipe may be cut anywhere along its entire length and assembled with gasketed joints with only end chamfering needed.
	• Lower forces required to insert pipe into casings or deteriorated pipelines for rehabilitation.
	• Allows longer distance bored tunnels with lower jacking loads, thereby reducing shaft requirements and increasing safety margins.

Lightweight HOBAS pipes handle easier and lay faster with less expensive equipment.

Smooth, constant OD of HOBAS pipes permits cutting and joining anywhere along its entire length.

HOBAS push-on FWC coupling joints assemble easily and provide leak-free service.

Features	Benefits
Resilient inner liner	• Excellent abrasion resistance.
	• High crack resistance.
Computer controlled manufacturing process	• Consistent, reproducible high quality pipes.
Standardized designs & dimensions	• Multiple pressure & stiffness classes to meet most project requirements.
	• OD's compatible with standard ductile iron fittings.
50 year history of successful applications	• Service tested and time proven performance record.

As you can see, HOBAS fiberglass reinforced polymer mortar pipes save you money during installation and in operation. These initial and daily savings compounded with the elimination of expense for repairs, rehabilitation or premature replacement, make our fiberglass pipes YOUR BEST VALUE IN CORROSION RESISTANT PIPING.

Computer controlled and monitored production results in consistent, high quality HOBAS pipes.

Product Range

Standard section length is 20 ft. although shorter pipes are available.

Nominal Diameters

18″	20″	24″	27″	28″	30″	33″	36″	41″	42″
44″	45″	48″	51″	54″	57″	60″	63″	66″	69″
72″	78″	84″	85″	90″	96″	104″	110″	120″	126″

Note: Actual dimensions are given in Appendix B. Other nominal diameters may be available. Please inquire.

Stiffness Classes (SN)

Installation	SN 18	SN 36	SN 46	SN 72	SN >72
Direct Bury	Very Unusual	Infrequent	Standard	Standard	Infrequent
Sliplining Non Pressure	Infrequent	Standard	Standard	Infrequent	Very Unusual
Sliplining Pressure	Very Unusual	Standard	Standard	Infrequent	Very Unusual
Pipe Bursting, Jacking & Microtunneling	Very Unusual	Very Unusual	Very Unusual	Very Unusual	Standard
Tunnel Carrier Pipe	Very Unusual	Standard	Standard	Standard	Infrequent
Aboveground	See page 17, 46 & 47				Infrequent

Standard

Infrequent

Very Unusual

SN is minimum pipe stiffness in psi.

Lengths

Standard 20 foot sections (Special lengths and even divisions of 20 ft. are available.)

Diameter range is 18” to 126”.

Riser pipes are available for both new construction and rehabilitation.

Fittings

Fiberglass reinforced polymer flanges, elbows, reducers, tees, manholes, wyes & laterals, constructed by contact molding or from mitered sections of fiberglass reinforced polymer mortar pipe joined by glass-fiber-reinforced overlays, are available for all non-pressure and many pressure applications. Protected ductile iron, fusion-bonded epoxy- coated steel or stainless steel fittings are typically compatible and may be used with all HOBAS pressure classes. Fitting details may be found in Section 9 and Appendix E.

Pressure Classes

Dia. (in.)	PN (psi) 25	50	100	150	200	250
18						
20						
24						
27						
28						
30						
33						
36						
41						
42						
44						
45						
48						
51						
54						
57						
60						
63						
66					Non-Standard	
69						
72						
78						
84						
85						
90						
96						
104						
110						
120						
126						

A variety of manhole fittings and options are available to suit your needs.

Pipe Stiffness Selection

Direct Bury Applications

Appropriate pipe stiffness is a function of native soil characteristics, trench construction, cover depth, embedment conditions, and haunching. Figure 1 (See below) relates these parameters assuming a minimum width trench as defined in Figure 11 (pg. 39). (Under certain circumstances, pipe stiffness less than 36 psi may be suitable.)

For pipes with vacuum operating conditions, see Allowable Negative Pressure in Section 6 (pg. 19) for appropriate pipe stiffness for various installations and negative pressures.

For shallow buried pipes with surface loads, see Traffic Loads in Section 6 (pg. 20) for appropriate pipe stiffness for various installations and cover depths.

High stiffness HOBAS pipes may be buried safely at depths exceeding 50 ft.

NATIVE SOIL [2, 5]	COVER DEPTH[1] (ft.)	EMBEDMENT CONDITION[3] 1	2	3	4
ROCK Stiff to V. Hard Cohesive (Qu ≥ 1 Tsf) Compact to V. Dense Granular (SPT N ≥ 8 bpf)	10 & <	SN[5] 36	SN[5] 36	SN[5] 36	SN[5] 72
	>10 to 20	SN[5] 36	SN[5] 36	SN 46	ALTERNATE INSTALLATION[6]
	>20 to 30	SN 46	SN 46	SN 72	ALTERNATE INSTALLATION[6]
	>30 to 40	SN 72	SN 72	ALTERNATE INSTALLATION[6]	ALTERNATE INSTALLATION[6]
	>40 to 50	SN 72	SN 72	ALTERNATE INSTALLATION[6]	ALTERNATE INSTALLATION[6]
	>50 to 60	SN 90	SN 90	ALTERNATE INSTALLATION[6]	ALTERNATE INSTALLATION[6]
	>60 to 70	SN 120	SN 120	ALTERNATE INSTALLATION[6]	ALTERNATE INSTALLATION[6]
Medium Cohesive (Qu ≥ 0.5 Tsf) Loose Granular (SPT N = 4 to 7 bpf)	10 & <	SN 36	SN 36	SN 36	SN 72
	>10 to 20	SN 36 / SN 46	SN 36 / SN 46	SN 46 / SN 72	ALTERNATE INSTALLATION[6]
	>20 to 30	SN 72	SN 72	ALTERNATE INSTALLATION[6]	ALTERNATE INSTALLATION[6]
	>30 to 40	SN 72	SN 72	ALTERNATE INSTALLATION[6]	ALTERNATE INSTALLATION[6]
Soft Cohesive (Qu ≥ 0.25 Tsf) V. Loose Granular (SPT N = 2 to 3 bpf)	10 & <	SN 36	SN 36	SN 72	ALTERNATE INSTALLATION[6]
	>10 to 20	SN 46 / SN 72	SN 46 / SN 72	ALTERNATE INSTALLATION[6]	ALTERNATE INSTALLATION[6]
	>20 to 30	ALTERNATE INSTALLATION[6]	ALTERNATE INSTALLATION[6]	ALTERNATE INSTALLATION[6]	ALTERNATE INSTALLATION[6]
V. Soft Cohesive (Qu ≥ 0.125 Tsf) V. V. Loose Granular (SPT N ~ 1 bpf)	10 & <	SN 72	SN 72	ALTERNATE INSTALLATION[6]	ALTERNATE INSTALLATION[6]
	>10 to 20	ALTERNATE INSTALLATION[6]	ALTERNATE INSTALLATION[6]	ALTERNATE INSTALLATION[6]	ALTERNATE INSTALLATION[6]

[1] Assuming typ. 1.5 x OD Trench Width (or as in Figure 11)
[2] Soils adjacent to pipe (pipe zone elevation)
[3] Defined in Figure 13
[4] For zero blow (weight of hammer) soils, use Alternate Installation & SN 72
[5] SN is nominal stiffness in PSI
[6] Alternate Installation per section 14, A8-Typ. SN 72 min.

STIFFNESS CLASS KEY

SN 36, SN 46, SN 72, SN 90, SN 120, Alternate Installation

FIGURE 1 - Pipe Stiffness Selection for Standard Installations[1]

HOBAS pipes easily withstand a full vacuum service condition due to the high stiffness design.

Sliplining Applications

Appropriate pipe stiffness is a function of the insertion compressive load, grouting pressure, grouting deformation loads and external hydrostatic head.

- The table below lists safe (F of S ≈ 3) compressive loads for pushing "straight" for various pipe stiffness classes and diameters. When pushing around curves, allowable safe loads will be reduced depending on the curve radius and pipe section length.

- For safe compressive loads when pushing "straight" on pipe with the flush bell-spigot joint, see the table in the "Tunnel Carrier Pipe Applications" portion of this section on page 18.

- Maximum safe (F of S ≈ 2.0) grouting pressure (psi) without support bracing or counter pressurization is shown in Chart A.

- Net uplift forces (displaced grout weight minus pipe and flow weight) must be coordinated with pipe stiffness to control pipe deformation to within acceptable limits.

- Safe (F of S ≈ 1.5) long-term external hydrostatic head (ft.) for an ungrouted installation is shown in Chart B.

Low-Profile Bell-Spigot Joint Allowable Compressive Load

Nom. Dia. (in.)	O.D. (in.)		Safe Compressive Load Pushing "Straight" (U.S. Tons)		
	Pipe Wall	Bell	SN 36	SN 46	SN72
18	19.5	20.4	–	25 (SN 62)	27
20	21.6	22.5	–	29	36
24	25.8	26.8	39	44	54
27	28.0	29.0	48	54	66
28	30.0	31.0	56	63	77
30	32.0	33.0	51	58	74
33	34.0	35.0	60	67	85
36	38.3	39.3	82	92	115
41	42.9	44.0	108	122	149
42	44.5	45.6	119	134	162
44	45.9	47.0	128	143	175
45	47.7	48.8	141	159	192
48	50.8	51.9	164	183	220
51	53.9	55.0	188	211	254
54	57.1	58.2	215	239	288
57	60.0	61.2	242	268	322
60	62.9	64.1	271	297	358
63	66.0	67.2	302	333	396
66	69.2	70.4	305	342	412
69	72.5	73.8	339	378	458
72	75.4	76.7	373	417	501
78	81.6	82.9	448	496	595
84	87.0	88.4	520	575	686
85	88.6	90.0	544	601	717
90	94.3	95.7	625	690	820
96	99.5	101.0	702	776	924
104	108.0	109.5	844	930	1101
110	114.0	115.5	950	1050	1240
120	126.0	127.5	1190	1300	1535
126	132.5	134.3	1300	1420	1705

Max. Safe Grouting Pressure (psi)		
Fluid Flow Level / Dia. Difference	None or low	over $^1/_2$ to full
≤ 5%	SN÷4	SN÷3
≤ 10%	SN÷5	SN÷4
≤ 20%	SN÷6	SN÷5
> 20%	SN÷7	SN÷6

Chart A

Max. Safe Long-term External Head (ft.) for an Ungrouted Installation	
Fluid Flow Level / Dia. Difference	All Flow levels
≤ 5%	SN÷2
≤ 10%	SN÷2.5
≤ 20%	SN÷3
> 20%	SN÷4

Chart B

Notes:

Diameter Difference =

$$\left(\frac{\text{ID Host Pipe - OD Liner Pipe}}{\text{OD Liner Pipe}}\right) \text{X } 100$$

SN is nominal pipe stiffness in psi

Jacking Applications

Non-Pressure

Appropriate pipe stiffness is a function of the jacking compressive load and installation conditions. The jacking contractor must control the jacking loads within the safe limits for the pipe. The adjacent table shows allowable safe jacking loads (pushing "straight") for the typical design. However, the ultimate pipe load capacity is the choice and responsibility of the purchaser and can be affected by a number of factors including the anticipated loads, the amount of steering, the amount of over-cut, the amount of lubrication, the pipe section length, the distance of the jacking operation and any point loading.

Pressure

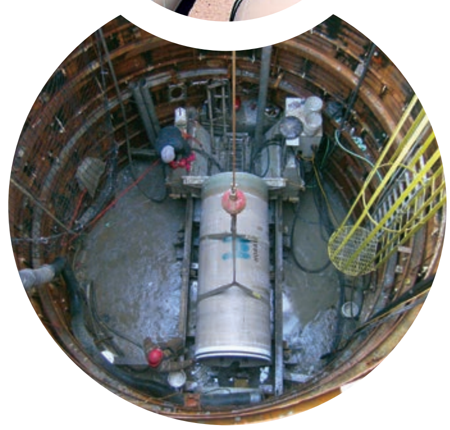
Details of pressure service jacking pipes are available on a custom design basis depending on jacking loads, operating parameters, and installation conditions.

Jacking Bell-Spigot Joint Allowable Compressive Load

Nom. Dia. (in.)	O.D. (in.)	Nom. Inside Dia. (in.)	Min. Pipe Wall Thickness (in.)	Min. Pipe Wall Thickness @ Gasket Groove (in.)	Allowable Safe Jacking Load Pushing "Straight" (U.S. Tons)		Weight (lb/ft)
					F of S = 3.0	F of S = 2.5	
24	25.8	22.7	1.40	0.99	125	150	107
27	28.0	24.8	1.47	1.06	145	175	120
28	30.0	26.6	1.53	1.12	166	200	137
30	32.0	28.3	1.71	1.21	191	230	159
33	34.0	30.1	1.80	1.29	216	260	179
36	38.3	34.3	1.85	1.31	250	300	208
41	42.9	38.7	1.91	1.32	283	340	245
42	44.5	40.3	1.93	1.33	295	355	255
44	45.9	41.7	1.95	1.34	308	370	263
45	47.7	43.4	1.98	1.35	325	390	280
48	50.8	46.4	2.03	1.37	350	420	306
51	53.9	49.4	2.07	1.38	375	450	333
54	57.1	52.5	2.10	1.39	400	480	361
57	60.0	55.4	2.13	1.40	425	510	380
60	62.9	58.2	2.16	1.41	450	540	408
63	66.0	61.2	2.20	1.42	475	570	438
66	69.2	64.2	2.31	1.43	500	600	478
69	72.5	67.4	2.38	1.47	541	650	512
72	75.4	70.1	2.46	1.52	583	700	553
78	81.6	76.0	2.58	1.60	667	800	634
84	87.0	81.2	2.70	1.68	750	900	701
85	88.6	82.8	2.73	1.69	770	925	727
90 *	94.3	88.2	2.85	1.76	854	1025	800
96 *	99.5	93.1	3.00	1.87	958	1150	886
104 *	108.0	101.3	3.13	1.94	1083	1300	1009
110 *	114.0	106.9	3.29	2.05	1208	1450	1129
120 *	126.0	118.4	3.58	2.25	1470	1765	1350
126	132.5	124.5	3.76	2.37	1600	1920	1500

Note: Alternate pipe designs are available upon request.
* *Lead times may be lengthy, please inquire.*

48-inch aerial interceptor at a WWTP in Odessa, TX withstands high temperatures.



HOBAS jacking pipes have the lowest drive loads.

Aboveground Applications

Appropriate pipe stiffness is a function of the pipe support scheme, pipe diameter, imposed loads and the level of negative operating pressure, if any. Section 14D on above-ground installation provides guidance on pipe support requirements for various pipe classes and diameters. Maximum negative pressure is as given in the adjacent table.

Aboveground Allowable Negative Pressure

Pipe Stiffness (psi)	Allowable Negative Pressure* (% of full vacuum)
18	25
36	50
46	60
72	100

* *at 75° F.*

Tunnel Carrier and Slipline Pipe Applications

Lightweight HOBAS pipes transport easily into the tunnel.

Appropriate pipe stiffness is a function of the external loads and conditions, insertion compressive loads (multiple pipe pushing), grouting pressure, grouting deformation loads, and the blocking scheme. Typically, SN 36 pipes have sufficient performance capability to safely withstand most controlled installations and are used most often. However, because the conditions and installation for tunnel projects tend to be unique, all criteria should be checked for each application to verify the proper pipe stiffness.

The table below lists the dimensions for the typical minimum wall pipes on which the flush bell-spigot joint is available and the safe (F of S ≈ 3) compressive loads when pushing "straight". These flush joint pipe designs may be used in tunnel carrier or in tight fit sliplining installations.

Flush Relining Bell-Spigot Joint Allowable Compressive Load

Nom. Dia. (in.)	O.D. (in.)	Min. Pipe Wall Thickness. (in.)	Nom. Pipe Stiffness (psi.)	Min. Pipe Thickness @ Gasket Groove (in.)	Safe Compressive Load Pushing "Straight" (U.S. Tons)	Weight (lb/ft)
20	21.6	0.75	245	0.34	34	48
24	25.8	0.76	160	0.35	42	62
27	28.0	0.76	130	0.35	46	68
28	30.0	0.76	105	0.35	49	73
30	32.0	0.86	130	0.36	54	87
33	34.0	0.87	110	0.37	59	94
36	38.3	0.90	90	0.40	73	110
41	42.9	0.96	83	0.44	91	131
42	44.5	0.99	82	0.46	99	140
44	45.9	1.02	82	0.47	105	148
45	47.7	1.05	80	0.49	114	158
48	50.8	1.09	74	0.51	127	175
51	53.9	1.13	69	0.53	141	192
54	57.1	1.17	65	0.55	155	210
57	60.0	1.21	62	0.58	173	225
60	62.9	1.27	62	0.61	191	251
63	66.0	1.33	62	0.64	211	276
66	69.2	1.45	71	0.66	228	315
69	72.5	1.47	64	0.67	243	335
72	75.4	1.49	59	0.68	257	352
78	81.6	1.53	51	0.71	292	393
84	87.0	1.57	45	0.75	330	430
85	88.6	1.58	43	0.76	342	440
90	94.3	1.66	42	0.82	394	491
96	99.5	1.75	42	0.88	448	547
104	108.0	1.85	39	0.94	521	628
110	114.0	1.94	38	0.99	580	695
120	126.0	2.10	36	1.09	710	829
126	132.5	2.20	36	1.16	780	915

Pipe Capabilities & Design

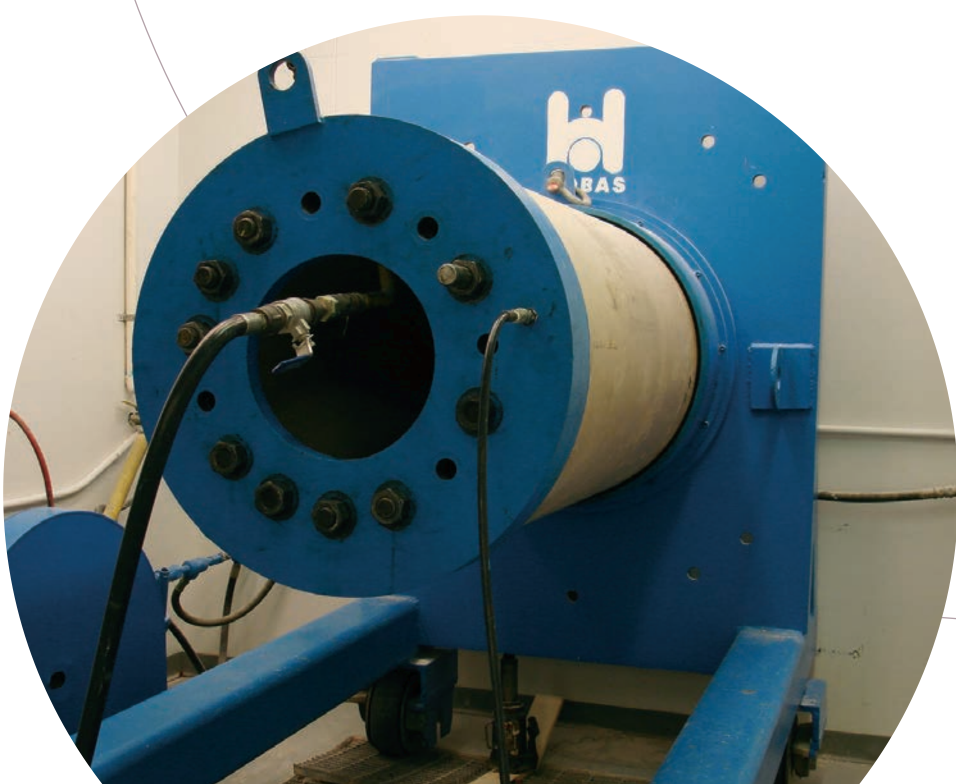
Hydrostatic Pressure

Pressure Class (PN)	Maximum Sustained Operating Pressure[1] (psi)	Maximum Transient Pressure[1] (psi)	Maximum Field Test Pressure[1] (psi)	Maximum Factory Test Pressure (psi)	Minimum Initial Burst Pressure (psi)
25	25	35	40	50	120
50	50	70	75	100	200
100	100	140	150	200	400
150	150	210	225	300	600
200	200	280	300	400	800
250	250	350	375	500	1000

[1] Maximum pressure may be reduced for buried pipes.

Buried Allowable Negative Pressure

Embedment Condition[2]	Allowable Negative Pressure (% of full vacuum)[4, 5]		
	SN 18	SN 36 or 46	SN 72
1	50	100	100
2	50	100	100
3	—	50	100
4[3]	—	—	100



[2] See Figure 13 in Section 14.
[3] Pipe zone backfill foot tamped.
[4] At the corresponding maximum cover depth shown on figure 1 in section 5.
[5] Allowable negative pressure may be reduced for burials in native soils with qu < 1 Tsf or SPT blows / ft. < 8.

Allowable Cover Depth

See Figure 1 in section 5.

Burst pressure is regularly verified at our factory.

Traffic Loads

Embedment Condition[1]	Minimum Cover (ft) for AASHTO HS-20 Load[2] SN 18	SN 36 or 46	SN 72
1	4	3	2
2	5	4	3
3	–	5	4
4	–	–	5

[1] See Figure 13 in Section 14.
[2] Installation in poor soils or at shallower cover depths is possible with improved pipe support such as cement stabilized sand or concrete encasement.

Flotation

A minimum of 1/2 to one diameter of cover is typically needed to prevent an empty submerged pipe from floating (depending on the density of the cover material) when full saturation to the surface exists. Other options may be acceptable to restrain the pipe against flotation.

Abrasion Resistance

Through comparative tests conducted on several types of pipe using sand, stones and water, HOBAS pipes exhibited superior abrasion resistance to all other materials tested. The abrasion resistance (as measured in this rocking test) for all of the plastic products including the HOBAS pipe was 3 to 10 times better than for cementitious materials such as RCP, CSC, asbestos-cement, and cement lined ductile iron or steel.

Pipe Design

Design calculations to compute the performance of HOBAS Pipe USA fiberglass reinforced polymer mortar pipes in various conditions can be generated using the principles and equations of flexible conduit theory. These include Spangler's deflection equation, Molin's bending equation and constrained buckling analysis. Through extensive research conducted on fiberglass pipes in the 1980's, these equations and others have been refined and combined into a complete design analysis procedure. This information was first printed in Appendix A of the 1988 revision to AWWA Standard C950. It is now contained in the AWWA Fiberglass Pipe Design Manual, M45.

HOBAS Pipe USA can provide design calculations to demonstrate the performance of our pipes in specific conditions on individual projects. This service is available upon request when the pipeline operating conditions are known.

High strength HOBAS pipes withstand high pressure and heavy loads.

Buried HOBAS pipes safely withstand surface loads.

General

The centrifugal casting manufacturing process used to produce HOBAS pipes results in a glass smooth interior surface which will not deteriorate due to chemical attack because of its high corrosion resistance. Research has shown that smooth wall pipes maintain superior flow characteristics over time due to less build-ups and shorter slime lengths (sewers).

Hydraulic Characteristics

Gravity Flow

Users have reported Manning's "n" flow coefficients for HOBAS pipes of 0.0090 new and 0.0105 after several years of sanitary sewer service.

Pressure

Tests conducted on an aged HOBAS pressure pipe system (approximately 100 psi) yielded an average Hazen-Williams "C" value of 155.

The glass smooth interior surface results in higher flow capacity in gravity lines and significant energy savings in pumped systems.

Flow Capacity

Gravity System

For equal flow volumes on the same slope, HOBAS pipes may be 13% smaller than pipes with an "n" value of 0.013. Depending on the condition of an existing (host) pipe, sliplining with HOBAS pipe will frequently improve the renewed line's flow capacity. See the comparison table on the next page for various combinations of criteria. A ratio on the table greater than 1.000 indicates an improved flow volume after lining, while a value less than 1.000 means a reduced flow capacity will result from the diameter change. For example, a 1.150 ratio is a 15% increase in capacity and a ratio of 0.950 is a 5% decrease. The table may also be used to compare diameters for new construction.

Pressure

For equal head loss, HOBAS pipes may be slightly smaller than pipes with worse flow characteristics. However, it is normally more advantageous to maintain the same diameter and enjoy the benefit of 30% to 50% lower head loss versus traditional pipes. The reduced head loss translates into significant energy savings and lower pump horsepower requirements. The projected figures depend on the system operating conditions. If these parameters are known, we would be pleased to compute the future savings possible with HOBAS pipes on your project. Please contact us.

QHOBAS / QExisting

HOBAS Relining Pipe Flow Coefficients, n		Host Pipe Existing Flow Coefficient, n								
		0.013	0.014	0.015	0.016	0.017	0.018	0.020	0.022	0.024
18	0.009	0.722	0.777	0.833	0.888	0.944	0.999	1.110	1.221	1.332
into	0.010	0.649	0.699	0.749	0.799	0.849	0.899	0.999	1.099	1.199
24	0.011	0.590	0.636	0.681	0.727	0.772	0.817	0.908	0.999	1.090
20	0.009	0.961	1.035	1.109	1.183	1.257	1.331	1.479	1.627	1.774
into	0.010	0.865	0.932	0.998	1.065	1.131	1.198	1.331	1.464	1.597
24	0.011	0.786	0.847	0.907	0.968	1.028	1.089	1.210	1.331	1.452
24	0.009	0.860	0.926	0.992	1.059	1.125	1.191	1.323	1.456	1.588
into	0.010	0.774	0.834	0.893	0.953	1.012	1.072	1.191	1.310	1.429
30	0.011	0.704	0.758	0.812	0.866	0.920	0.974	1.083	1.191	1.299
30	0.009	0.945	1.017	1.090	1.163	1.235	1.308	1.453	1.599	1.744
into	0.010	0.850	0.916	0.981	1.046	1.112	1.177	1.308	1.439	1.570
36	0.011	0.773	0.832	0.892	0.951	1.011	1.070	1.189	1.308	1.427
36	0.009	1.008	1.086	1.163	1.241	1.318	1.396	1.551	1.706	1.861
into	0.010	0.907	0.977	1.047	1.117	1.186	1.256	1.396	1.535	1.675
42	0.011	0.825	0.888	0.952	1.015	1.079	1.142	1.269	1.396	1.523
42	0.009	1.057	1.139	1.220	1.301	1.383	1.464	1.627	1.789	1.952
into	0.010	0.952	1.025	1.098	1.171	1.244	1.318	1.464	1.610	1.757
48	0.011	0.865	0.932	0.998	1.065	1.131	1.198	1.331	1.464	1.597
48	0.009	1.103	1.187	1.272	1.357	1.442	1.527	1.696	1.866	2.036
into	0.010	0.992	1.069	1.145	1.221	1.298	1.374	1.527	1.679	1.832
54	0.011	0.902	0.972	1.041	1.110	1.180	1.249	1.388	1.527	1.666
54	0.009	1.140	1.227	1.315	1.403	1.490	1.578	1.754	1.929	2.104
into	0.010	1.026	1.105	1.184	1.263	1.341	1.420	1.578	1.736	1.894
60	0.011	0.933	1.004	1.076	1.148	1.219	1.291	1.435	1.578	1.722
60	0.009	1.145	1.233	1.322	1.410	1.498	1.586	1.762	1.938	2.114
into	0.010	1.031	1.110	1.189	1.269	1.348	1.427	1.586	1.744	1.903
66	0.011	0.937	1.009	1.081	1.153	1.225	1.298	1.442	1.586	1.730
66	0.009	1.173	1.264	1.354	1.444	1.534	1.625	1.805	1.986	2.166
into	0.010	1.056	1.137	1.218	1.300	1.381	1.462	1.625	1.787	1.949
72	0.011	0.960	1.034	1.108	1.182	1.255	1.329	1.477	1.625	1.772
72	0.009	1.193	1.285	1.376	1.468	1.560	1.652	1.835	2.019	2.202
into	0.010	1.074	1.156	1.239	1.321	1.404	1.487	1.652	1.817	1.982
78	0.011	0.976	1.051	1.126	1.201	1.276	1.351	1.502	1.652	1.802
78	0.009	1.210	1.303	1.396	1.489	1.582	1.675	1.861	2.048	2.234
into	0.010	1.089	1.173	1.256	1.340	1.424	1.508	1.675	1.843	2.010
84	0.011	0.990	1.066	1.142	1.218	1.295	1.371	1.523	1.675	1.828
84	0.009	1.194	1.286	1.378	1.470	1.562	1.653	1.837	2.021	2.204
into	0.010	1.075	1.157	1.240	1.323	1.405	1.488	1.653	1.819	1.984
90	0.011	0.977	1.052	1.127	1.202	1.278	1.353	1.503	1.653	1.804
85	0.009	1.054	1.135	1.216	1.297	1.378	1.459	1.622	1.784	1.946
into	0.010	0.949	1.022	1.095	1.168	1.240	1.313	1.459	1.605	1.751
96	0.011	0.862	0.929	0.995	1.061	1.128	1.194	1.327	1.459	1.592
96	0.009	1.225	1.320	1.414	1.508	1.602	1.697	1.885	2.074	2.262
into	0.010	1.103	1.188	1.273	1.357	1.442	1.527	1.697	1.866	2.036
102	0.011	1.003	1.080	1.157	1.234	1.311	1.388	1.542	1.697	1.851
96	0.009	1.052	1.133	1.214	1.295	1.376	1.457	1.619	1.781	1.942
into	0.010	0.947	1.020	1.093	1.165	1.238	1.311	1.457	1.603	1.748
108	0.011	0.861	0.927	0.993	1.060	1.126	1.192	1.324	1.457	1.589
104	0.009	1.134	1.221	1.308	1.395	1.483	1.570	1.744	1.919	2.093
into	0.010	1.020	1.099	1.177	1.256	1.334	1.413	1.570	1.727	1.884
114	0.011	0.928	0.999	1.070	1.142	1.213	1.284	1.427	1.570	1.712
110	0.009	1.143	1.230	1.318	1.406	1.494	1.582	1.758	1.934	2.109
into	0.010	1.028	1.107	1.187	1.266	1.345	1.424	1.582	1.740	1.898
120	0.011	0.935	1.007	1.079	1.151	1.222	1.294	1.438	1.582	1.726
120	0.009	1.152	1.240	1.329	1.417	1.506	1.595	1.772	1.949	1.126
into	0.010	1.036	1.116	1.196	1.276	1.355	1.435	1.596	1.754	1.914
132	0.011	0.942	1.015	1.087	1.160	1.232	1.305	1.450	1.595	1.740

* HOBAS diameters are nominal for 36psi stiffness   ** Existing sewer assumed full size. Nominal Diameter = I.D.

Joint Designs

Several joint designs are available to meet the requirements of many different applications. The FWC coupling is normally utilized for direct bury, aboveground, and some other installations. For sliplining, jacking, and tunnel installations, special joints are available. Closure couplings are available for tie-ins. Joint dimensions are given in Appendix C.

Joining Forces for HOBAS Couplings

Approximate average straight alignment (pounds)		
Nominal Pipe Size (in)	Avg. FWC Joining Force (lbs.)	Flush and LPB (lbs.)
18	3150	2150
20	3500	2350
24	4200	2850
27	4725	3200
28	4900	3300
30	5250	3550
33	5775	3900
36	6300	4250
41	7175	4800
42	7350	4950
44	7700	5150
45	7875	5300
48	8400	5650
51	8925	6000
54	9450	6350
57	9975	6700
60	10500	7050
63	11025	7400
66	11550	7750
69	12075	8100
72	12600	8450
78	13650	9150
84	14700	9850
85	14875	9950
90	15750	10550
96	16800	11250
104	18200	12200
110	19250	12850
120	21000	14050
126	22000	14700

Joint Selection

Installation	Service: Non-Pressure	Service: Pressure
Direct Bury	FWC Coupling	FWC Coupling
Sliplining	Low Profile Bell-Spigot*	Pressure Relining
Jacking	Flush Bell-Spigot	Flush FWC Coupling
Aboveground	FWC Coupling	FWC Coupling
Tunnel Carrier Pipe	Flush Bell-Spigot**	Pressure Relining
Tie-ins	Closure Coupling	Steel Mechanical Coupling

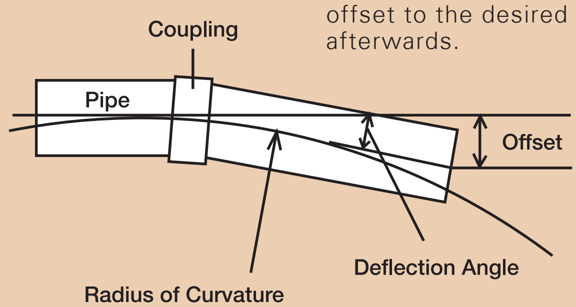
* May use flush bell-spigot joint in very tight fit situations.
** May use FWC coupling in some situations.

Minimum Radius of Curvature for Various Deflected Joints

Max Deflected Angle in Degrees	Max Offset (inches)			Min Radius of Curvature (feet)		
	Section Length (feet)			Section Length (feet)		
	5	10	20	5	10	20
3	3	6	12	95	191	382
2	2	4	8	143	286	573
1.75	1.75	3.5	7	164	327	655
1.5	1.5	3	6	191	382	764
1.25	1.25	2.5	5	229	458	917
1	1	2	4	286	573	1146
0.75	0.75	1.5	3	383	764	1528
0.5	0.5	1	2	573	1146	2292

* See specific joints for capability

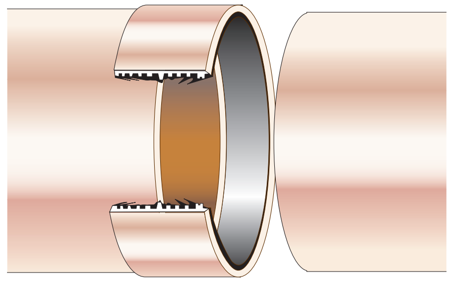
Note: Always join pipes in "straight" alignment and then offset to the desired angle afterwards.



FWC Joint Gap & Angular Deflection

Diameter (inches)	Coupling Width (inches)*	Joint Gap (inches)	Max Deflection Angle, (degrees)
18-20	8	1	3
24-33	10	1	2
36-42	10	1	1.5
44-54	10	1	1
57-60	11.5	1	1
63-78	11.5	1	0.75
84-126	13.75	1	0.5

*This is just a summary table. Contact HOBAS for specific diameter capability.
**The gap is measured from center register to pipe end.



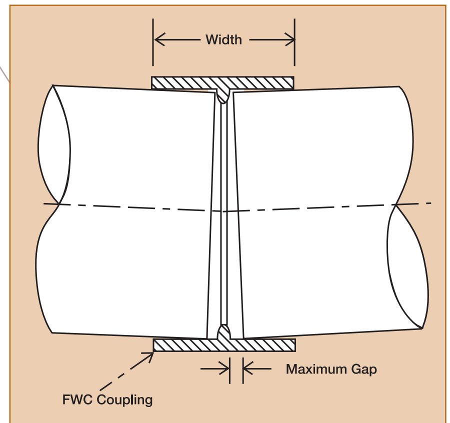
FWC coupling.

FWC Coupling

Description & Capability

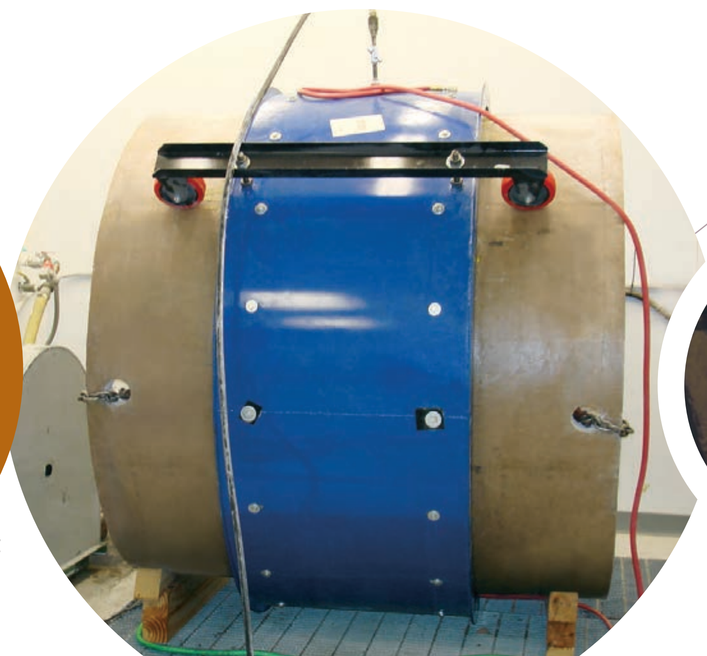
The FWC coupling is a structural filament wound sleeve overwrapped and mechanically locked to an internal full-face elastomeric membrane. The sealing design includes both lip and compression elements so the joint is suitable for both non-pressure and for pressure service up to 250 psi. The coupling is factory assembled to one end of each pipe for ease of use in the field.

Per the performance requirements of ASTM D4161, the FWC joint will remain leak-free from twice the rated class pressure to a -0.8 atmosphere vacuum under pressure even when angularly turned and vertically deflected. HOBAS pipes, because of their constant OD and their centrifugally cast mold smooth exterior surface, may be joined with the FWC coupling at any place along their entire length with no preparation or machining other than chamfering of the pipe ends.



HOBAS FWC coupling.

HOBAS FWC couplings are tested internally and externally (shown) to prove leak-free capability.

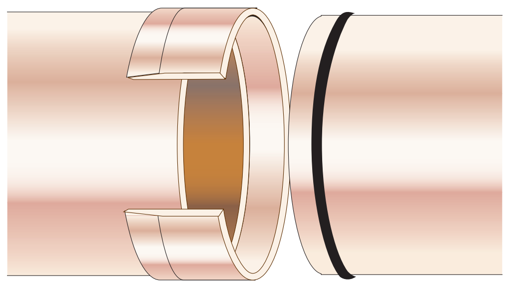


Pushing home HOBAS FWC coupling with a backhoe bucket makes assembly fast & easy.

Low Profile Bell-Spigot

Rubber-ring-sealed low profile bell-spigot joints provide a positive seal.

Description & Capability
The low profile bell-spigot joint consists of an integral straight bell fixed to one pipe end that seals to the spigot end of another pipe by compressing an elastomeric gasket contained in a groove on the spigot. This joint is intended for sliplining applications for non-pressure service. The bell OD is smaller than the OD of the FWC coupling. See Appendix C for dimension details. Joining force is substantially less than the FWC coupling joint.



Low profile bell-spigot (LPB).

Minimum Joint Angular Deflection Capability

Diameter (in)	Max Angle
18 to 30	2º
33 to 45	1.5º
48 to 126	1º

*This is just a summary table. Contact HOBAS for specific diameter capability.

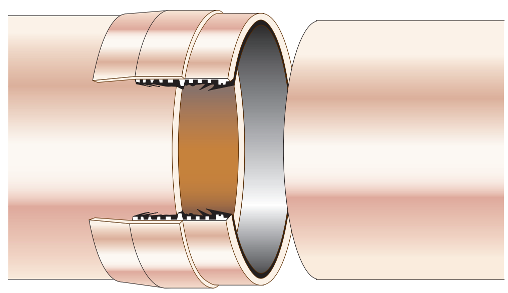
Pressure Relining

Description & Capability
The pressure relining joint consists of a structural filament wound sleeve overwrapped and mechanically locked to an internal full-face elastomeric membrane. Like the FWC coupling, the sealing design includes both lip and compression elements, so the joint is suitable for both non-pressure and for pressure service up to 250 psi for sliplining installations.

The coupling is fixed permanently at the factory to one end of each pipe and is protected from sliding abrasion by an overwrap. Each mating spigot is chamfered at the pipe end to aid assembly.

The joint OD is slightly greater than the FWC coupling OD See Appendix C for dimension details.

Joint angular deflection limits and joining force are similar to the FWC coupling.

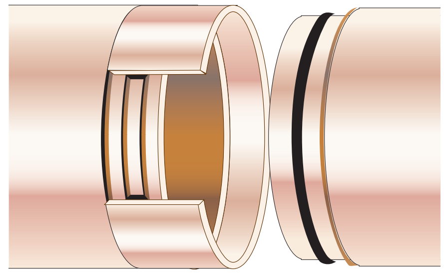


Pressure relining.

Flush Bell-Spigot

Description & Capability

The flush bell-spigot joint consists of an integral straight bell fixed to one pipe end that seals to the spigot end of another pipe by compressing an elastomeric gasket contained in a groove on the spigot. The joint has approximately the same OD as the pipe, so when assembled, the joint is essentially flush with the pipe outside surface. It is designed for nonpressure service in jacking and tunnel carrier installations, although it may be used in nonpressure relining applications. Typical allowable joint angular deflection is between 1 and 2 degrees depending on the spacer thickness and joint configuration. Joining force is substantially less than the FWC coupling joint.



Flush bell-spigot.

Flush Joint Gap*

Nominal Diameter (in)	Gap (in)
18 to 28	0.60
30 to 44	0.70
45 to 63	1.36
66 to 126	2.00

* The corresponding angle for each allowable joint gap may be calculated by using the formula: deflection angle in degrees = arctan (gap in inches/O.D.in inches).

* This joint gap is provided for sealing purposes only and does not address installation loads. See Section 14 for installation specific information.

*This is just a summary table. Contact HOBAS for specific diameter capability.

Jacking pipes have rubber-ring-sealed flush bell-spigot joints for quick assembly.

Closure Couplings

Gravity Flow

Closures are Stainless Steel Couplings which are straight, loose collars with internal gasket systems. The joints seal by compressing the gaskets between the natural OD of any HOBAS pipe and the inside of the collar. The typical assembly sequence is shown in Figure 2. Easiest assembly is accomplished with the pipes and coupling in "straight" alignment with an adequate bevel (chamfer) on the outside edge of the pipes to be joined.

Stainless Steel Coupling

This consists of a casing, gasket and a lockpart. The purpose of the casing is to house the gasket and to press it onto the pipe surface when the lockpart is closed. The lockpart is designed to pull the two ends of the casing together circumferentially around the pipe. In order to achieve this, the coupling is labeled with a torque to ensure the gasket is compressed sufficiently against the pipe surface.

Couplings are sold individually, however, a pair are typically utilized at each closure location.

Pressure Systems

To effect closures in force mains, utilize mechanical couplings (with appropriate corrosion protection) such as manufactured by Dresser or Viking-Johnson.

Flush FWC Coupling

The flush FWC coupling joint consists of a reduced diameter FWC coupling fixed to one pipe end (in a recess) that seals to the spigot (recessed) end of another pipe by compressing the elastomeric gasket contained on the inside of the coupling. The joint has approximately the same OD as the pipe, so when assembled, the joint is essentially flush with the pipe outside surface. It is designed for pressure service in jacking installations. Allowable angular deflection limits and joining force are similar to the FWC coupling.

Stainless steel closure coupling.

Note: When using mechanical joints, torque bolts to the minimum needed for sealing - maximum 25 ft-lbs.

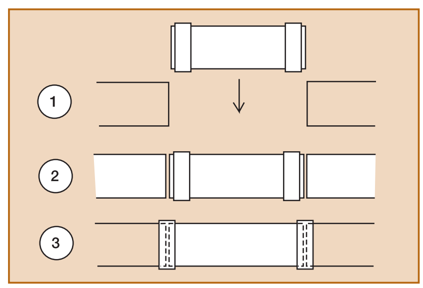
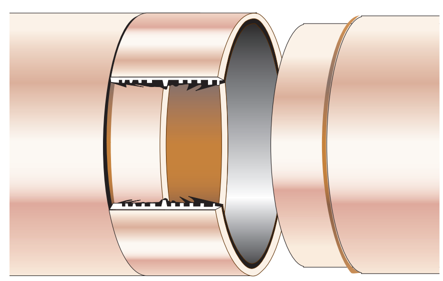


FIGURE 2 - Closure coupling installation & assembly.



Flush FWC Coupling.

Pressure jacking pipes' leak-free, flush joints.

Connections to Other Pipe Material Systems

Connections to other pipe material systems may be accomplished by several methods. Because of compatible OD's, HOBAS pipes, 18" to 48", may be joined directly with ductile iron pipes using either our couplings or ductile iron gasketed joints. In some diameters and applications, Fernco couplings may be suitable. Additionally, HOBAS Pipe USA can frequently custom fabricate the mating bell or spigot for other gasket-sealed systems when the proper dimensions are known. Further, custom fabricated mechanical couplings capable of connecting pipes of different OD's maybe utilized. Although typically the most expensive method, flanges built to ANSI or other drilling specs may also be used. Contact us regarding suitability of or experience with other procedures.

Note: When using mechanical joints, torque bolts to the minimum needed for sealing - maximum 25 ft.-lbs.

Fiberglass bell fabricated to mate to RCP spigot.

Special spigot end to join with RCP bell.

Joining HOBAS pipes (left) to ductile iron with a HOBAS FWC coupling.

HOBAS pipes' OD is compatible with DI joints from 18" to 48".

General

Figure 3 shows the general configuration of standard HOBAS Pipe USA fittings, although almost any mitered fitting can be constructed. These fittings are available for all non-pressure and for many pressure applications. All branch fittings (tees, wyes) must be prevented from deforming. Typically this is accomplished by concrete encasement. Pressure applications will require thrust restraints and may require full encasement in reinforced concrete to resist deformation due to internal pressure. Contact HOBAS Pipe USA for assistance to determine details and requirements for your specific situation. Dimensions for standard fittings are given in Appendix E. Details for diameter combinations and angles not shown or for other fitting configurations are available upon request.

Almost any fitting configuration and angle can be constructed with HOBAS fiberglass reinforced polymer mortar pipe.

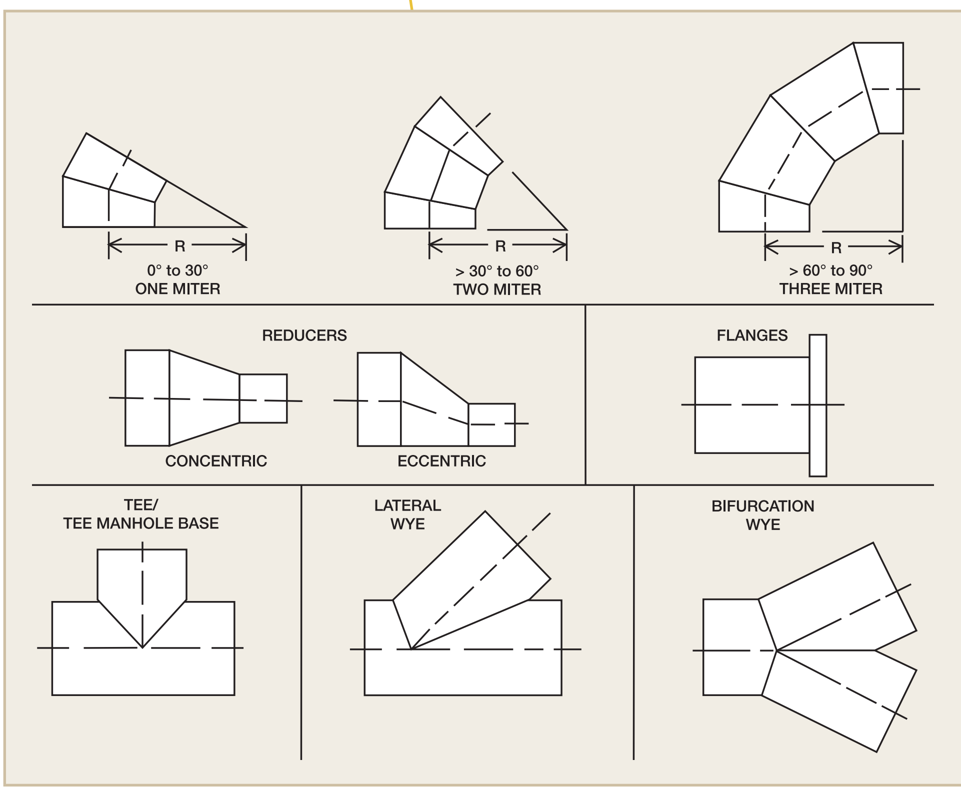


FIGURE 3 - Fittings

HOBAS pipe fittings
may be field connected
with any of our coupling
or flange options.

Quality flange
connections
are routine.

Compatibility

HOBAS Pipe USA pipes are dimensionally compatible with standard ductile iron fittings (18″ to 48″). Corrosion protection consistent with project conditions should be provided for these parts, if used. Stainless steel or fusion bonded epoxy-coated steel fittings may also be suitable.

Installation

HOBAS Pipe USA fiberglass fittings are designed to join our pipe using our standard FWC coupling or one of our other gasket-sealed joints (Section 8). Adequate thrust restraint(s) should be provided in pressure systems.

HOBAS pipes can be used with a wide variety of commercially available manholes including:

- HOBAS tee base system
- Precast concrete
- Cast-in-place concrete

Others may be adaptable. Please consult us for assistance.

HOBAS Tee Base System

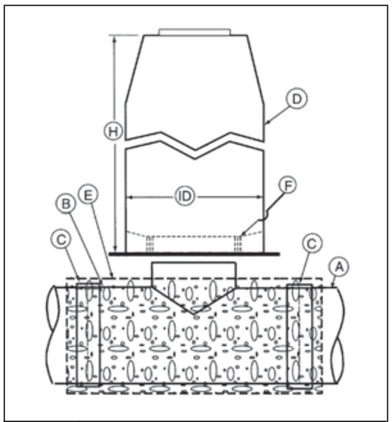
Description & Versatility

The HOBAS tee base manhole system consists of a HOBAS tee base and a one-piece fiberglass riser (two options available - Figures 4 & 5). As shown, the manhole in Figure 5 is not suitable for traffic loading, although options for that condition are available. Consult manufacturer for limitations on riser loading and flat top weight. The tee base is available with mitered angles for alignment changes. The HOBAS tee base may also be used with RCP riser sections.

Assembly & Installation

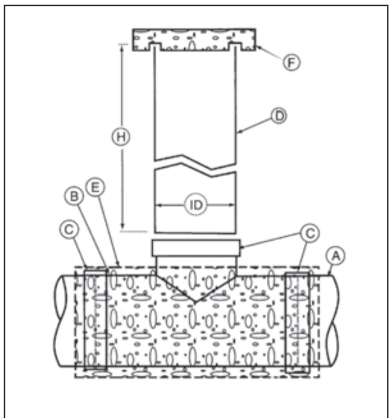
The tee base is assembled to both the mainline sewer pipe and the fiberglass riser section with HOBAS push-on, gasket-sealed FWC couplings (see Section 8). Fully concrete encase the tee base so only the indicated length of the riser neck remains exposed. In most cases, the concrete encasement must be designed to support all riser loads and extend past the nearest couplings. More detailed instructions are available. Place the riser sections after the concrete cures.

HOBAS tee base manholes are available in any size and angle.



Item	Description
A	HOBAS Line Pipe
B	HOBAS Tee Base
C	HOBAS FWC Coupling
D	Fiberglass Riser with Cone
E	Concrete Encasement
F	HOBAS FWC Coupling and Riser Invert
H	Riser Height (2 to 40)
ID	Riser ID (48", 60", 72")

FIGURE 4 – HOBAS Tee Base Manhole System with Riser & Cone



Item	Description
A	HOBAS Line Pipe
B	HOBAS Tee Base
C	HOBAS FWC Coupling
D	HOBAS Riser Pipe
E	Concrete Encasement
F	Concrete Flat Top
H	Riser Height (2 to 20)
ID	Riser ID (Equal to neck Dia.≤ line Dia.)

FIGURE 5 – HOBAS Tee Base Manhole System with Riser & Flat Top

Pre-Cast or Cast-in-place Manholes

HOBAS pipes can be easily connected by traditional methods to many pre-cast or cast-in-place concrete manholes as shown in Figures 6, 7, 8 and 9. Other methods may be suitable. Contact us for assistance.

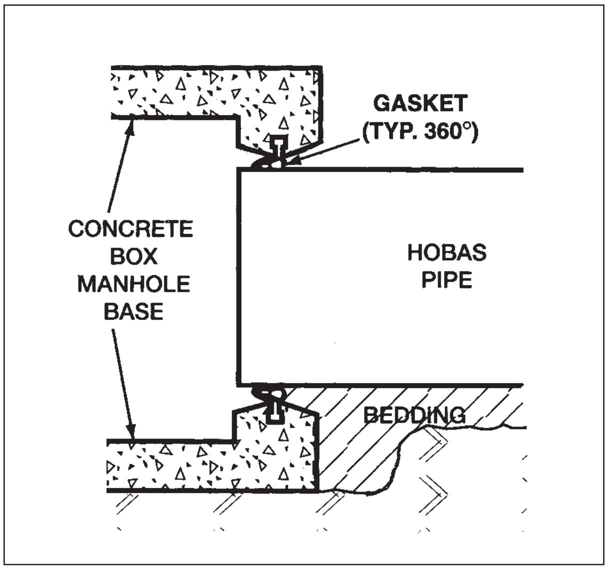


FIGURE 6 – Cast-In Gasket Connection

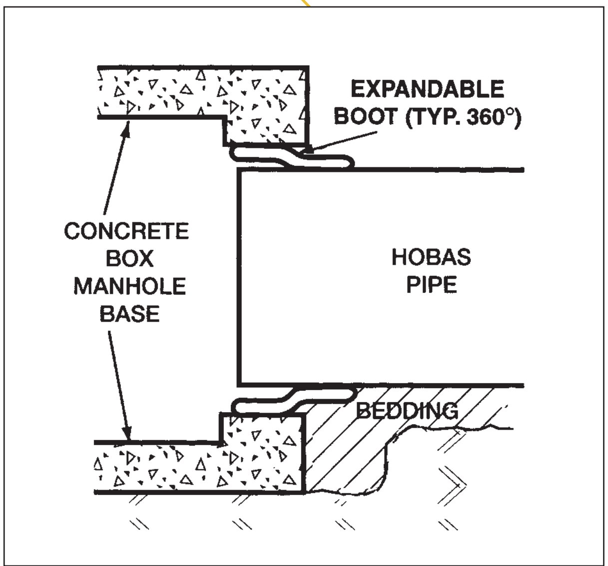


FIGURE 7 – Expandable Boot Seal Connection

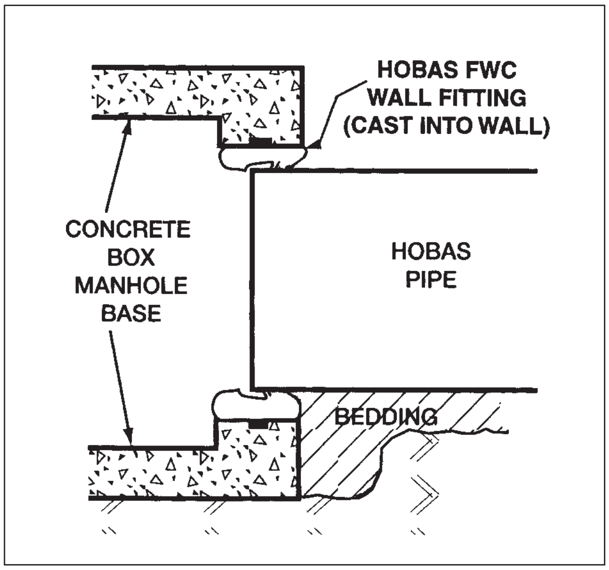


FIGURE 8 - HOBAS FWC Wall Fitting Connection

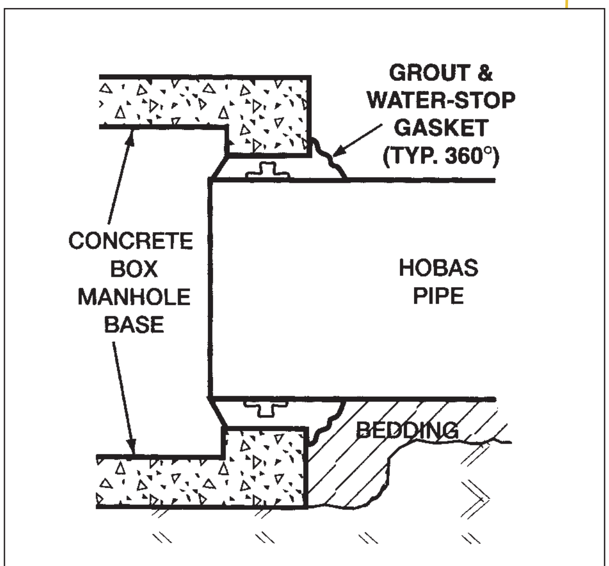
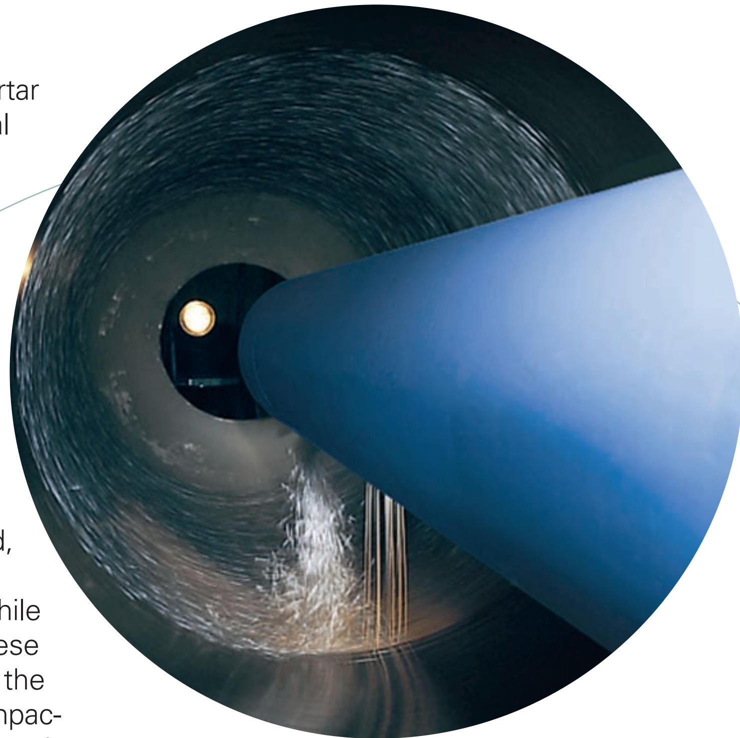


FIGURE 9 – Grout with Water-Stop Connection

* Such as A-Lok or Press-Seal Econoseal
** Such as Kor-N-Seal or Press-Seal PSX
*** In large diameters it may be best to utilize a rigid encasement adjacent to the structure.

Centrifugal Casting Process

HOBAS fiberglass reinforced polymer mortar pipes are produced by a unique centrifugal casting process. The sophisticated pipe wall structure is built up from the outside surface to the interior surface within an external rotating mold. While the mold is revolving at a relatively slow speed, the pipe raw materials of thermosetting resin, reinforcing glass fibers and aggregates are precisely distributed in specific layers at computer controlled rates. The resin is specially formulated to not polymerize during the filling process. When all the material has been positioned, the mold rotational speed is increased to produce centrifugal forces of up to 75g while the polymerization of the resin begins. These forces compress the composition against the mold causing total deaeration and full compaction. In a short time thereafter, the completed, cured pipe is removed from the mold.



Sophisticated materials feeding process for HOBAS centrifugally cast pipe production.

The centrifugal casting process produces a superior, high density fiberglass reinforced polymer mortar pipe product. Because the process is fully computer controlled, all pipes of each size, stiffness and pressure class have very consistent, high quality. All pipes also have a mold smooth exterior surface and an equally smooth, centrifugally cast interior surface.

Because the pipe materials are placed in many layers, the wall structure can be varied to produce the desired and most economical characteristics for most applications, pressure or non-pressure. Typically, the reinforcing glass-fiber layers are predominantly positioned near the two pipe surfaces, on both sides of the bending neutral axis. The intermediate space is comprised primarily of a glass-fiber fortified aggregate and resin mixture. By virtue of this "sandwich" construction, the pipe wall reacts to bending like an I-beam (Figure 10).

The centrifugal casting process and sophisticated pipe wall structure combine to make HOBAS pipes the most technically advanced fiberglass pipes available today.

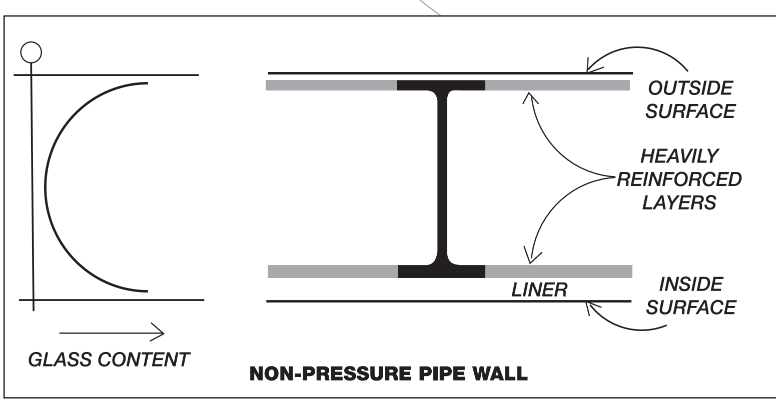


FIGURE 10 - I-Beam Effect In Pipe Wall Bending

Pipe materials feeders are computer controlled. This helps assure consistent high quality. Multiple facilities around the world manufacture CCFRPM pipe using HOBAS technology.

Fabrication of HOBAS FWC high strength coupling.

Reinforcing fibers are distributed in specific layers at computer controlled rates that are monitored continuously.

Quality Control

The constituent raw materials and the pipe production are routinely sampled and tested according to ASTM and AWWA standards to confirm that the desired characteristics and design performance are consistently maintained.

Raw Materials

Resin
All resin shipments have certified test results from the manufacturer for over 10 critical characteristics. Our laboratory randomly verifies these parameters.

Glass Fibers
The lots are checked for moisture, yield and sizing/binder content.

Aggregate
Shipments are monitored for gradation, moisture content and impurities.

The quality of each of the raw materials components is routinely verified.

Raw material properties are checked to ensure suitability.

Process Control

- All process settings are predetermined for each size, type and class of pipe by a multiparameter computer program.
- Process operation, including materials placement and feed rates, is computer controlled to eliminate human errors.
- Actual quantities of materials fed for each pipe are measured automatically and are compared to design minimums to assure proper strengths and other characteristics are achieved.

Pipe materials feed rates and placement are computer controlled for performance consistency.

Finished Pipe

- Verification for all pipes includes pipe wall thickness, liner thickness, degree of cure, component materials' weights, length and visual inspection of both surfaces for imperfections or other defects.
- Pipe production is periodically sampled per ASTM requirements at a rate of no less than 1 percent and tested for stiffness, deflection characteristics and mechanical properties.

Pipe stiffness is tested frequently to assure high performance.

All pipes and couplings are completely inspected.

Standards

Product Standards

HOBAS Pipe USA manufactures pipes according to the applicable U.S. product standards as follows:

Application	Standard
Non-pressure Sanitary Sewers	ASTM D3262
Sewer Force Mains Industrial Effluents (Pressure)	ASTM D3754
Pressure Water Systems	AWWA C950
Fiberglass Pipe Design	AWWA M45

All of these standards include quality control requirements for:

- Workmanship
- Dimensions
- Pipe Stiffness
- Ring Deflection without Cracking
- Ring Deflection without Failure
- Hoop Tensile Strength
- Axial Tensile Strength

Routine Testing

Routine testing on HOBAS Pipe USA production is conducted to assure full compliance is maintained.

Long-Term Performance & Durability

Long-term performance and durability is measured by extended pressure and ring bending tests that continue for a minimum of 10,000 hours. Test results are extrapolated by regression analysis per ASTM standards to determine the 50 year performance value. Safe operating limits are established by applying design factors as given in the AWWA Fiberglass Pipe Design Manual, M45.

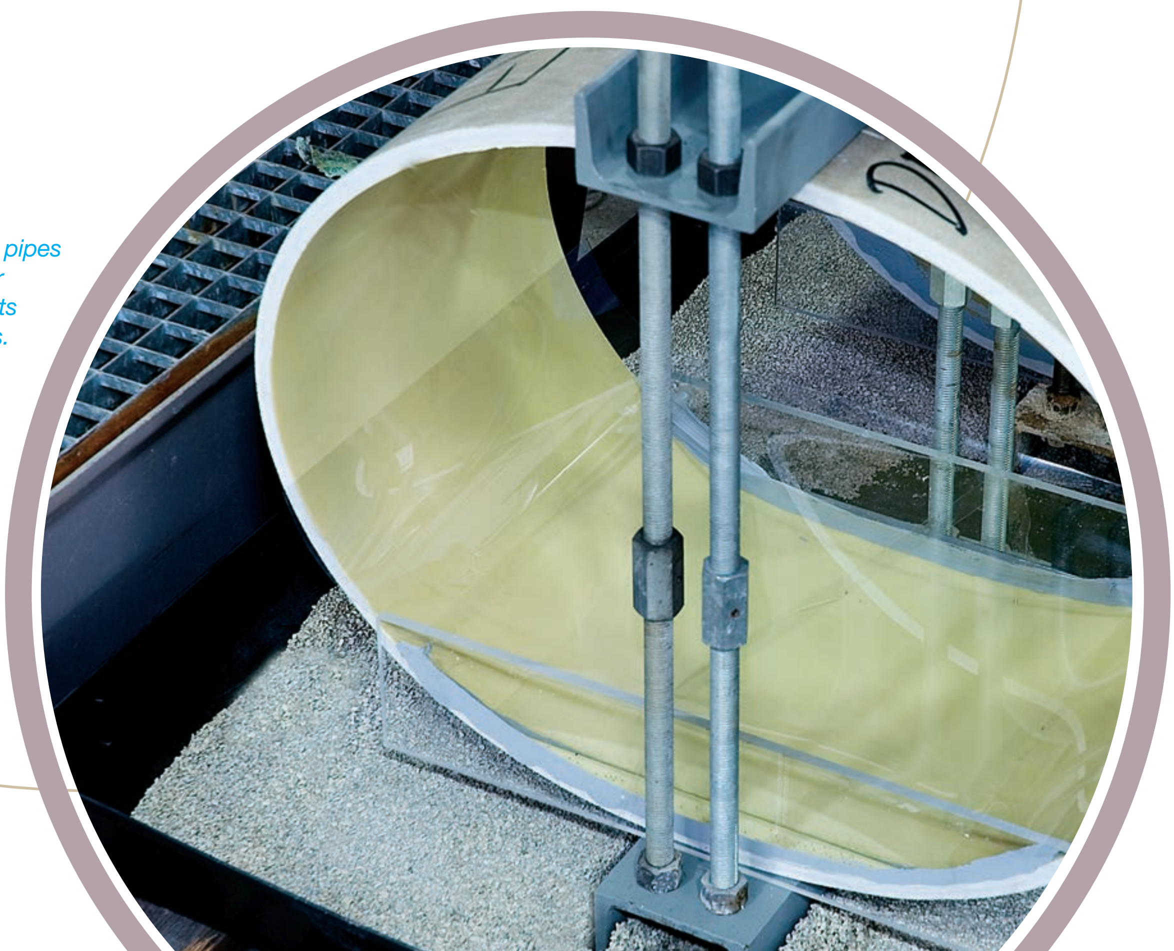
ASTM and AWWA standards define requirements for HOBAS pipes for most applications.

Test Methods

The listed test methods are used to measure the pipe performance and characteristics:

Test Designation	Purpose
ASTM D638	Tensile Properties by Coupon
ASTM D695	Compression by Coupon
ASTM D1599	Quick Burst
ASTM D2290	Tensile Strength by Split Disk
ASTM D2412	Pipe Stiffness
ASTM D2583	Barcol Hardness (cure)
ASTM D2584	Composition by Loss on Ignition
ASTM D2992	HDB Procedure
ASTM D3567	Dimensions
ASTM D3681	Chemical Resistance - Deflected

HOBAS Pipe USA pipes are acid tested per ASTM requirements for sanitary sewers.



A Direct Bury

A1 Trench Construction

A1.1 Trench width

The minimum trench width shall provide sufficient working room at the sides of the pipe to permit accurate placement and adequate compaction of the pipe zone backfill material. Suggested minimum trench dimensions are given in Figure 11.

A1.1.1 Wide trenches

There is no maximum limit on trench width, however, it is required that the pipe zone backfill material be placed and compacted as specified for the full width of the trench or a distance of two diameters on each side of the pipe, whichever is less.

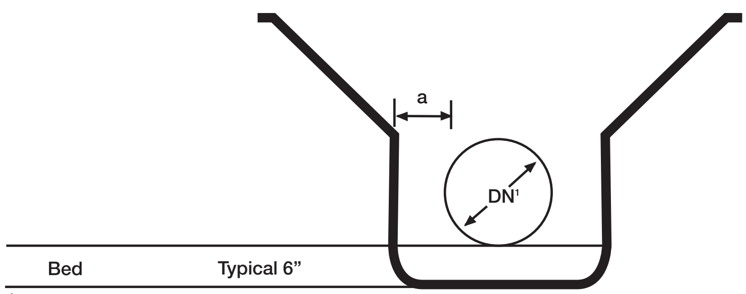
A1.2 Supported trench

When a permanent or temporary trench shoring is used, minimum trench width shall be as per paragraph A1.1 and Figure 11. When using movable trench supports, care should be exercised not to disturb the pipe location, jointing or its embedment. Removal of any trench protection below the top of the pipe and within two pipe diameters is not recommended after the pipe embedment has been compacted unless all voids created by sheeting removal are filled with properly densified embedment material and any loose soils at pipe zone elevation are properly compacted prior to loading the pipe with overburden. When possible, use movable trench supports on a shelf above the pipe with the pipe installed in a narrow, vertical wall subditch.

A1.3 Dewatering

Where conditions are such that running or standing water occurs in the trench bottom or the soil in the trench bottom displays a "quick" tendency, the water should be removed by pumps and suitable means such as well points or underdrain bedding. This system should be maintained in operation until the backfill has been placed to a sufficient height to prevent pipe flotation. Care should be taken that any underdrain is of proper gradation and thickness to prevent migration of material between the underdrain, pipe embedment and native soils in the trench, below and at the sides of the pipe.

DN (in.)	Typical Min. a (in.)	
	SPT[2] ≤ 8	SPT[2] > 8
18 to 20	6	4
24 to 33	9	6
36 to 48	12	8
51 to 72	18	12
78 to 126	24	16



[1] DN is nominal diameter

[2] Standard Penetration Test Blows/ft.per ASTM D1586

FIGURE 11 - Standard Trench Dimensions

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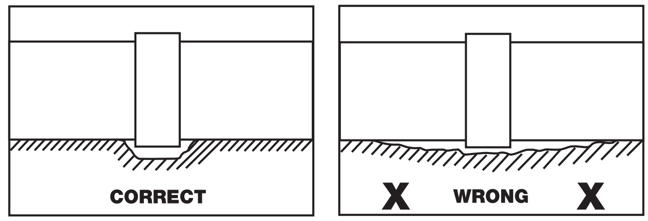
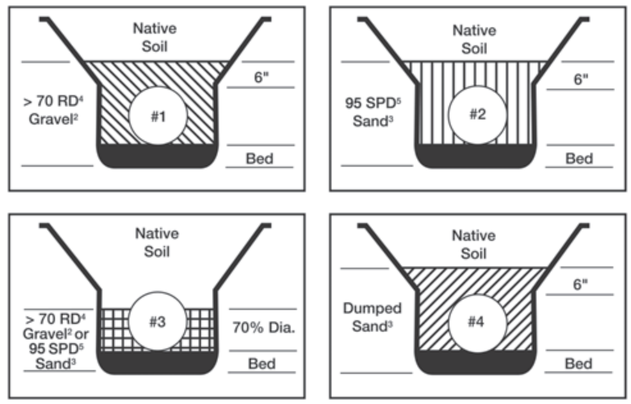
A1.4 Preparation of Trench Bottom

The trench bottom should be constructed to provide a firm, stable and uniform support for the full length of the pipe. Bell holes (Figure 12) should be provided at each joint to permit proper joint assembly and alignment. Any part of the trench bottom excavated below grade should be backfilled to grade and should be compacted as required to provide firm pipe support. When an unstable subgrade condition is encountered which will provide inadequate pipe support, additional trench depth should be excavated and refilled with suitable foundation material. In severe conditions special foundations may be required such as wood pile or sheeting capped by a concrete mat, wood sheeting with keyed-in plank foundation, or foundation material processed with cement or chemical stabilizers. A cushion of acceptable bedding material should always be provided between any special foundation and the pipe. Large rocks and debris should be removed to provide four inches of soil cushion below the pipe and accessories.



Note: After joint assembly, fill the bell holes with bedding material and compact as required.

FIGURE 12 - Bell Holes



[2] Gravel is defined in section 14, paragraph A3
[3] Sand is defined in section 14, paragraph A3
[4] RD is relative density per ASTM D4253.
[5] SPD is standard proctor density per ASTM D698.

FIGURE 13 - Standard Embedment Conditions

A2 Standard Embedment Conditions

Four standard embedment conditions are given in Figure 13. Others may be acceptable. Please consult us for advice on options.

A3 Pipe Zone (Embedment) Backfill Materials

Most coarse grained soils as classified by ASTM D2487, Classification of Soils for Engineering Purposes, are acceptable bedding and pipe zone (embedment) backfill materials as given in the adjacent table.

Specification	Definition	Symbols
Gravel	Gravel or crushed rock	GW, GP GW-GC, GW-GM GP-GC, GP-GM
Sand	Sand or sand-gravel mixtures	SW, SP SW-SC, SW-SM SP-SC, SP-SM

Maximum grain size should typically not exceed 1 to $1^1/_2$ times the pipe wall thickness or $1^1/_2$ inches whichever is smaller.

Well graded materials that will minimize voids in the embedment materials should be used in cases where migration of fines in the trench wall material into the embedment can be anticipated. Alternatively, separate the open graded material from the non-cohesive soil with a filter fabric to prevent migration of the smaller grained soil into the open graded material. Such migration is undesirable since it would reduce the soil density near the pipe zone and thereby lessen the pipe support.

Embedment materials should contain no debris, foreign or frozen materials.

A4 Bedding

A firm, uniform bed should be prepared to fully support the pipe along its entire length (Figure 14). Bedding material should be as specified on Figure 13 and in paragraph A3. Bedding minimum depth should be equal to 25% of the nominal diameter or six inches, whichever is less (Figure 11).

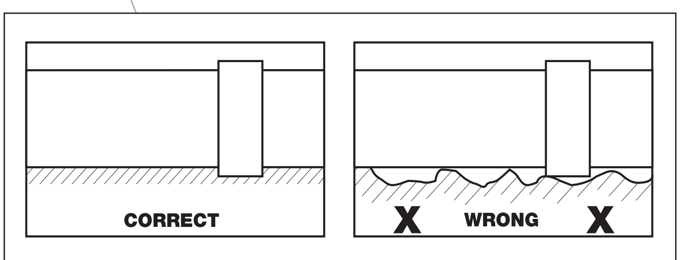


FIGURE 14 - Bedding

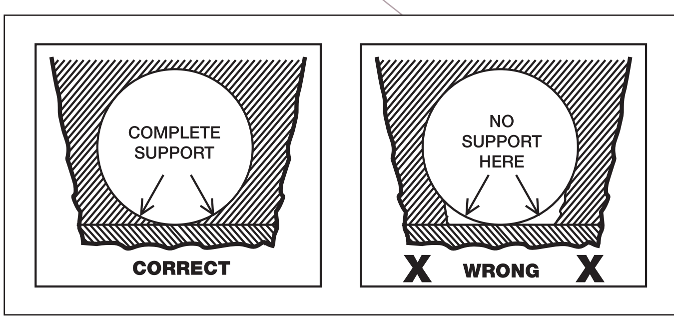


FIGURE 15 - Haunching

A firm trench bottom must be provided (see paragraphs A1.3 and A1.4). Initially place and compact bedding to achieve $^2/_3$ of the total bed thickness (normally four inches). Loosely place the remaining bedding material to achieve a uniform soft cushion in which to seat the pipe invert (bottom).

After joining pipes, assure that all bell holes are filled with the appropriate embedment materials and compacted as specified.

Note: Do not use blocking to adjust pipe grade.

A5 Haunching

A very important factor affecting pipe performance and deflection is the haunching material and its density. Material should be placed and consolidated under the pipe (Figure 15) while avoiding both vertical and lateral displacement of the pipe from proper grade and alignment.

A6 Backfilling

Pipe zone (embedment) material shall be as specified on Figure 13 and in paragraph A3. (It must be the same as the bedding material to prevent potential migration.)

Place and compact the embedment material in lifts to achieve the depths and densities specified on Figure 13. Little or no tamping of the initial backfill directly over the top of the pipe should be done to avoid disturbing the embedded pipe.

Remaining backfill may be the native trench material provided clumps and boulders larger than three to four inches in size are not used until 12 inches of pipe cover has been achieved.

FIGURE 16 - Maximum Cover Depth[1]

NATIVE SOIL [2, 5]	COVER DEPTH[1] (ft.)	EMBEDMENT CONDITION[3] 1	2	3	4
ROCK Stiff to V. Hard Cohesive (Qu ≥ 1 Tsf) Compact to V. Dense Granular (SPT N ≥ 8 bpf)	10 & <	SN[5] 36	SN[5] 36	SN[5] 36	SN[5] 72
	>10 to 20	SN[5] 36	SN[5] 36	SN 46	ALTERNATE INSTALLATION[6]
	>20 to 30	SN 46	SN 46	SN 72	ALTERNATE INSTALLATION[6]
	>30 to 40	SN 72	SN 72	ALTERNATE INSTALLATION[6]	ALTERNATE INSTALLATION[6]
	>40 to 50	SN 72	SN 72	ALTERNATE INSTALLATION[6]	ALTERNATE INSTALLATION[6]
	>50 to 60	SN 90	SN 90	ALTERNATE INSTALLATION[6]	ALTERNATE INSTALLATION[6]
	>60 to 70	SN 120	SN 120	ALTERNATE INSTALLATION[6]	ALTERNATE INSTALLATION[6]
Medium Cohesive (Qu ≥ 0.5 Tsf) Loose Granular (SPT N = 4 to 7 bpf)	10 & <	SN 36	SN 36	SN 36	SN 72
	>10 to 20	SN 46	SN 46	SN 46 / SN 72	ALTERNATE INSTALLATION[6]
	>20 to 30	SN 72	SN 72	ALTERNATE INSTALLATION[6]	ALTERNATE INSTALLATION[6]
	>30 to 40	SN 72	SN 72	ALTERNATE INSTALLATION[6]	ALTERNATE INSTALLATION[6]
Soft Cohesive (Qu ≥ 0.25 Tsf) V. Loose Granular (SPT N = 2 to 3 bpf)	10 & <	SN 36	SN 36	SN 72	ALTERNATE INSTALLATION[6]
	>10 to 20	SN 46 / SN 72	SN 46 / SN 72	ALTERNATE INSTALLATION[6]	ALTERNATE INSTALLATION[6]
	>20 to 30	ALTERNATE INSTALLATION[6]	ALTERNATE INSTALLATION[6]	ALTERNATE INSTALLATION[6]	ALTERNATE INSTALLATION[6]
V. Soft Cohesive (Qu ≥ 0.125 Tsf) V. V. Loose Granular (SPT N ~ 1 bpf)	10 & <	SN 72	SN 72	ALTERNATE INSTALLATION[6]	ALTERNATE INSTALLATION[6]
	>10 to 20	ALTERNATE INSTALLATION[6]	ALTERNATE INSTALLATION[6]	ALTERNATE INSTALLATION[6]	ALTERNATE INSTALLATION[6]

[1] Assuming typ. 1.5 x OD Trench Width (or as in Figure 11)
[2] Soils adjacent to pipe (pipe zone elevation)
[3] Defined in Figure 13
[4] For zero blow (weight of hammer) soils, use Alternate Installation & SN 72
[5] SN is nominal stiffness in PSI
[6] Alternate Installation per section 14, A8-Typ. SN 72 min.

STIFFNESS CLASS KEY
SN 36 | SN 46 | SN 72 | SN 90 | SN 120 | Alternate Installation

A6.1 Maximum Cover Depth
Maximum recommended cover depth is given in Figure 16.

A6.2 Minimum Cover for Traffic Load Application
Minimum recommended cover depth of compacted fill above the pipe crown prior to application of vehicle loads is given in the above chart. Installation in poor soils or at shallower cover depths is possible by using a surface bridging slab or pipe encasement in concrete or similar.

Embedment Condition[1]	Minimum Cover (ft) for HS20 Load[2] SN 18	SN 36 or 46	SN 72
1	4	3	2
2	5	4	3
3	–	5	4
4	–	–	5

[1] See Figure 13.
[2] Installation in poor soils or at shallower cover depths is possible with improved pipe support such as cement stabilized sand or concrete encasement.

A7 Pipe Deflection
Pipe initial vertical cross-section deflection measured within the first 24 hours after completion of all backfilling and removal of dewatering systems, if used, shall not exceed 3% of the original pipe diameter. (See Appendix G for minimum inside diameters.)

Pipe deflection after 30 days should typically not exceed 4% of the original pipe diameter. Maximum long-term pipe deflection is 5% of the original pipe diameter. (See Appendix G for minimum inside diameters.) Maximum long-term deflection for pipes with vinyl ester resin liner is 4%.

For very high stiffness pipes (approx. SN 120 and above), the maximum long-term deflection may be reduced and the 24 hour and 30 day deflection limits also decreased proportionally.

A8 Alternate Installations
Alternate installations, as indicated on Figure 16, include cement stabilized embedment, wide trenching, permanent sheeting, geo-fabrics or combinations of these systems. Installation design for these situations should be engineered to satisfy the specific conditions and circumstances that are present.

B Sliplining

B1 Existing Pipe Preparation

The existing sewer may be maintained in operation during the relining process. Obstructions such as roots, large joint off-sets, rocks or other debris, etc. that would prevent passage or damage the liner pipe sections must be removed or repaired prior to installing the new pipe. Prior to starting the liner insertion, verify the existing pipe diameter is sufficient by pulling a mandrel through the line.

It must be determined that the rehabilitated pipeline will be sufficient structurally to carry the overburden loads for the intended design life.

B2 Liner Pipe Insertion

Liner pipes may be pushed or pulled into the existing pipe. The pipes must be inserted spigot end first with the bell end trailing. Sometimes the leading pipe spigot end is protected by a nose piece designed to ride-up and over off-set joints and other minor inconsistencies or debris in the invert. The pushing force must be applied to the pipe wall end inside of the bell as shown in Figure 17. DO NOT apply the pushing load to the end of the bell. Assure that the safe (F of S ≈ 3) jacking loads given in the above table are not exceeded. For pipes with flush bell-spigot joints, see the table on page 48 for typical allowable push loads. Allowable safe jacking loads may be reduced by point loading (i.e. pushing through curves). Maximum allowable joint angular deflection is given on p. 25.

Low-Profile Bell-Spigot Joint Allowable Compressive Load

Nom. Dia. (in.)	O.D. (in.)		Safe Compressive Load Pushing "Straight" (U.S. Tons)		
	Pipe Wall	Bell	SN 36	SN 46	SN72
18	19.5	20.4	–	25 (SN 62)	27
20	21.6	22.5	–	29	36
24	25.8	26.8	39	44	54
27	28.0	29.0	48	54	66
28	30.0	31.0	56	63	77
30	32.0	33.0	51	58	74
33	34.0	35.0	60	67	85
36	38.3	39.3	82	92	115
41	42.9	44.0	108	122	149
42	44.5	45.6	119	134	162
44	45.9	47.0	128	143	175
45	47.7	48.8	141	159	192
48	50.8	51.9	164	183	220
51	53.9	55.0	188	211	254
54	57.1	58.2	215	239	288
57	60.0	61.2	242	268	322
60	62.9	64.1	271	297	358
63	66.0	67.2	302	333	396
66	69.2	70.4	305	342	412
69	72.5	73.8	339	378	458
72	75.4	76.7	373	417	501
78	81.6	82.9	448	496	595
84	87.0	88.4	520	575	686
85	88.6	90.0	544	601	717
90	94.3	95.7	625	690	820
96	99.5	101.0	702	776	924
104	108.0	109.5	844	930	1101
110	114.0	115.5	950	1050	1240
120	126.0	127.5	1190	1300	1535
126	132.5	134.3	1300	1420	1705

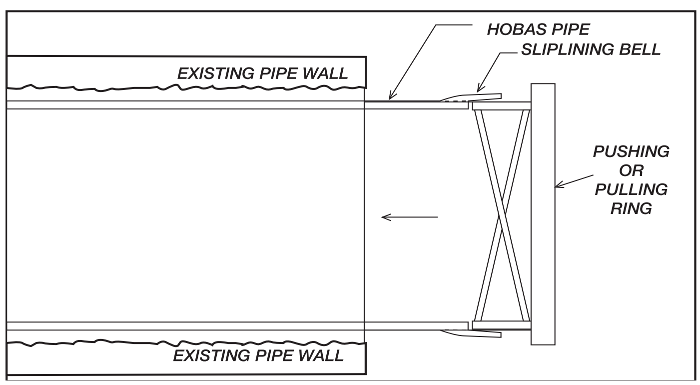


FIGURE 17 - Pipe Insertion

Small access pits needed for sliplining with HOBAS pipes save time, money and surface disruption.

14 | Installation

B3 Laterals

Laterals may be typically reconnected to the new liner pipe using "Inserta Tees" or similar accessories.

B4 Grouting

Grout the annular space between the OD of the installed liner pipe and the ID of the existing pipe with a cement or chemical based grout. Minimum compressive strength of the grout shall be as required to assure the structural adequacy of the rehabilitated pipe. During grout placement, assure that the safe (F of S ≈ 2) grouting pressure given in the table below is not exceeded and that the grout density, lift heights and sewage flow depth are coordinated to control the liner pipe flotation and deformation to within allowable limits.

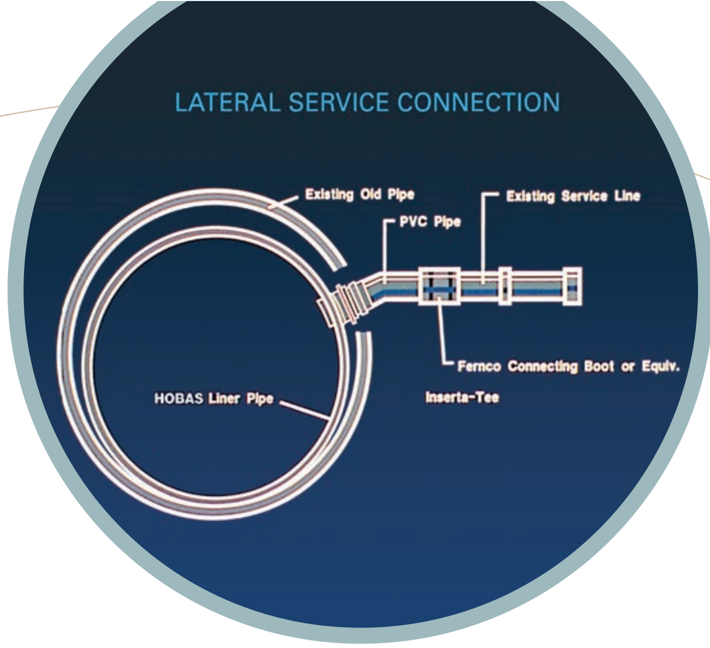
Max. Safe Grouting Pressure (psi)		
	Fluid Flow Level	
Diameter Difference	None or low	Over ½ to full
≤ 5%	SN÷4	SN÷3
≤ 10%	SN÷5	SN÷4
≤ 20%	SN÷6	SN÷5
> 20%	SN÷7	SN÷6

Notes:

Diameter Difference =

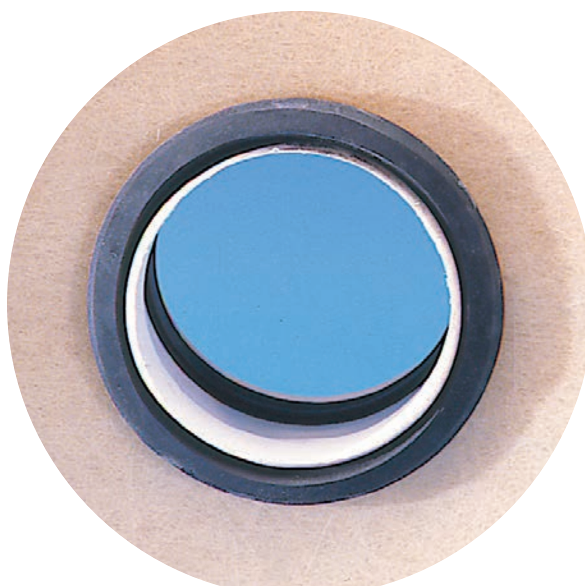
$$\left(\frac{\text{ID Host Pipe - OD Liner Pipe}}{\text{OD Liner Pipe}}\right) \text{X } 100$$

SN is nominal pipe stiffness in psi



Lateral Service reconnection using an "Inserta Tee".

"Inserta Tee" installed in HOBAS Pipe.



Underside (inside) of "Inserta Tee" installation.

C Jacking

C1 General

A boring head begins the tunnel excavation from an access shaft and is pushed along by a hydraulic jacking unit that remains in the pit. The link to the boring head is maintained by adding jacking pipe between the pushing unit and the head. By this procedure, the pipe is installed as the tunnel is bored.

C2 Maximum Allowable Safe Jacking Load

The jacking contractor must control the jacking loads within the safe limits for the pipe. The adjacent table shows allowable safe jacking loads (pushing "straight") for the typical design. However, the ultimate pipe load capacity is the choice and responsibility of the purchaser and can be affected by a number of factors including the anticipated loads, the amount of steering, the amount of over-cut, the amount of lubrication, the pipe section length, the distance of the jacking operation and any point loading. Pipes should be jacked bell-trailing.

C3 Tunnel Diameter

Overcut the tunnel diameter and lubricate the annular space to minimize jacking loads. Take care to control the external pressure to within the safe buckling capacity of the pipe.

C4 Joint & Pipe Deflection

The typical allowable joint angular deflection is between one and two degrees depending on the spacer thickness and joint configuration. Maximum long-term pipe deflection is typically 3% of the original pipe diameter. For pipes with stiffness exceeding 400 psi, a lower deflection limit normally applies.

Jacking Bell-Spigot Joint Allowable Compressive Load

Nom. Dia. (in.)	O.D. (in.)	Nom. Inside Dia. (in.)	Min. Pipe Wall Thickness (in.)	Min. Pipe Wall Thickness @ Gasket Groove (in.)	Allowable Safe Jacking Load Pushing "Straight" (U.S. Tons) F of S = 3.0	F of S = 2.5	Weight (lb/ft)
24	25.8	22.7	1.40	0.99	125	150	107
27	28.0	24.8	1.47	1.06	145	175	120
28	30.0	26.6	1.53	1.12	166	200	137
30	32.0	28.3	1.71	1.21	191	230	159
33	34.0	30.1	1.80	1.29	216	260	179
36	38.3	34.3	1.85	1.31	250	300	208
41	42.9	38.7	1.91	1.32	283	340	245
42	44.5	40.3	1.93	1.33	295	355	255
44	45.9	41.7	1.95	1.34	308	370	263
45	47.7	43.4	1.98	1.35	325	390	280
48	50.8	46.4	2.03	1.37	350	420	306
51	53.9	49.4	2.07	1.38	375	450	333
54	57.1	52.5	2.10	1.39	400	480	361
57	60.0	55.4	2.13	1.40	425	510	380
60	62.9	58.2	2.16	1.41	450	540	408
63	66.0	61.2	2.20	1.42	475	570	438
66	69.2	64.2	2.31	1.43	500	600	478
69	72.5	67.4	2.38	1.47	541	650	512
72	75.4	70.1	2.46	1.52	583	700	553
78	81.6	76.0	2.58	1.60	667	800	634
84	87.0	81.2	2.70	1.68	750	900	701
85	88.6	82.8	2.73	1.69	770	925	727
90 *	94.3	88.2	2.85	1.76	854	1025	800
96 *	99.5	93.1	3.00	1.87	958	1150	886
104*	108.0	101.3	3.13	1.94	1083	1300	1009
110*	114.0	106.9	3.29	2.05	1208	1450	1129
120*	126.0	118.4	3.58	2.25	1470	1765	1350
126*	132.5	124.5	3.76	2.37	1600	1920	1500

Note: Alternate pipe designs are available upon request.
* Lead times may be lengthy, please inquire.

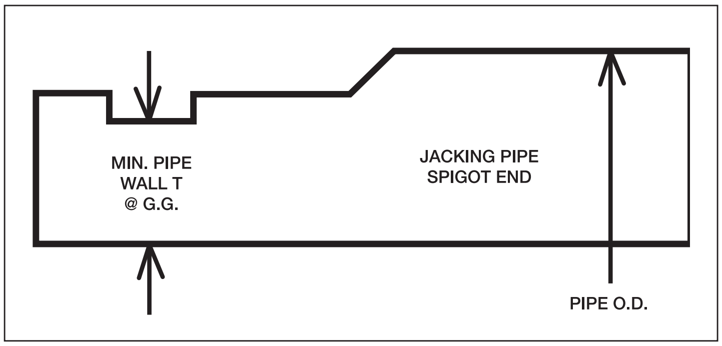


FIGURE 18 - Jacking Pipe Spigot End

HOBAS pipes are the only inherently corrosion resistant, resilient product strong enough to safely withstand the high pushing loads for direct jacking.

D Aboveground

D1 Support Configuration

Recommended pipe support configuration for ambient temperatures is shown on Figures 19 & 20. Pipe diameters and classes shown acceptable (Figure 19) for support scheme A (Figure 20) require only one support location per 20 ft. section. This is best accomplished by a single cradle support on each FWC coupling. These pipes may also be supported as shown in scheme B (Figure 20) with cradles on the pipe wall immediately adjacent to both sides of each coupling, however the mid-point support is not required.

Pipe diameters and classes shown acceptable (Figure 19) for support scheme B (Figure 20) require supports on 10 ft. centers. This must include a double pipe wall cradle bridging each FWC coupling and a mid-span pipe wall cradle support.

Special pipe designs are available for elevated temperature applications or longer support spans.

Pipe Support Configurations*							
PN**	25 & 50			100	150	200	250
DIA. (In.)	SN+ 18	36/46	≥72	≥18	≥36	≥36	≥72
18 & 20	SCHEME A FIGURE 20 10' C - C or SCHEME B FIGURE 20						
24 to 28							
30 to 36							
41 to 45					SCHEME A FIGURE 20		
48 & 51							
54 & 57							
60 & 63							NON-STANDARD
66 to 72							
78 to 126							

FIGURE 19 - Pipe Support Configurations

* At ambient temperature
**PN is pipe pressure class in psi
+ SN is pipe stiffness class in psi

Protection from long-term exposure to ultraviolet rays is typically required to prevent surface degradation to joints and fittings.

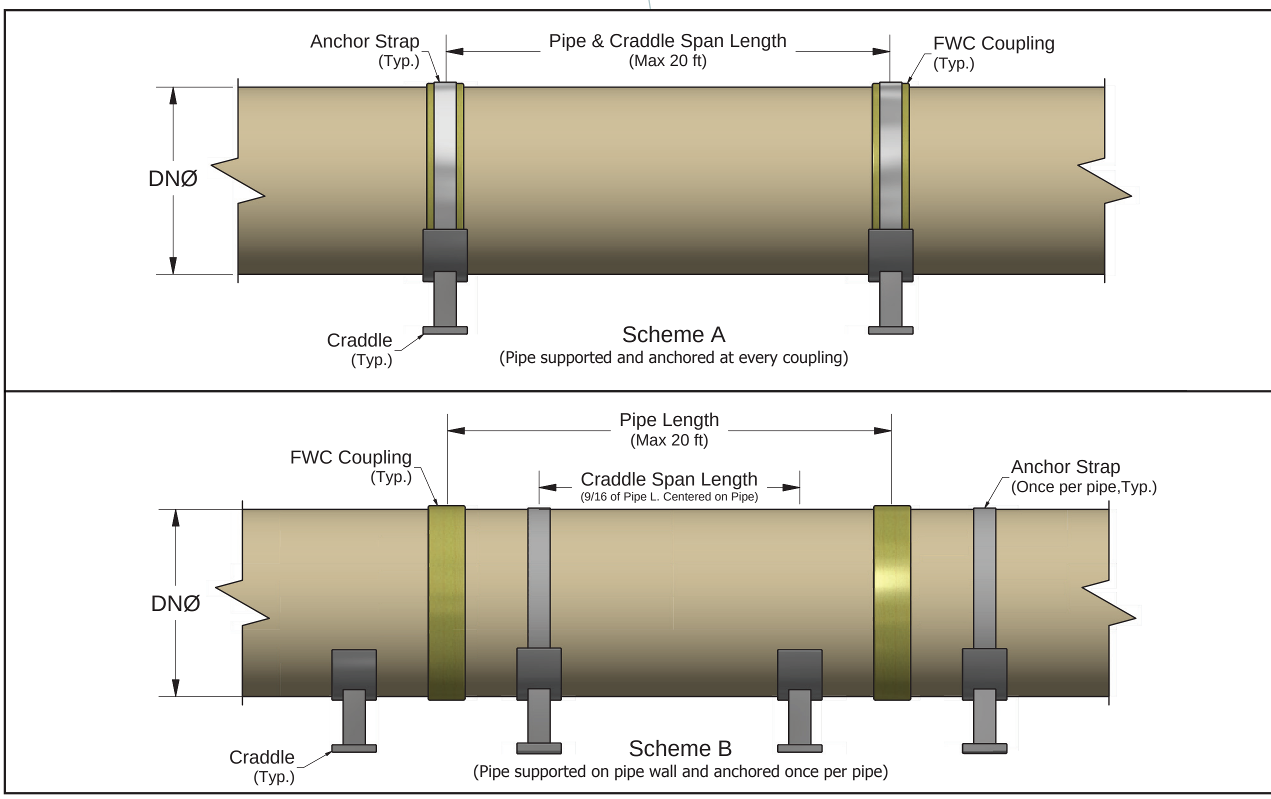


FIGURE 20 - Pipe Support Spacing and Scheme

D2 Cradles

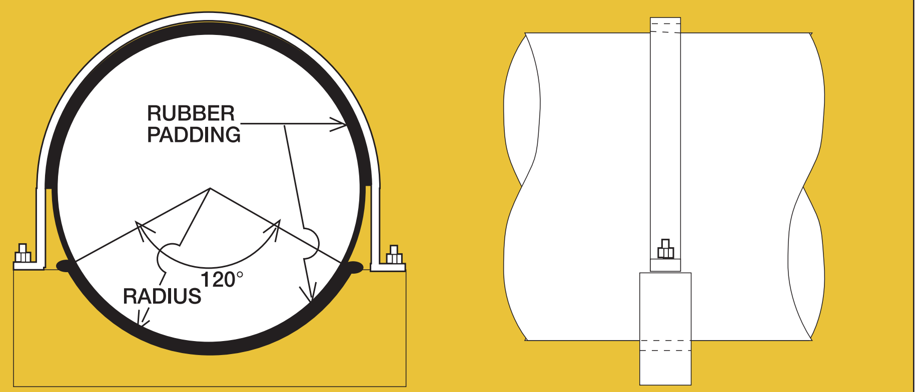
Cradles shall have a minimum 120° support arc and be dimensioned as shown on Figure 21. All cradles shall be faced with a 1/4″ thick rubber padding (approx. 50 to 60 durometer).

D3 Anchors

Both support schemes require one anchored cradle (Figure 21) for each pipe section. The anchor strap over the pipe or coupling shall be padded with rubber to create maximum friction resistance to pipe movement. In support scheme A, all cradle positions (support on FWC coupling) must be anchored. In support scheme B, one pipe wall cradle (near the FWC coupling) per section should be anchored as shown on Figure 20. At the other cradle locations the pipe may be restrained loosely to prevent lateral or vertical movement, but should not be so fixed as to restrict axial sliding.

D4 Pipe Restraint

The pipe support and restraint system must be designed to withstand any unbalanced thrust forces at angularly deflected joints or at fittings that may be developed due to pipe pressurization. Other loads caused by wind, temperature changes, fluid momentum, etc. must also be considered.



SUPPORT LOCATION	CRADLE RADIUS TO RUBBER FACE	MIN. CRADLE WIDTH
ON PIPE WALL (SCHEME B)	PIPE O.D.*/2	18″ to 24″ dia. = 3″ 27″ to 44″ dia. = 4″ 45″ to 78″ dia. = 6″ 84″ to 126″ dia. = 8″
ON FWC COUPLING (SCHEME A)	FWC O.D.**/2	WIDTH OF FWC COUPLING (8″, 10″ or 11 $^1/_2$″)

**See Appendix B for Pipe O.D. Dimensions*
*** See Appendix C for FWC O.D. Dimensions*

FIGURE 21 - Single Cradle w/Anchor Detail

Dimensional consistency makes above ground installations with HOBAS pipe easy.

E Tunnel Carrier

E1 Carrier Pipe Insertion

Carrier pipes may be placed in the tunnel one at a time or may be inserted in a continuous push. If the insertion method involves sliding, the HOBAS carrier pipes must be protected from excessive abrasion. Normally, insert the carrier pipes spigot end first with the pushing force, if used, applied to the pipe wall end inside of the bell as shown in Figure 17 on page 43. DO NOT apply the pushing load to the end of the bell. Assure that the allowable safe (F of S ≈ 3) pushing load given in the adjacent table is not exceeded.

E2 Blocking Schemes

The carrier pipes must be blocked within the tunnel to fix line and grade, and to aid in control of deformation of the carrier pipes during grouting. Two typical blocking schemes are shown in Figures 22 and 23. The actual blocking scheme must be designed so the uplift contact pressure of the blocks on the pipe wall does not exceed allowable limits (maximum contact pressure approximately equal to the pipe stiffness).

Flush Relining Bell-Spigot Joint Allowable Compressive Load

Nom. Dia. (in.)	O.D. (in.)	Min. Pipe Wall Thickness. (in.)	Nom. Pipe Stiffness (psi.)	Min. Pipe Thickness @ Gasket Groove(in.)	Safe Compressive Load Pushing "Straight" (U.S. Tons)	Wt. lb./ft.
20	21.6	0.75	245	0.34	34	48
24	25.8	0.76	160	0.35	42	62
27	28.0	0.76	130	0.35	46	68
28	30.0	0.76	105	0.35	49	73
30	32.0	0.86	130	0.36	54	87
33	34.0	0.87	110	0.37	59	94
36	38.3	0.90	90	0.40	73	110
41	42.9	0.96	83	0.44	91	131
42	44.5	0.99	82	0.46	99	140
44	45.9	1.02	82	0.47	105	148
45	47.7	1.05	80	0.49	114	158
48	50.8	1.09	74	0.51	127	175
51	53.9	1.13	69	0.53	141	192
54	57.1	1.17	65	0.55	155	210
57	60.0	1.21	62	0.58	173	225
60	62.9	1.27	62	0.61	191	251
63	66.0	1.33	62	0.64	211	276
66	69.2	1.45	71	0.66	228	315
69	72.5	1.47	64	0.67	243	335
72	75.4	1.49	59	0.68	257	352
78	81.6	1.53	51	0.71	292	393
84	87.0	1.57	45	0.75	330	430
85	88.6	1.58	43	0.76	342	440
90	94.3	1.66	42	0.82	394	491
96	99.5	1.75	42	0.88	448	547
104	108.0	1.85	39	0.94	521	628
110	114.0	1.94	38	0.99	580	695
120	126.0	2.10	36	1.09	710	829
126	132.5	2.2	36	1.16	780	915

E3 Grouting

Grout the annular space between the tunnel I.D. and the carrier pipe O.D. with a cement or chemical based grout. Minimum compressive strength of the grout shall be as required to assure the structural adequacy of the completed installation. During grout placement, assure that both the safe (F of S ≈ 2) grouting pressure of the carrier pipe (pipe stiffness ÷ 5) is not exceeded and that the grout density, lift heights and blocking scheme are coordinated to control the carrier pipe deformation loads to within allowable limits.

HOBAS pipes' constant OD makes blocking simpler.

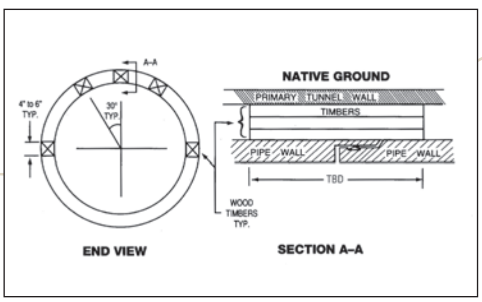


FIGURE 22 - Typical blocking scheme at each flush joint.

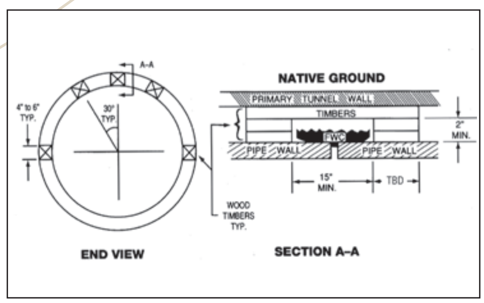


FIGURE 23 - Typical blocking scheme at each FWC coupling joint.

CCFRPM Pipe for Direct Bury Installation - Gravity Service

Part I General

1.01 Section Includes

A. Centrifugally Cast Fiberglass Reinforced Polymer Mortar Pipe. (CCFRPM)

1.02 References

A. ASTM D3262 - Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Sewer Pipe.

B. ASTM D4161 - Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe Joints Using Flexible Elastomeric Seals.

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

D. ASTM D3681 – Standard Test Method for Chemical Resistance of "Fiber glass" Pipe in a Deflected Condition.

E. ASTM D638 – Test Method for Tensile Properties of Plastics.

1.03 Specifications

A. The specifications contained herein govern, unless otherwise agreed upon between purchaser and supplier.

Part 2 Products

2.01 Materials

A. Resin Systems: The manufacturer shall use only polyester resin systems with a proven history of performance in this particular application. The historical data shall have been acquired from a composite material of similar construction and composition as the proposed product.

B. Glass Reinforcements: The reinforcing glass fibers used to manufacture the components shall be of highest quality commercial grade E-glass filaments with binder and sizing compatible with impregnating resins.

C. Silica Sand: Sand shall be minimum 98% silica with a maximum moisture content of 0.2%.

D. Additives: Resin additives, such as curing agents, pigments, dyes, fillers, thixotropic agents, etc., when used, shall not detrimentally effect the performance of the product.

E. Elastomeric Gaskets: Gaskets shall meet ASTM F477 and be supplied by qualified gasket manufacturers and be suitable for the service intended.

2.02 Manufacture and Construction

A. Pipes: Manufacture pipe by the centrifugal casting process to result in a dense, nonporous, corrosion-resistant, consistent composite structure. The interior surface of the pipes exposed to sewer flow shall provide crack resistance and abrasion resistance. The exterior surface of the pipes shall be comprised of a sand and resin layer which provides UV protection to the exterior. Pipes shall be Type 1, Liner 2, Grade 3 per ASTM D3262.

B. Joints: Unless otherwise specified, the pipe shall be field connected with fiberglass sleeve couplings that utilize elastomeric sealing gaskets as the sole means to maintain joint watertightness. The joints must meet the performance requirements of ASTM D4161. Joints at tie-ins, when needed, may utilize gasket-sealed closure couplings.

C. Fittings: Flanges, elbows, reducers, tees, wyes, laterals and other fittings shall be capable of withstanding all operating conditions when installed. They may be contact molded or manufactured from mitered sections of pipe joined by glass-fiber-reinforced overlays. Properly protected standard ductile iron, fusion-bonded epoxy- coated steel and stainless steel fittings may also be used.

D. Acceptable Manufacturer: HOBAS Pipe USA.

2.03 Dimensions

A. Diameters: The actual outside diameter (18" to 48") of the pipes shall be in accordance with ASTM D3262. For other diameters, OD's shall be per manufacturer's literature.

B. Lengths: Pipe shall be supplied in nominal lengths of 20 feet. Actual laying length shall be nominal +1, -4 inches. At least 90% of the total footage of each size and class of pipe, excluding special order lengths, shall be furnished in nominal length sections.

C. Wall Thickness: The minimum wall thickness shall be the stated design thickness.

D. End Squareness: Pipe ends shall be square to the pipe axis with a maximum tolerance of 1/8".

2.04 Testing

A. Pipes: Pipes shall be manufactured and tested in accordance with ASTM D3262.

B. Joints: Coupling joints shall meet the requirements of ASTM D4161.

C. Stiffness: Minimum pipe stiffness when tested in accordance with ASTM D2412 shall normally be 36 psi.

2.05 Customer Inspection

A. The Owner or other designated representative shall be entitled to inspect pipes or witness the pipe manufacturing.

B. Manufacturer's Notification to Customer: Should the Owner request to see specific pipes during any phase of the manufacturing process, the manufacturer must provide the Owner with adequate advance notice of when and where the production of those pipes will take place.

2.06 Packaging, Handling, Shipping

A. Packaging, handling, and shipping shall be done in accordance with the manufacturer's instructions.

Part 3 Execution

3.01 Installation

A. Burial: The bedding and burial of pipe and fittings shall be in accordance with the project plans and specifications and the manufacturer's requirements (Section 14 A of the product brochure)

B. Pipe Handling: Use textile slings, other suitable materials or a forklift. Use of chains or cables is not recommended.

C. Jointing:

1. Clean ends of pipe and coupling components.

2. Apply joint lubricant to pipe ends and elastomeric seals of coupling. Use only lubricants approved by the pipe manufacturer.

3. Use suitable equipment and end protection to push or pull the pipes together.

4. Do not exceed forces recommended by the manufacturer for coupling pipe.

5. Join pipes in straight alignment then deflect to required angle. Do not allow the deflection angle to exceed the deflection permitted by the manufacturer.

D. Field Tests:

1. Infiltration / Exfiltration Test: Maximum allowable leakage shall be per local specification requirements.

2. Low Pressure Air Test: Each reach may be tested with air pressure (max 5 psi). The system passes the test if the pressure drop due to leakage through the pipe or pipe joints is less than or equal to the specified amount over the prescribed time period.

3. Individual Joint Testing: For pipes large enough to enter, individual joints may be pressure tested with a portable tester to 5 psi max. with air or water in lieu of line infiltration, exfiltration or air testing.

4. Deflection: Maximum allowable long-term deflection is normally 5% of the initial diameter.

CCFRPM Pipe for Sliplining Installation - Gravity Service

PART 1 General

1.01 Section Includes

A. Centrifugally Cast Fiberglass Reinforced Polymer Mortar Pipe. (CCFRPM)

1.02 References

A. ASTM D3262 - Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Sewer Pipe.

B. ASTM D4161 - Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe Joints Using Flexible Elastomeric Seals.

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

D. ASTM D3681 – Standard Test Method for Chemical Resistance of "Fiber glass" Pipe in a Deflected Condition.

E. ASTM D638 – Test Method for Tensile Properties of Plastics.

1.03 Specifications

A. The specifications contained herein govern, unless otherwise agreed upon between purchaser and supplier.

PART 2 Products

2.01 Materials

A. Resin Systems: The manufacturer shall use only polyester resin systems with a proven history of performance in this particular application. The historical data shall have been acquired from a composite material of similar construction and composition as the proposed product.

B. Glass Reinforcements: The reinforcing glass fibers used to manufacture the components shall be of highest quality commercial grade E-glass filaments with binder and sizing compatible with impregnating resins.

C. Silica Sand: Sand shall be minimum 98% silica with a maximum moisture content of 0.2%.

D. Additives: Resin additives, such as curing agents, pigments, dyes, fillers, thixotropic agents, etc., when used, shall not detrimentally effect the performance of the product.

E. Elastomeric Gaskets: Gaskets shall meet ASTM F477 and be supplied by qualified gasket manufacturers and be suitable for the service intended.

2.02 Manufacture and Construction

A. Pipes: Manufacture pipe by the centrifugal casting process to result in a dense, nonporous, corrosion-resistant, consistent composite structure. The interior surface of the pipes exposed to sewer flow shall be manufactured using a resin which shall provide crack resistance and abrasion resistance. The exterior surface of the pipes shall be comprised of a sand and resin layer which provides UV protection to the exterior. Pipes shall be Type 1, Liner 2, Grade 3 per ASTM D3262.

B. Joints: Unless otherwise specified, the pipe shall be field connected with low-profile, fiberglass bell-spigot joints or flush fiberglass bell-spigot joints, when the fit requires. Either joint shall utilize elastomeric sealing gaskets as the sole means to maintain joint water tightness and shall meet the performance requirements of ASTM D4161. Joints at tie-ins, when needed, may utilize gasket-sealed closure couplings.

C. Fittings: Flanges, elbows, reducers, tees, wyes, laterals and other fittings shall be capable of withstanding all operating conditions when installed. They may be contact molded or manufactured from mitered sections of pipe joined by glass-fiber-reinforced overlays.

D. Acceptable Manufacturer: HOBAS Pipe USA.

2.03 Dimensions

A. Diameters: The actual outside diameter (18" to 48") of the pipe barrel shall be in accordance with ASTM D3262. For other diameters, OD's shall be per manufacturer's literature.

B. Lengths: Pipe shall be supplied in nominal lengths of 20 feet. When required by radius curves, pit size, sewer irregularities, etc., pipe shall be supplied in nominal lengths of 10 feet or other even divisions of 20 feet. Actual laying length shall be nominal +1, -4 inches. At least 90% of the total footage of each size and class of pipe, excluding special order lengths, shall be furnished in nominal length sections.

C. Wall Thickness: The minimum wall thickness shall be the stated design thickness.

D. End Squareness: Pipe ends shall be square to the pipe axis with a maximum tolerance of 1/8".

2.04 Testing

A. Pipes: Pipes shall be manufactured and tested in accordance with ASTM D3262.

B. Joints: Joints shall meet the requirements of ASTM D4161.

C. Stiffness: Minimum pipe stiffness when tested in accordance with ASTM D2412 shall normally be 36 psi (may range from 18 psi to 46 psi and sometimes higher).

2.05 Customer Inspection

A. The Owner or other designated representative shall be entitled to inspect pipes or witness the pipe manufacturing.

B. Manufacturer's Notification to Customer: Should the Owner request to see specific pipes during any phase of the manufacturing process, the manufacturer must provide the Owner with adequate advance notice of when and where the production of those pipes will take place.

2.06 Packaging, Handling, and Shipping

A. Packaging, handling, and shipping shall be done in accordance with the manufacturer's instructions.

PART 3 Execution

3.01 Installation

A. Installation: The installation of pipe and fittings shall be in accordance with the project plans and specs and the manufacturer's requirements (Section 14 B of product brochure).

B. Pipe Grouting: Annular space grouting shall not damage the liner and shall conform to the manufacturer's requirements (Section 14 B of product brochure).

C. Pipe Handling: Use textile slings, other suitable materials or a forklift. Use of chains or cables is not recommended.

D. Jointing

1. Clean ends of pipe and joint components.

2. Apply joint lubricant to the bell interior surface and the elastomeric seals. Use only lubricants approved by the pipe manufacturer.

3. Use suitable equipment and end protection to push or pull the pipes together.

4. Do not exceed forces recommended by the manufacturer for joining or pushing pipe .

5. Join pipes in straight alignment then deflect to the required angle. Do not allow the deflection angle to exceed the deflection permitted by the manufacturer.

E. Field Tests

1. Acceptance of the installed liner shall be based on a videotaped TV inspection after grouting to assure all joints are properly assembled, no damage exists and that any leakage or deformation is within the allowable limits.

CCFRPM Pipe for Jacking Installation - Gravity Service

Part 1 General

1.01 Section Includes

A. Centrifugally Cast Fiberglass Reinforced Polymer Mortar Pipe. (CCFRPM)

1.02 References

A. ASTM D3262 - Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Sewer Pipe.

B. ASTM D4161 - Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe Joints Using Flexible Elastomeric Seals.

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

D. ASTM D3681 – Standard Test Method for Chemical Resistance of "Fiber glass" Pipe in a Deflected Condition.

E. ASTM D638 – Test Method for Tensile Properties of Plastics.

1.03 Specifications

A. The specifications contained herein govern, unless otherwise agreed upon between purchaser and supplier.

Part 2 Products

2.01 Materials

A. Resin Systems: The manufacturer shall use only polyester resin systems with a proven history of performance in this particular application. The historical data shall have been acquired from a composite material of similar construction and composition as the proposed product.

B. Glass Reinforcements: The reinforcing glass fibers used to manufacture the components shall be of highest quality commercial grade E-glass filaments with binder and sizing compatible with impregnating resins.

C. Silica Sand: Sand shall be minimum 98% silica with a maximum moisture content of 0.2%.

D. Additives: Resin additives, such as curing agents, pigments, dyes, fillers, thixotropic agents, etc., when used, shall not detrimentally effect the performance of the product.

E. Elastomeric Gaskets: Gaskets shall meet ASTM F477 and be supplied by qualified gasket manufacturers and be suitable for the service intended.

2.02 Manufacture and Construction

A. Pipes: Manufacture pipe by the centrifugal casting process to result in a dense, nonporous, corrosion-resistant, consistent composite structure. The interior surface of the pipes exposed to sewer flow shall provide crack resistance and abrasion resistance. The exterior surface of the pipes shall be comprised of a sand and resin layer which provides UV protection to the exterior. Pipes shall be Type 1, Liner 2, Grade 3 per ASTM D3262.

B. Joints: Unless otherwise specified, the pipe shall be field connected with fiberglass sleeve couplings or bell-spigot joints that utilize elastomeric sealing gaskets as the sole means to maintain joint watertightness. The joints must meet the performance requirements of ASTM D4161. The joint shall have approximately the same O.D. as the pipe, so when the pipes are assembled, the joints are essentially flush with the pipe outside surface. Joints at tie-ins, when needed, may utilize gasket-sealed closure couplings.

C. Fittings: Flanges, elbows, reducers, tees, wyes, laterals and other fittings shall be capable of withstanding all operating conditions when installed. They may be contact molded or manufactured from mitered sections of pipe joined by glass-fiber-reinforced overlays. Properly protected standard ductile iron, fusion-bonded epoxy- coated steel and stainless steel fittings may also be used.

D. Acceptable Manufacturer: HOBAS Pipe USA.

2.03 Dimensions

A. Diameters: The actual outside diameter (18" to 48") of the pipes shall be in accordance with ASTM D3262. For other diameters, OD's shall be per manufacturer's literature.

B. Lengths: Pipe shall be supplied in nominal lengths of 10 or 20 feet. Actual laying length shall be nominal +1, -4 inches. At least 90% of the total footage of each size and class of pipe, excluding special order lengths, shall be furnished in nominal length sections.

C. Wall Thickness: The minimum wall thickness, measured at the bottom of the spigot gasket groove where the wall cross-section has been reduced, is determined from the maximum jacking load. Minimum factor of safety against jacking force is 2.5 based on straight alignment.

D. End Squareness: Pipe ends shall be square to the pipe axis with a maximum tolerance of 1/16".

2.04 Testing

A. Pipes: Pipes shall be manufactured and tested in accordance with ASTM D3262.

B. Joints: Joints shall meet the requirements of ASTM D4161.

C. Stiffness: Minimum pipe stiffness when tested in accordance with ASTM D2412 shall normally be 140 psi.

2.05 Customer Inspection

A. The Owner or other designated representative shall be entitled to inspect pipes or witness the pipe manufacturing.

B. Manufacturer's Notification to Customer: Should the Owner request to see specific pipes during any phase of the manufacturing process, the manufacturer must provide the Owner with adequate advance notice of when and where the production of those pipes will take place.

2.06 Packaging, Handling, and Shipping

A. Packaging, handling, and shipping shall be done in accordance with the manufacturer's instructions.

Part 3 Execution

3.01 Installation

A. Installation: The installation of pipe and fittings shall be in accordance with the project plans and specifications and the manufacturer's requirements (Section 14 C of product brochure).

B. Pipe Handling: Use textile slings, other suitable materials or a forklift. Use of chains or cables is not recommended.

C. Jointing:

1. Clean ends of pipe and joint components.

2. Apply joint lubricant to the bell interior surface and the elastomeric seals. Use only lubricants approved by the pipe manufacturer.

3. Use suitable equipment and end protection to push the pipes together.

4. Do not exceed forces recommended by the manufacturer for joining or pushing pipe.

D. Field Tests:

1. Infiltration / Exfiltration Test: Maximum allowable leakage shall be per local specification requirements.

2. Low Pressure Air Test: Each reach may be tested with air pressure (max 5 psi). The system passes the test if the pressure drop due to leakage through the pipe or pipe joints is less than or equal to the specified amount over the prescribed time period.

3. Individual Joint Testing: For pipes large enough to enter, individual joints may be pressure tested with a portable tester to 5 psi max. with air or water in lieu of line infiltration, exfiltration or air testing.

4. Deflection: Maximum allowable long-term deflection is typically 3% of the initial diameter.

CCFRPM Pipe for Above Ground Installation - Gravity Service

Part 1 General

1.01 Section Includes

A. Centrifugally Cast Fiberglass Reinforced Polymer Mortar Pipe. (CCFRPM)

1.02 References

A. ASTM D3262 - Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Sewer Pipe.

B. ASTM D4161 - Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe Joints Using Flexible Elastomeric Seals.

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

D. ASTM D3681 – Standard Test Method for Chemical Resistance of "Fiberglass" Pipe in a Deflected Condition.

E. ASTM D638 – Test Method for Tensile Properties of Plastics.

1.03 Specifications

A. The specifications contained herein govern, unless otherwise agreed upon between the purchaser and supplier.

Part 2 Products

2.01 Materials

A. Resin Systems: The manufacturer shall use only polyester resin systems with a proven history of performance in this particular application. The historical data shall have been acquired from a composite material of similar construction and composition as the proposed product.

B. Glass Reinforcements: The reinforcing glass fibers used to manufacture the components shall be of highest quality commercial grade E-glass filaments with binder and sizing compatible with impregnating resins.

C. Silica Sand: Sand shall be minimum 98% silica with a maximum moisture content of 0.2%.

D. Additives: Resin additives, such as curing agents, pigments, dyes, fillers, thixotropic agents, etc., when used, shall not detrimentally effect the performance of the pipe.

E. Elastomeric Gaskets: Gaskets shall meet ASTM F477 and be supplied by qualified gasket manufacturers and be suitable for the service intended.

2.02 Manufacture and Construction

A. Pipes: Manufacture pipe by the centrifugal casting process to result in a dense, nonporous, corrosion-resistant, consistent composite structure. The interior surface of the pipes exposed to sewer flow shall provide crack resistance and abrasion resistance. The exterior surface of the pipes shall be comprised of a sand and resin layer which provides UV protection to the exterior. Pipes shall be Type 1, Liner 2, Grade 3 per ASTM D3262.

B. Joints: Unless otherwise specified, the pipe shall be field connected with fiberglass sleeve couplings that utilize elastomeric sealing gaskets as the sole means to maintain joint watertightness. The joints must meet the performance requirements of ASTM D4161. Joints at tie-ins, when needed, may utilize gasket-sealed closure couplings.

C. Fittings: Flanges, elbows, reducers, tees, wyes, laterals and other fittings shall be capable of withstanding all operating conditions when installed. They may be contact molded or manufactured from mitered sections of pipe joined by glass-fiber-reinforced overlays. Properly protected standard ductile iron, fusion-bonded epoxy- coated steel and stainless steel fittings may also be used.

D. Acceptable Manufacturer: HOBAS Pipe USA.

2.03 Dimensions

A. Diameters: The actual outside diameter (18" to 48") of the pipes shall be in accordance with ASTM D 3262. For other diameters, OD's shall be per manufacturer's literature.

B. Lengths: Pipe shall be supplied in nominal lengths of 20 feet. Actual laying length shall be nominal +1, -4 inches. At least 90% of the total footage of each size and class of pipe, exclud¬ing special order lengths, shall be furnished in nominal length sections.

C. Wall Thickness: The minimum wall thickness shall be the stated design thickness.

D. End Squareness: Pipe ends shall be square to the pipe axis with a maximum tolerance of 1/8".

2.04 Testing

A. Pipes: Pipes shall be manufactured and tested in accordance with ASTM D3262.

B. Joints: Coupling joints shall meet the requirements of ASTM D4161.

C. Stiffness: Minimum pipe stiffness when tested in accordance with ASTM D2412 shall normally be 18 psi.

2.05 Customer Inspection

A. The Owner or other designated representative shall be entitled to inspect pipes or witness the pipe manufacturing.

B. Manufacturer's Notification to Customer: Should the Owner request to see specific pipes during any phase of the manufacturing process, the manufacturer must provide the Owner with adequate advance notice of when and where the production of those pipes will take place.

2.06 Packaging, Handling, Shipping

A. Packaging, handling, and shipping shall be done in accordance with the manufacturer's instructions.

Part 3 Execution

3.01 Installation

A. The installation of pipe and fittings shall be in accordance with the project plans and specifications and the manufacturer's requirements (Section 14 D of the product brochure).

B. Pipe Handling: Use textile slings, other suitable materials or a forklift. Use of chains or cables is not recommended.

C. Jointing:

1. Clean ends of pipe and coupling components.

2. Apply joint lubricant to pipe ends and the elastomeric seals of coupling. Use only lubricants approved by the pipe manufacturer.

3. Use suitable equipment and end protection to push or pull the pipes together.

4. Do not exceed forces recommended by the manufacturer for coupling pipe.

5. Join pipes in straight alignment then deflect to required angle. Do not allow the deflection angle to exceed the deflection permitted by the manufacturer.

D. Field Tests:

1. Infiltration / Exfiltration Test: Maximum allowable leakage shall be per local specification requirements.

2. Individual Joint Testing: For pipes large enough to enter, individual joints may be pressure tested with a portable tester to 5 psi max.with air or water in lieu of line infiltration, exfiltration or air testing.

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CCFRPM Pipe for Tunnel Carrier Installation - Gravity Service

Part 1 General

1.01 Section Includes

A. Centrifugally Cast Fiberglass Reinforced Polymer Mortar Pipe. (CCFRPM)

1.02 References

A. ASTM D3262 - Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Sewer Pipe.

B. ASTM D4161 - Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe Joints Using Flexible Elastomeric Seals.

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

D. ASTM D3681 – Standard Test Method for Chemical Resistance of "Fiber glass" Pipe in a Deflected Condition.

E. ASTM D638 – Test Method for Tensile Properties of Plastics.

1.03 Specifications

A. The specifications contained herein govern, unless otherwise agreed upon between the purchaser and supplier.

Part 2 Products

2.01 Materials

A. Resin Systems: The manufacturer shall use only polyester resin systems with a proven history of performance in this particular application. The historical data shall have been acquired from a composite material of similar construction and composition as the proposed product.

B. Glass Reinforcements: The reinforcing glass fibers used to manufacture the components shall be of highest quality commercial grade E-glass filaments with binder and sizing compatible with impregnating resins.

C. Silica Sand: Sand shall be minimum 98% silica with a maximum moisture content of 0.2%.

D. Additives: Resin additives, such as curing agents, pigments, dyes, fillers, thixotropic agents, etc., when used, shall not detrimentally effect the performance of the product.

E. Elastomeric Gaskets: Gaskets shall meet ASTM F477 and be supplied by qualified gasket manufacturers and be suitable for the service intended.

2.02 Manufacture and Construction

A. Pipes: Manufacture pipe by the centrifugal casting process to result in a dense, nonporous, corrosion-resistant, consistent composite structure. The interior surface of the pipes exposed to sewer flow provide crack resistance and abrasion resistance. The exterior surface of the pipes shall be comprised of a sand and resin layer which provides UV protection to the exterior. Pipes shall be Type 1, Liner 2, Grade 3 per ASTM D3262.

B. Joints: Unless otherwise specified, the pipe shall be field connected with fiberglass sleeve couplings or bell-spigot joints, "flush" or "non-flush", that utilize elastomeric sealing gaskets as the sole means to maintain joint watertightness. The joints must meet the performance requirements of ASTM D4161. Joints at tie-ins, when needed, may utilize gasket-sealed closure couplings.

C. Fittings: Flanges, elbows, reducers, tees, wyes, laterals and other fittings shall be capable of withstanding all operating conditions when installed. They may be contact molded or manufactured from mitered sections of pipe joined by glass-fiber-reinforced overlays. Properly protected standard ductile iron, fusion-bonded epoxy-coated steel and stainless steel fittings may also be used.

D. Acceptable Manufacturer: HOBAS Pipe USA.

2.03 Dimensions

A. Diameters: The actual outside diameter (18" to 48") of the pipes shall be in accordance with ASTM D3262. For other diameters, OD's shall be per manufacturer's literature.

B. Lengths: Pipe shall be supplied in nominal lengths of 20 feet. When required by radius curves, pit size, or other limitations restrict the pipe to shorter lengths, nominal sections of 10 feet or other even divisions of 20 feet shall be used. Actual laying length shall be nominal +1, -4 inches. At least 90% of the total footage of each size and class of pipe, excluding special order lengths, shall be furnished in nominal length sections.

C. Wall Thickness: The minimum wall thickness shall be the stated design thickness.

D. End Squareness: Pipe ends shall be square to the pipe axis with a maximum tolerance of 1/8".

2.04 Testing

A. Pipes: Pipes shall be manufactured and tested in accordance with ASTM D3262.

B. Joints: Joints shall meet the requirements of ASTM D4161.

C. Stiffness: Minimum pipe stiffness when tested in accordance with ASTM D2412 shall normally be 36 psi.

2.05 Customer Inspection

A. The Owner or other designated representative shall be entitled to inspect pipes or witness the pipe manufacturing.

B. Manufacturer's Notification to Customer: Should the Owner request to see specific pipes during any phase of the manufacturing process, the manufacturer must provide the Owner with adequate advance notice of when and where the production of those pipes will take place.

2.06 Packaging, Handling, Shipping

A. Packaging, handling, and shipping shall be done in accordance with the manufacturer's instructions.

Part 3 Execution

3.01 Installation

A. Installation: The installation of pipe and fittings shall be in accordance with the project plans and specifications and the manufacturer's require¬ments (Section 14 E of the product brochure).

B. Pipe Grouting: Annular space grouting shall not damage the liner and shall conform to the manufacturer's requirements (Section 14 E of product brochure).

C. Pipe Handling: Use textile slings, other suitable materials or a forklift. Use of chains or cables is not recommended.

D. Jointing:

1. Clean ends of pipe and coupling components.

2. Apply joint lubricant to pipe ends or bell interior surfaces and the elastomeric seals. Use only lubricants approved by the pipe manufacturer.

3. Use suitable equipment and end protection to push or pull the pipes together.

4. Do not exceed forces recommended by the manufacturer for joining or pushing pipe.

5. Join pipes in straight alignment then deflect to required angle. Do not allow the deflection angle to exceed the deflection permitted by the manufacturer.

E. Field Tests

1. Infiltration / Exfiltration Test: Maximum allowable leakage shall be per local specification requirements.

2. Low Pressure Air Test: Each reach may be tested with air pressure (max 5 psi). The system passes the test if the pressure drop due to leakage through the pipe or pipe joints is less than or equal to the specified amount over the prescribed time period.

3. Individual Joint Testing: For pipes large enough to enter, individual joints may be pressure tested with a portable tester to 5 psi max. with air or water in lieu of line infiltration, exfiltration or air testing.

4. Deflection: Maximum allowable long-term deflection is normally 5% of the initial diameter.

CCFRPM Pipe for Pressure Service

Part 1 General

1.01 Section Includes

A. Centrifugally Cast Fiberglass Reinforced Polymer Mortar Pipe. (CCFRPM)

1.02 References

A. ASTM D3754 - Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Sewer and Industrial Pressure Pipe.

B. AWWA C950 - AWWA Standard for Fiberglass Pressure Pipe

C. ASTM D4161 - Standard Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe Joints Using Flexible Elastomeric Seals.

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

1.03 Specifications

A. The specifications contained herein govern, unless otherwise agreed upon between purchaser and supplier.

Part 2 Products

2.01 Materials

A. Resin Systems: The manufacturer shall use only polyester resin systems with a proven history of performance in this particular application. The historical data shall have been acquired from a composite material of similar construction and composition as the proposed product.

B. Glass Reinforcements: The reinforcing glass fibers used to manufacture the components shall be of highest quality commercial grade E-glass filaments with binder and sizing compatible with impregnating resins.

C. Silica Sand: Sand shall be minimum 98% silica with a maximum moisture content of 0.2%.

D. Additives: Resin additives, such as curing agents, pigments, dyes, fillers, thixotropic agents, etc., when used, shall not detrimentally effect the performance of the product.

E. Elastomeric Gaskets: Gaskets shall meet ASTM F477 and be supplied by qualified gasket manufacturers and be suitable for the service intended.

2.02 Manufacture and Construction

A. Pipes: Manufacture pipe by the centrifugal casting process to result in a dense, nonporous, corrosion-resistant, consistent composite structure. The pipe nominal pressure class (PN) shall be equal to or greater than the maximum sustained operating pressure of the line. The maximum transient (operating plus surge) pressure of the line shall not exceed the pipe nominal pressure class by more than 40%. Pipes shall be Type 1, Liner 2, Grade 3 per ASTM D3754.

B. Joints: Unless otherwise specified, the pipe shall be field connected with fiberglass sleeve couplings that utilize elastomeric sealing gaskets as the sole means to maintain joint watertightness. The joints must meet the performance requirements of ASTM D4161. Tie-ins, when needed, may utilize gasket-sealed mechanical couplings.

C. Fittings: Flanges, elbows, reducers, tees, wyes, laterals and other fittings shall be capable of withstanding all operating conditions when installed. They may be contact molded or manufactured from mitered sections of pipe joined by glass-fiber-reinforced overlays. Properly protected standard ductile iron, fusion-bonded epoxy-coated steel and stainless steel fittings may also be used. Unbalanced thrust forces shall be restrained with thrust blocks or other suitable methods. Fiberglass tees, wyes, laterals, or other similar fittings shall be fully encased in reinforced concrete designed to withstand the pressure forces.

D. Acceptable Manufacturer: HOBAS Pipe USA.

2.03 Dimensions

A. Diameters: The actual outside diameter (18" to 48") of the pipes shall be in accordance with AWWA C950. For other diameters, OD's shall be per manufacturer's literature.

B. Lengths: Pipe shall be supplied in nominal lengths of 20 feet. Actual laying length shall be nominal +1, -4 inches. At least 90% of the total footage of each size and class of pipe, excluding special order lengths, shall be furnished in nominal length sections.

C. Wall Thickness: The minimum wall thickness shall be the stated design thickness.

D. End Squareness: Pipe ends shall be square to the pipe axis with a maximum tolerance of 1/8".

2.04 Testing

A. Pipes: Pipes shall be manufactured in accordance with the applicable standard.
B. Joints: Coupling joints shall meet the requirements of ASTM D4161.

C. Stiffness: Minimum pipe stiffness when tested in accordance with ASTM D2412 shall normally be 36 psi.

D. Tensile Strength: Pipe hoop tensile strength for pressure pipe shall be verified as specified in applicable standard (ASTM D3754 or AWWA C950) or by random burst testing at the same sampling frequency. All pipes shall be capable of withstanding a test pressure of two (2) times the maximum sustained operating pressure of the line without leaking or cracking. This performance shall be verified as agreed between the buyer and seller.

2.05 Customer Inspection

A. The Owner or other designated representative shall be entitled to inspect pipes or witness the pipe manufacturing.

B. Manufacturer's Notification to Customer: Should the Owner request to see specific pipes during any phase of the manufacturing process, the manufacturer must provide the Owner with adequate advance notice of when and where the production of those pipes will take place.

2.06 Packaging, Handling, and Shipping

A. Packaging, handling, and shipping shall be done in accordance with the manufacturer's instructions.

Part 3 Execution

3.01 Installation

A. Installation: The installation of pipe and fittings shall be in accordance with the project plans and specifications and the manufacturer's requirements (Section 14 of product brochure).

B. Pipe Handling: Use textile slings, other suitable materials or a forklift. Use of chains or cables is not recommended.

C. Jointing:

1. Clean ends of pipe and coupling components.

2. Apply joint lubricant to pipe ends and the elastomeric seals of coupling. Use only lubricants approved by the pipe manufacturer.

3. Use suitable equipment and end protection to push or pull the pipes together.

4. Do not exceed forces recommended by the manufacturer for coupling pipe.

5. Join pipes in straight alignment then deflect to required angle. Do not allow the deflection angle to exceed the deflection permitted by the manufacturer.

D. Field Tests:

1. Pressure Test: Pressure pipes may be field tested after completion of the installation (including required thrust restraints) at a maximum pressure of 1.5 times the system operating pressure not to exceed 1.5 x PN. Prior to testing, assure that all work has been properly completed. When filling the line assure that all air is expelled to avoid dangerous build-up of compressed air potential energy. Pressurize the line slowly, so pressure surges exceeding test pressures are not developed. Check for leaks when the test pressure has stabilized.

2. Deflection: Maximum Allowable long-term deflection is normally 5% of the initial diameter.

Class SN 18* (minimum pipe stiffness of 18 psi)

Nominal Pipe Size (in.)	Pipe O.D. (in.)	Class PN**/SN					
		25 /18		50/18		100/18	
		min. wall t (in.)	weight (lb/ft)	min. wall t (in.)	weight (lb/ft)	min. wall t (in.)	weight (lb/ft)
18	19.5	0.30	19	0.29	19	0.29	18
20	21.6	0.32	23	0.32	23	0.32	22
24	25.8	0.38	32	0.37	31	0.37	30
27	28.0	0.41	38	0.40	37	0.40	35
28	30.0	0.43	42	0.43	42	0.42	39
30	32.0	0.46	48	0.45	47	0.45	45
33	34.0	0.48	53	0.48	53	0.47	50
36	38.3	0.54	67	0.53	66	0.52	61
41	42.9	0.60	83	0.59	82	0.58	77
42	44.5	0.62	89	0.61	88	0.60	82
44	45.9	0.64	95	0.63	93	0.62	87
45	47.7	0.66	101	0.65	100	0.64	94
48	50.8	0.70	114	0.69	113	0.68	106
51	53.9	0.74	128	0.73	126	0.72	118
54	57.1	0.78	143	0.77	141	0.76	132
57	60.0	0.82	157	0.81	155	0.80	146
60	62.9	0.86	173	0.84	169	0.83	159
63	66.0	0.90	189	0.88	185	0.87	174
66	69.2	0.94	207	0.92	203	0.91	191
69	72.5	0.98	226	0.97	224	0.95	209
72	75.4	1.02	245	1.00	240	0.99	226
78	81.6	1.10	285	1.08	280	1.07	264
84	87.0	1.17	323	1.15	318	1.13	297
85	88.6	1.19	334	1.17	329	1.15	308
90	94.3	1.26	377	1.24	371	1.22	347
96	99.5	1.33	419	1.31	413	1.29	387
104	108.0	1.44	492	1.42	485	1.40	455
110	114.0	1.52	546	1.51	542		
120	126.0	1.68	659	1.67	655		
126	132.5	1.76	720	1.75	716		

* Normally not available for direct bury. ** Maximum nominal working pressure class in psi.

Class SN 36 (minimum pipe stiffness of 36 psi)

Nominal Pipe Size (in.)	Pipe O.D. (in.)	Class PN*/SN									
		25 /36		50/36		100/36		150/36		200/36	
		min. wall t (in.)	weight (lb/ft)	min. wall t (in.)	weight (lb/ft)	min. wall t (in.)	weight (lb/ft)	min. wall t (in.)	weight (lb/ft)	min. wall t (in.)	weight (lb/ft)
18	19.5	0.36	23	0.36	23	0.35	21	0.35	21	0.34	20
20	21.6	0.40	28	0.39	28	0.39	26	0.38	25	0.37	24
24	25.8	0.46	39	0.46	39	0.45	36	0.45	35	0.44	33
27	28.0	0.50	45	0.50	45	0.49	42	0.48	40	0.47	38
28	30.0	0.53	51	0.53	51	0.52	48	0.51	45	0.50	44
30	32.0	0.57	59	0.56	58	0.55	54	0.54	51	0.53	49
33	34.0	0.60	66	0.59	64	0.58	60	0.57	57	0.56	55
36	38.3	0.67	82	0.66	81	0.65	76	0.64	72	0.63	69
41	42.9	0.74	101	0.74	101	0.73	95	0.71	89	0.70	86
42	44.5	0.77	109	0.76	108	0.75	101	0.74	96	0.72	92
44	45.9	0.79	116	0.79	116	0.77	107	0.76	102	0.74	97
45	47.7	0.82	125	0.81	123	0.80	116	0.78	109	0.77	105
48	50.8	0.87	141	0.86	139	0.85	131	0.83	123	0.82	119
51	53.9	0.92	157	0.91	156	0.90	147	0.88	138	0.86	132
54	57.1	0.97	176	0.97	176	0.95	164	0.93	155	0.91	148
57	60.0	1.02	194	1.01	192	1.00	181	0.98	171		
60	62.9	1.07	213	1.06	211	1.04	197	1.02	186		
63	66.0	1.12	234	1.11	232	1.09	217	1.06	203		
66	69.2	1.17	256	1.16	254	1.14	237	1.12	225		
69	72.5	1.22	279	1.21	277	1.20	261	1.17	246		
72	75.4	1.27	302	1.26	300	1.24	281				
78	81.6	1.37	353	1.36	350	1.34	328				
84	87.0	1.46	400	1.45	398	1.43	373				
85	88.6	1.49	416	1.48	413	1.45	385				
90	94.3	1.58	469	1.57	466	1.54	435				
96	99.5	1.66	520	1.65	516	1.62	482				
104	108.0	1.80	611	1.79	608						
110	114.0	1.90	680	1.89	676						
120	126.0	2.10	829	2.08	821						
126	132.5	2.20	900	2.18	892						

* Maximum nominal working pressure class in psi.

Class SN 46 (minimum pipe stiffness of 46 psi)

Nominal Pipe Size (in.)	Pipe O.D. (in.)	Class PN*/SN									
		25/46		50/46		100/46		150/46		200/46	
		min. wall t (in.)	weight (lb/ft)	min. wall t (in.)	weight (lb/ft)	min. wall t (in.)	weight (lb/ft)	min. wall t (in.)	weight (lb/ft)	min. wall t (in.)	weight (lb/ft)
18	19.5	0.39	25	0.39	25	0.38	23	0.37	22	0.37	21
20	21.6	0.43	30	0.42	29	0.42	28	0.41	27	0.40	25
24	25.8	0.50	42	0.50	42	0.49	39	0.48	37	0.47	35
27	28.0	0.54	49	0.53	48	0.53	46	0.52	43	0.51	41
28	30.0	0.57	55	0.57	55	0.56	51	0.55	49	0.54	47
30	32.0	0.61	63	0.60	62	0.60	59	0.58	55	0.57	53
33	34.0	0.64	70	0.64	70	0.63	65	0.62	62	0.60	59
36	38.3	0.72	88	0.72	88	0.70	81	0.69	77	0.68	75
41	42.9	0.80	109	0.80	109	0.78	101	0.77	96	0.75	92
42	44.5	0.83	117	0.82	116	0.81	109	0.79	103	0.78	99
44	45.9	0.85	124	0.85	124	0.84	117	0.82	110	0.80	105
45	47.7	0.89	135	0.88	133	0.87	125	0.85	118	0.83	113
48	50.8	0.94	151	0.93	150	0.92	141	0.90	133	0.88	127
51	53.9	1.00	171	0.99	169	0.97	158	0.95	149	0.93	142
54	57.1	1.05	190	1.04	188	1.03	177	1.01	167	0.98	159
57	60.0	1.10	209	1.09	207	1.08	195	1.05	183		
60	62.9	1.15	228	1.15	228	1.13	213	1.10	200		
63	66.0	1.21	252	1.20	250	1.18	234	1.15	220		
66	69.2	1.27	277	1.26	275	1.24	257	1.21	242		
69	72.5	1.32	301	1.31	299	1.29	280	1.26	264		
72	75.4	1.38	328	1.36	323	1.34	303				
78	81.6	1.48	380	1.47	377	1.45	354				
84	87.0	1.58	432	1.57	429	1.54	400				
85	88.6	1.61	448	1.60	445	1.57	416				
90	94.3	1.71	506	1.69	500	1.67	470				
96	99.5	1.80	562	1.79	559	1.76	522				
104	108.0	1.95	660	1.93	654						
110	114.0	2.06	710	2.04	703						
120	126.0	2.27	863	2.25	855						
126	132.5	2.38	975	2.36	967						

* Maximum nominal working pressure class in psi.

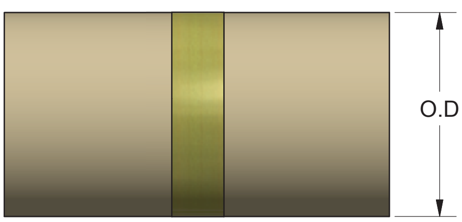
Class SN 72 (minimum pipe stiffness of 72 psi)

Nominal Pipe Size (in.)	Pipe O.D. (in.)	Class PN*/SN									
		25 & 50/72		100/72		150/72		200/72		250/72	
		min. wall t (in.)	weight (lb/ft)	min. wall t (in.)	weight (lb/ft)	min. wall t (in.)	weight (lb/ft)	min. wall t (in.)	weight (lb/ft)	min. wall t (in.)	weight (lb/ft)
18	19.5	0.44	28	0.44	26	0.43	25	0.42	24	0.42	24
20	21.6	0.49	34	0.48	32	0.47	30	0.47	29	0.46	28
24	25.8	0.57	47	0.56	44	0.56	42	0.55	41	0.54	40
27	28.0	0.62	55	0.61	52	0.60	49	0.59	47	0.58	46
28	30.0	0.66	63	0.65	59	0.64	56	0.63	54	0.62	52
30	32.0	0.70	71	0.69	67	0.68	64	0.67	61	0.66	59
33	34.0	0.74	80	0.73	75	0.72	71	0.71	69		
36	38.3	0.83	101	0.81	94	0.80	89	0.79	86		
41	42.9	0.92	125	0.91	117	0.89	111	0.88	107		
42	44.5	0.95	134	0.94	126	0.93	120	0.91	115		
44	45.9	0.98	142	0.97	134	0.95	126	0.94	122		
45	47.7	1.02	153	1.00	143	0.99	137	0.97	131		
48	50.8	1.08	173	1.07	163	1.05	154	1.03	148		
51	53.9	1.15	195	1.13	182	1.11	173	1.10	167		
54	57.1	1.21	217	1.19	203	1.17	193	1.16	187		
57	60.0	1.27	239	1.25	224	1.23	212				
60	62.9	1.33	263	1.31	246	1.29	233				
63	66.0	1.39	288	1.37	270	1.35	256				
66	69.2	1.46	317	1.44	297	1.41	280				
69	72.5	1.53	348	1.50	324	1.48	308				
72	75.4	1.59	375	1.56	350						
78	81.6	1.71	437	1.69	410						
84	87.0	1.82	495	1.79	463						
85	88.6	1.86	515	1.83	482						
90	94.3	1.97	581	1.94	543						
96	99.5	2.08	646	2.05	605						
104	108.0	2.25	758								
110	114.0	2.38	817								
120	126.0	2.62	992								
126	132.5	2.75	1125								

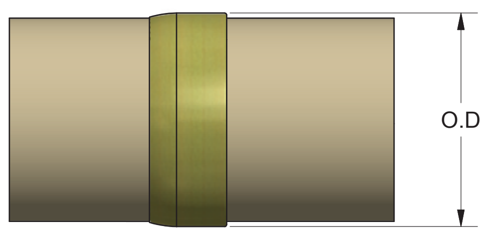
* Maximum nominal working pressure class in psi.

Appendix C
Joint Dimensions & Weights

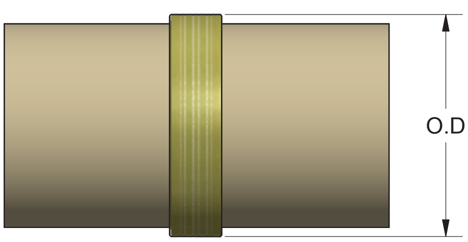
Nominal Pipe Size (in.)	Nominal Outside Diameter, OD (in.)							
	FWC Coupling					Low Profile Bell	Flush Bell-Spigot	Pressure Relining
	PN 25 PN 50	PN 100	PN 150	PN 200	PN 250			
18	21.3	21.3	21.3	21.3	21.4	20.4	19.5	
20	23.4	23.4	23.4	23.4	23.6	22.5	21.6	
24	27.6	27.6	27.6	27.7	27.9	26.8	25.8	
27	29.8	29.8	29.8	30.0	30.2	29.0	28.0	
28	31.9	31.9	32.0	32.1	32.3	31.0	30.0	
30	33.9	33.9	34.0	34.2	34.4	33.0	32.0	
33	35.9	35.9	36.1	36.3		35.0	34.0	
36	40.2	40.2	40.4	40.6		39.3	38.3	
41	44.9	44.9	45.2	45.5		44.0	42.9	FWC
42	46.5	46.5	46.8	47.2		45.6	44.5	
44	47.9	47.9	48.2	48.6		47.0	45.9	
45	49.7	49.7	50.0	50.4		48.8	47.7	
48	52.8	52.9	53.2	53.6		51.9	50.8	
51	56.0	56.1	56.5	56.8		55.0	53.9	
54	59.2	59.4	59.8	60.1		58.2	57.1	O.D.'s Plus
57	62.2	62.5	62.8			61.2	60.0	
60	65.2	65.5	65.9			64.1	62.9	
63	68.3	68.7	69.1			67.2	66.0	
66	71.6	72.0	72.4			70.4	69.2	
69	74.9	75.4	75.8			73.8	72.5	0.4
72	77.9	78.3				76.7	75.4	
78	84.2	84.7				82.9	81.6	
84	89.6	90.2				88.4	87.0	
85	91.4	92.0				90.0	88.6	
90	97.1	97.8				95.7	94.3	
96	102.5	103.1				101.0	99.5	
104	111.1					109.5	108.0	
110	117.2					115.5	114.0	
120	129.3					127.5	126.0	
126	135.8					134.0	132.5	



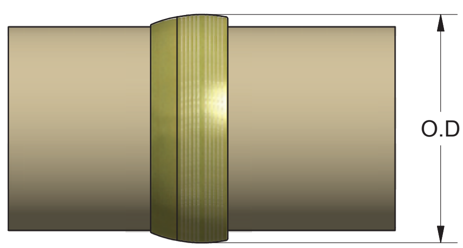
Flush Bell-Spigot



Low Profile Bell



FWC Coupling



Pressure Relining

Nominal Pipe Size (in.)	FWC Coupling Nominal Weight (lb.)				
	PN 25 PN 50	PN 100	PN 150	PN 200	PN 250
18	25	25	25	25	31
20	28	28	28	35	45
24	43	43	43	46	59
27	46	46	46	62	81
28	50	50	50	59	79
30	53	53	56	66	92
33	56	56	60	73	
36	64	64	71	86	
41	71	71	86	103	
42	74	74	91	138	
44	76	76	96	146	
45	79	79	101	153	
48	84	84	107	161	
51	89	96	149	186	
54	94	104	167	206	
57	100	111	184		
60	140	175	212		
63	148	189	240		
66	155	203	268		
69	166	221	294		
72	178	238			
78	194	256			
84	209	294			
85	215	305			
90	234	341			
96	251	377			
104	279				
110	306				
120	355				
126	450				

Appendix D
Pipe Material Properties & Characteristics

Material properties of HOBAS Pipe USA pipes exceed the requirements of ASTM D3262 for non-pressure applications and of AWWA C950 for pressure service. Actual properties vary depending on pressure and stiffness class. The following range of values covers most pipe constructions. For values specific to individual pipes contact HOBAS Pipe USA.

Pipe Property	Range of Values[1]	
E-Modulus[1] (10^6 psi):	**PN 0**	**PN 50 to 250**
* Circumferential Flexural	1.0 to 1.9	1.3 to 2.4
* Circumferential Tensile	–	0.5 to 2.8
* Axial Tensile	0.4 to 0.8	0.4 to 1.7
Strength[1] (10^3 psi):		
* Circumferential Tensile	–	7.0 to 33.0
* Axial Tensile	1.4 to 2.1	1.4 to 6.4
* Compressive	10.5	10.5
Thermal Coefficient of Linear Expansion (axial)	16×10^{-6}	in./in./°F.

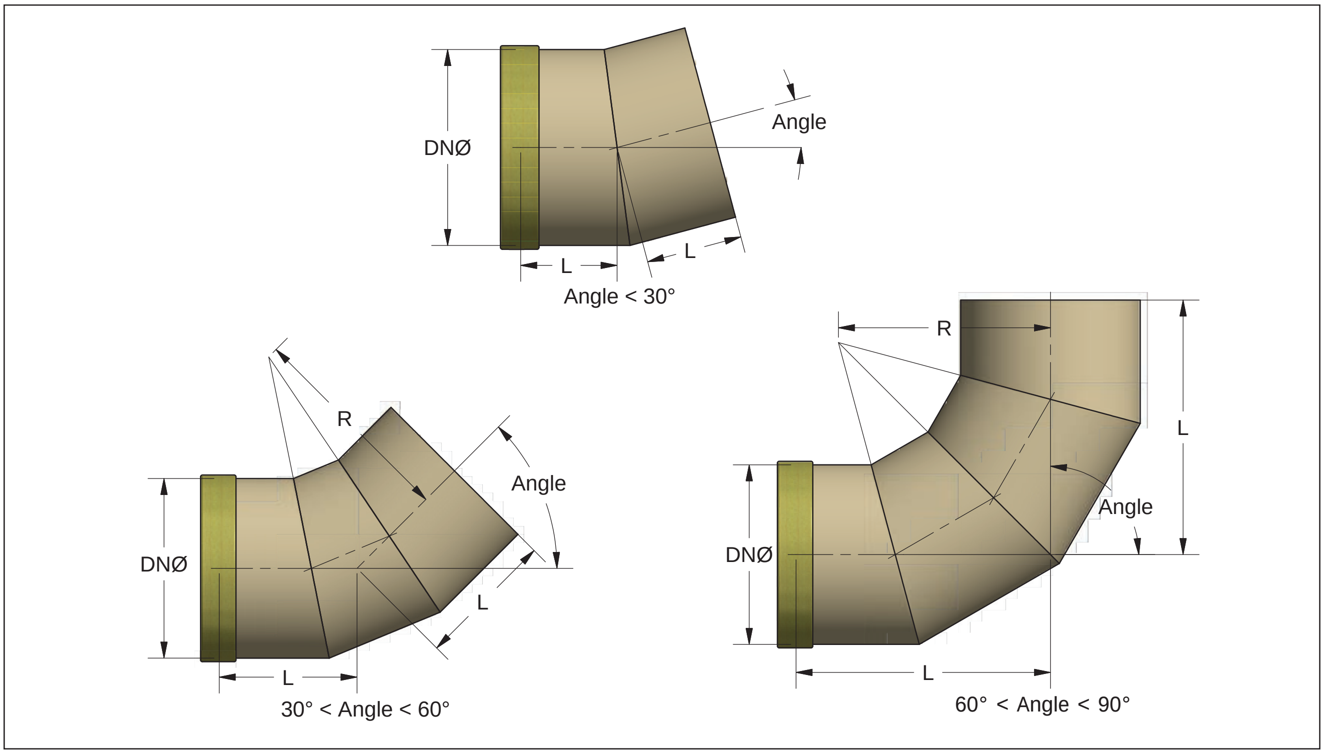
Note 1: Values given are for the reinforced wall (i.e. liner is not included).

Flow Factors vary somewhat with pipe diameter and flow rate. The following values have been found to be typically representative long-term and are commonly used.

** Hazen-Williams*	*"C" 155*
** Manning's*	*"n" 0.009*

Appendix | D

E1 Fiberglass Elbows



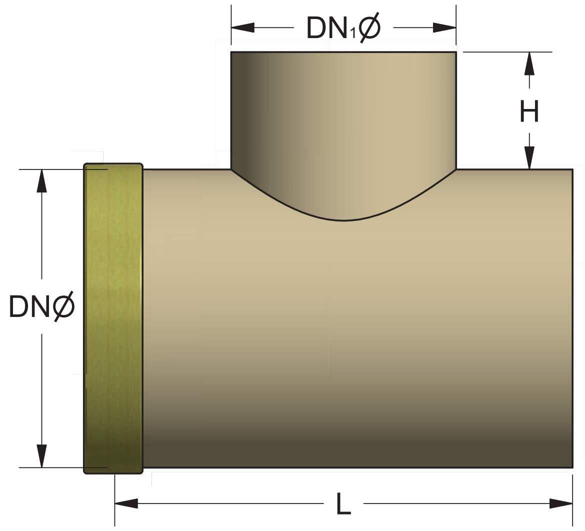
E1 Fiberglass Elbows

DN (in.)	R (in.)	L (in.) for ∝						P* (psi)
		11 1/4°	22 1/2°	30°	45°	60°	90°	
18	27	18	19	20	25	30	40	200
20	30	18	19	20	26	31	42	175
24	36	20	21	22	28	33	48	
27	38	20	21	22	29	34	50	
28	40	20	22	23	30	35	52	150
30	42	20	22	23	31	36	54	
33	44	20	22	24	32	37	56	
36	48	20	22	24	33	39	60	125
41	52	22	23	25	36	42	64	
42	54	23	25	26	37	43	66	
44	55	23	25	26	37	44	67	100
45	57	23	25	27	38	45	69	
48	60	25	25	27	39	46	72	
51	63	27	27	28	40	48	75	
54	66	28	28	28	41	49	78	
57	68	30	30	30	42	50	81	
60	70	31	31	31	43	51	84	
63	73	33	33	33	44	53	87	
66	75	34	34	34	45	54	90	
69	78	36	36	36	47	55	93	75
72	80	38	38	38	48	56	96	
78	84	41	41	41	51	60	102	
84	88	43	43	43	53	63	106	
85	90	44	44	44	54	64	108	
90	95	47	47	47	57	68	114	
96	100	50	50	50	60	72	120	
104	108	54	54	54	63	76	126	
110	112	57	57	57	66	80	132	
120	120	63	63	63	72	88	144	
126	126	66	66	66	72	88	144	50

Note 1: L may need to be increased if the design pressure exceeds P.

Note 2: Dimensions for other angles or different turning radii are available upon request.

E2-A Fiberglass Manhole Tee Bases



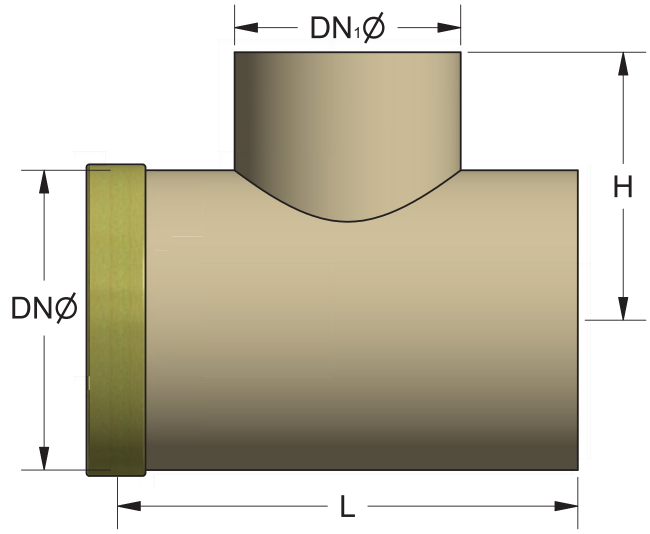
Elevation View

E2-A Fiberglass Manhole Tee Bases

DN (in.)	DN1[1] (in.)	L (in.)	H (in.)	DN1[1] (in.)	L (in.)	H (in.)	DN1[1] (in.)	L (in.)	H (in.)
30	24	54	15	30	60	15	30	60	15
33	24	54	15	30	60	15	30	60	15
36	24	54	15	36	78	15	36	78	15
41	24	54	15	36	78	15	36	78	15
42	24	54	15	36	78	15	36	78	15
44	24	54	15	36	78	15	36	78	15
45	24	54	15	36	78	15	36	78	15
48	24	54	15	36	78	15	48	108	15
51	24	54	15	36	78	15	48	108	15
54	24	54	15	36	78	15	48	108	15
57	24	78	15	36	78	15	48	108	15
60	24	78	15	36	78	15	48	108	15
63	24	78	15	36	78	15	48	108	15
66	24	78	15	36	78	15	48	108	15
69	24	78	15	36	78	15	48	108	15
72	24	78	15	36	78	15	48	108	15
78	24	78	15	36	78	15	48	108	15
84	24	108	15	36	108	15	48	108	15
85	24	108	15	36	108	15	48	108	15
90	24	108	15	36	108	15	48	108	15
96	24	108	15	36	108	15	48	108	15
104	24	108	15	36	108	15	48	108	15
110	24	108	15	36	108	15	48	108	15
120	24	114	15	36	114	15	48	114	15
126	24	114	15	36	114	15	48	114	15

Notes:
1. Total lay length "L" shown above is typical for (DN1) branch diameter shown. Adjustment to "L" are available.
2. All tee bases to be concrete encased to prevent deformations. Concrete design by others.
3. Complete manhole design by others to include allowance for transfer of surface loads (HS-20) away from branch (DN1).
4. "H" dimension shown is typical, it can be adjusted to allow for specific encasement heights, service laterals, FRP riser connections with FWC couplings, etc.
5. Configurations shown (DN x DN1) can be adjusted to meet specific designs.
6. DN1 can change but must be less than or equal to DN for all tee base configurations.
7. Above dimensions are for straight thru (180 deg.) configurations. Tee bases with angles (PI's) are available, with increased L

E2-B Fiberglass Lateral Tees



Plan View

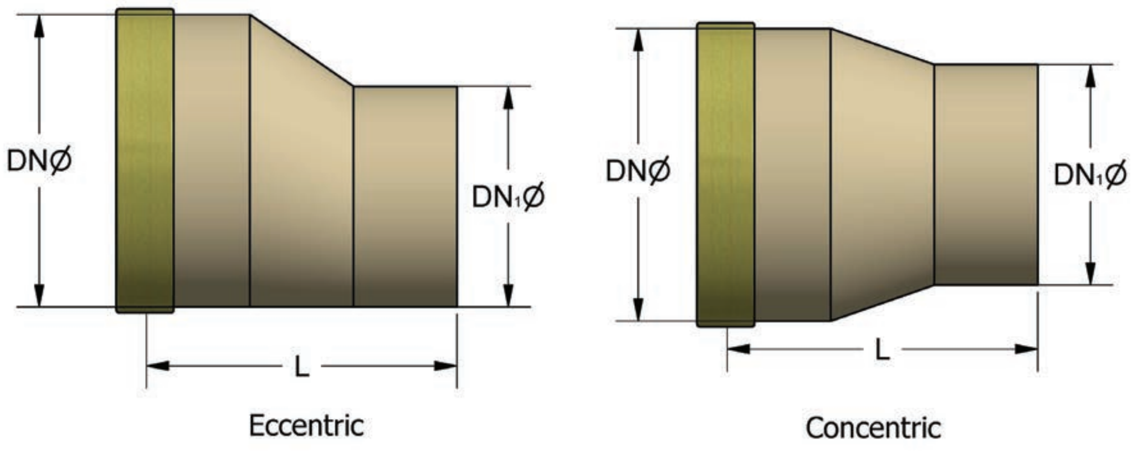
E2-B Fiberglass Lateral Tees

DN (in.)	DN1[1] (in.)	L (in.)	H (in.)	DN1[1] (in.)	L (in.)	H (in.)	DN1[1] (in.)	L (in.)	H (in.)
18	18	57	30	-	-	-	-	-	-
20	20	60	30	18	60	30	-	-	-
24	24	66	33	20	66	33	18	63	33
27	27	68	34	24	67	34	20	64	34
28	28	70	35	24	68	35	20	65	35
30	30	72	36	24	69	36	20	66	36
33	33	75	38	30	72	38	24	66	38
36	36	81	40	30	75	40	24	69	40
41	41	87	44	36	81	44	30	75	44
42	42	90	45	36	84	45	30	78	45
44	44	93	46	42	86	46	36	80	46
45	45	96	47	42	87	47	36	81	47
48	48	99	48	42	90	48	36	84	48
51	51	102	51	48	99	51	42	93	51
54	54	108	54	48	102	54	42	96	54
57	57	111	56	54	105	56	48	99	56
60	60	114	57	54	108	57	48	102	57
63	63	117	59	60	111	59	54	105	59
66	66	120	60	60	114	60	54	108	60
69	69	123	62	66	120	62	60	114	62
72	72	126	63	66	120	63	60	114	63
78	78	138	69	72	132	69	66	126	66
84	84	141	70	78	135	70	72	129	70
85	85	144	72	78	138	72	72	132	72
90	90	150	75	84	144	75	78	138	75
96	96	156	78	90	150	78	84	144	78
104	104	168	84	96	162	84	90	156	84
110	110	180	90	104	174	90	96	168	90
120	120	192	96	110	180	96	104	174	96
126	126	198	99	120	192	99	110	180	99

Note 1: Dimensions for other combinations of DN and DN 1 are available upon request.

Note 2: Dimensions shown are typical, but custom tees are routinely available.

E3 Fiberglass Reducers



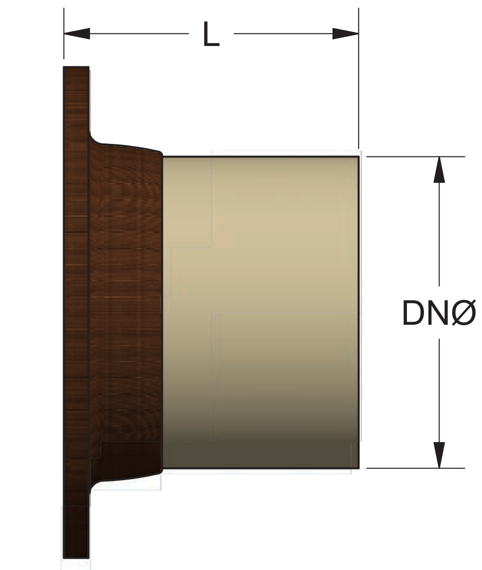
Note: Length of tapered portion is 1.5 x (DN - DN1)

E3 Fiberglass Reducers

DN (in.)	DN1[1] (in.)	L (in.)	DN1[1] (in.)	L (in.)	DN1[1] (in.)	L (in.)	DN1[1] (in.)	L (in.)	P (psi)
	20	18	48	-	-	-	-	-	-
24	20	54	18	57	-	-	-	-	250
27	24	54	20	60	18	63	-	-	
28	24	54	20	60	18	63	-	-	
30	24	57	20	63	18	66	-	-	
33	30	54	24	63	20	69	18	72	200
36	30	57	24	66	20	72	18	75	
41	36	57	30	66	24	75	20	81	
42	36	57	30	66	24	75	20	81	
44	36	60	30	69	24	78	20	84	175
45	42	54	36	63	30	72	24	81	
48	42	57	36	66	30	75	24	84	
51	48	54	42	63	36	72	30	81	150
54	48	57	42	66	36	75	30	84	
57	54	60	48	63	42	72	36	81	
60	54	63	48	66	42	75	36	84	
63	60	66	54	66	48	72	42	81	125
66	60	69	54	69	48	75	42	84	
69	66	72	60	72	54	72	48	81	
72	66	75	60	75	54	75	48	84	
78	72	81	66	81	60	81	54	84	100
84	78	87	72	87	66	87	60	87	
85	78	90	72	90	66	90	60	90	
90	84	96	78	96	72	96	66	96	
96	90	99	84	99	78	99	72	99	75
104	96	108	90	108	84	108	78	108	
110	104	114	96	114	90	114	85	114	
120	110	126	104	126	96	126	90	126	50
126	120	132	110	132	104	132	96	132	

Note 1: Dimensions for other combinations of DN and DN 1 are available upon request.
Note 2: L may need to be increased if the design pressure exceeds P.

E4 Fiberglass Flanges



E4 Fiberglass Flanges

DN (in.)	Minimum L (in.)	Minimum O.D. of Flange (in.)	Number 0f Bolts (in.)	Bolt Circle Diameter (in.)	Bolt Diameter (in.)	Minimum Bolt Hole Diam-eter (in.)
18	24	25.00	16	22.75	1.125	1.250
20	30	27.50	20	25.00	1.125	1.250
24	30	32.00	20	29.50	1.250	1.375
27	32	34.25	24	31.75	1.250	1.375
28	34	36.50	28	34.00	1.250	1.375
30	36	38.75	28	36.00	1.250	1.375
36	36	46.00	32	42.75	1.500	1.625
41	40	50.75	36	47.25	1.500	1.625
42	42	53.00	36	49.50	1.500	1.625
48	48	59.50	44	56.00	1.500	1.625
54	48	66.25	44	62.75	1.750	1.875
60	48	73.00	52	69.25	1.750	1.875
66	48	80.00	52	76.00	1.750	1.875
72	48	86.50	60	82.50	1.750	1.875
78	48	93.00	64	89.00	2.000	2.125
84	48	99.75	64	95.50	2.000	2.125
90	48	106.50	68	102.00	2.250	2.375
96	48	113.25	68	108.50	2.250	2.375
104	48	120.00	72	114.50	2.500	2.625
110	48	126.75	72	120.75	2.500	2.625
120	48	140.25	76	132.75	2.75	2.875
126	48	147.0	80	139.25	3.00	3.125

Note 1: Flange drilling dimensions are according to AWWA C207 Class D (150 psi) and ANSI B16.1 (125 psi)
Note 2: Fiberglass reinforced polymer flanges are available for non-pressure and some pressure applications. Protected ductile iron, fusion bonded epoxy coated steel or stainless steel flanges may be used at any pressure.

Appendix F

Corrosion Resistance Guide

Introduction

The following guide is a compilation of corrosion resistance information obtained from resin manufacturers and actual test results on our pipe. The recommendations are believed to represent acceptable continuous environments for satisfactory long-term pipe performance, however, individual project conditions should be considered when selecting the appropriate product construction. Also, pressure and stiffness ratings may be reduced at elevated temperatures. It is our intention to assist the design engineer as much as possible in making these evaluations.

Chemicals

Chemicals not listed on the following pages have probably not been tested with our pipe materials by the date of this publication. Contact us for new information.

Temperature

The recommended maximum temperature given is not always the absolute maximum acceptable service temperature. It is the highest temperature at which a resin or product has been tested, used or evaluated. A product may be suitable for higher temperature operation, but additional information or testing would be required in order to establish such performance.

Coupling Gaskets

The standard FWC coupling gasket material is an elastomeric compound. It exhibits superior chemical and temperature resistance and it is suitable for a wide variety of environments including sanitary sewage, water, salt water, many acids, bases, salts and other chemicals. Some types of gaskets may be sensitive to some chemicals such as some hydrocarbons and many chlorinated and aromatic solvents.

Alternate gasket materials may be available for these situations. We would be pleased to assist you in the selection of an appropriate gasket material and in the establishment of specific limitations for temperature and concentration based on your individual application.

Abbreviations & Symbols

Std. (Standard) - Std. refers to our standard pipe constructed with thermosetting polyester resins.

VE (Vinyl Ester) - VE refers to HOBAS pipes constructed using thermosetting vinyl ester resins.

NR (Not Recommended) - Product of this construction is not recommended for continuous service in this environment. However, it may be suitable at a lower concentration or for intermittent exposure.

- (Dash) - This symbol indicates no data is currently available.

Chemical	Concentration % By Weight	Maximum Recommended Temperature °F. Std.	Maximum Recommended Temperature °F. VE
A			
Acetaldehyde	All	NR	NR
Acetic Acid	0-25 25-50 50-75	— — —	150 150 —
Acetic Anhydride	All	NR	NR
Acetone	100	NR	NR
Acrylic Acid	25	—	100
Acrylonitrile	All	NR	NR
Alcohol, Butyl	All	NR	—
Alcohol, Ethyl	10 100	80 —	150 —
Alcohol, Isopropyl	10 100	80 NR	150 —
Alcohol, Methyl	10 100	NR NR	— NR
Alcohol, Methyl Isobutyl	10	NR	150
Alcohol, Secondary Butyl	10	NR	150
Allyl Chloride	All	NR	NR
Alum	All	100	180
Aluminum Chloride	All	100	180
Aluminum Fluoride	All	—	80
Aluminum Hydroxide	All	NR	150
Aluminum Nitrate	All	100	150
Aluminum Potassium Sulfate	All	90	180
Ammonia, Aqueous	0-20	NR	140
Ammonia, Gas		NR	100
Ammonia, Liquid		NR	NR
Ammonium Bicarbonate	0-50	NR	150
Ammonium Bisulfite	All	—	150
Ammonium Carbonate	All	NR	150

Appendix | F

Chemical	Concentration % By Weight	Maximum Recommended Temperature °F.	
		Std.	VE
Ammonium Chloride	All	90	180
Ammonium Citrate	All	—	150
Ammonium Fluoride	All	—	150
Ammonium Hydroxide	5 10 20 29	NR NR NR NR	150 150 150 100
Ammonium Nitrate	All	90	180
Ammonium Persulfate	All	NR	180
Ammonium Phosphate	65	90	180
Ammonium Sulfate	All	90	180
Amyl Acetate	100	NR	NR
Aniline	All	NR	NR
Aniline Hydrochloride	All	—	150
Aniline Sulfate	All	NR	180
Arsenious Acid	All	—	—
B			
Barium Acetate	All	NR	180
Barium Carbonate	All	NR	180
Barium Chloride	All	100	180
Barium Hydroxide	0-10	NR	150
Barium Sulfate	All	90	180
Barium Sulfide	All	NR	180
Beer		80	120
Benzene	100	NR	NR
5% Benzene in Kerosene		—	—
Benzene Sulfonic Acid	All	NR	180
Benzoic Acid	All	—	180
Benzyl Alcohol	100	NR	NR
Benzyl Chloride	100	NR	NR
Black Liquor Recovery, (furnace gasses)		NR	—
Bromine, Liquid		NR	NR
Bromine, Water	5	NR	—
Butyl Acetate	100	NR	NR
Butyric Acid	0-50 100	— NR	— —
C			
Cadmium Chloride	All	—	180
Calcium Bisulfite	All	—	180
Calcium Carbonate	All	NR	180
Calcium Chlorate	All	—	180
Calcium Chloride	All	100	180
Calcium Hydroxide	All	NR	180
Calcium Hypochlorite	All	NR	160
Calcium Nitrate	All	100	180
Calcium Sulfate	All	90	180
Calcium Sulfite	All	—	180

Chemical	Concentration % By Weight	Maximum Recommended Temperature °F.	
		Std.	VE
Cane Sugar Liquor	All	—	180
Caprylic Acid	100	—	180
Carbon Dioxide	100	—	180
Carbon Disulfide		NR	NR
Carbon Monoxide (gas)		100	180
Carbon Tetrachloride	100	NR	—
Carbon Acid		—	—
Carbowax	—	—	—
Castor Oil		—	180
Carboxy Methyl Cellulose	10	—	150
Chlorinated Brine Liquors (caustic chlorine cell)		—	—
Chlorinated Wax	All	—	180
Chlorine Dioxide/Air	15	NR	—
Chlorine Dioxide, Wet Gas	Satd.	NR	180
Chlorine, Dry Gas	100	NR	180
Chlorine, Wet Gas	100	NR	180
Chlorine, Liquid		NR	NR
Chlorine Water	All	NR	—
Chloracetic Acid	25 50 Con.	NR NR NR	— — NR
Chlorobenzene	100	NR	NR
Chloroform	100	NR	NR
Chlorosulfonic Acid	100	NR	NR
Chromic Acid	20 30	NR NR	— NR
Chromium Sulfate	All	—	—
Citric Acid	All	100	180
Coconut Oil		—	180
Copper Chloride	All	100	180
Copper Cyanide	All	NR	180
Copper Fluoride	All	NR	180
Copper Nitrate	All	100	180
Copper Sulfate	All	100	180
Corn Oil		—	180
Corn Starch	Slurry	—	180
Corn Sugar	All	—	180
Cottonseed Oil		—	180
Cresylic Acid	100	NR	NR
Crude Oil, Sour	100	80	180
Crude Oil, Sweet	100	80	180
Cyclohexane	100	NR	—
Cyclohexanone	100	NR	—

Chemical	Concentration % By Weight	Maximum Recommended Temperature °F. Std.	VE
D			
Detergents, Sulfonated	All	—	—
Dialfyl Phthalate	All	—	—
Di-Ammonium Phosphate	65	—	180
Dibromophenol	100	NR	NR
Dibutyl Ether	100	—	—
Dichloro Benzene	100	NR	NR
Dichloroethylene	100	NR	NR
Dichloromonomethane	100	NR	NR
Dichloropropane	100	NR	NR
Dichloropropene	100	NR	NR
Diesel Fuel	100	90	180
Diethanol Amine	100	—	—
Diethyl Amine	100	NR	NR
Diethyl Benzene	100	NR	
Diethyl Carbonate	100	NR	NR
Diethylene Glycol	100	—	—
Diethylhexyl Phosphoric Acid (in Kerosene)	20	—	120
Diethyl Sulfate	100	NR	NR
Diisopropanol Amine	100	—	—
Dimethyl Formamide	100	NR	NR
Dimethyl Morpholine	100	NR	NR
Dimethyl Phthalate	100	NR	—
Dioctyl Phthalate	100	NR	—
Dipropylene Glycol	100	—	—
E			
Electrosol	5	—	150
Epichlorohydrin	100	NR	NR
Epoxidized Soybean Oil	100	—	150
Ethyl Acetate	100	NR	NR
Ethyl Acrylate	100	NR	NR
Ethyl Benzene	100	NR	NR
Ethyl Bromide	100	NR	NR
Ethyl Chloride	100	NR	NR
Ethyl Ether	100	NR	NR
Ethylene Glycol	All	90	180
Ethyl Sulfate	100	—	—
F			
Fatty Acids	All	—	180
Ferric Chloride	All	100	180
Ferric Nitrate	All	100	180
Ferric Sulfate	All	100	180
Ferrous Chloride	All	100	180
Ferrous Nitrate	All	100	180
Ferrous Sulfate	All	100	180
Flue Gas		—	—
Fluoboric Acid	All	80	180
Fluosilisic Acid	10 20	80 —	180 160
Formaldehyde	All	—	—
Formic Acid	10 All	70 NR	180 100
Freon II		—	—
Fuel Oil	100	90	180
Furfural	5 10 100	— — NR	— — NR
G			
Gas, Natural		—	180
Gluconic Acid	50	—	180
Glucose	All	100	180
Glycerine	All	90	180
Gold Plating Solution: 63% Potassium Ferrocyanide .2% Potassium Gold Cyanide .8% Sodium Cyanide		—	180
H			
Heptane		—	150
Hexane		—	150
Hexylene Glycol		—	150
Hydraulic Fluid		—	180
Hydrazine		NR	NR
Hydrochloric Acid	0-20 20-37	NR NR	180 160
Hydrochloric Acid saturated with Chlorine gas	30	NR	—
Hydrocyanic Acid	All	—	180
Hydrofluoric Acid	10 20	NR NR	150 100
Hydrofluosilicic Acid	10	—	180
Hydrogen Bromide Wet Gas	100	—	180
Hydrogen Chloride Dry Gas	100	—	180
Hydrogen Chloride Wet Gas	100	—	180
Hydrogen Peroxide	0-30	NR	150
Hydrogen Sulfide, Dry	All	100	180
Hydrogen Sulfide, Aqueous	All	100	180
Hydrogen Fluoride, Vapor		—	180

Chemical	Concentration % By Weight	Maximum Recommended Temperature °F. Std.	VE
Hydrosulfite Bleach		—	180
Hypochlorous Acid	10 20	— NR	180 150

I

Chemical	Concentration % By Weight	Std.	VE
Isopropyl Amine	All	—	100
Isopropyl Palmitate	100	—	180

K

Chemical	Concentration % By Weight	Std.	VE
Kerosene		—	180

L

Chemical	Concentration % By Weight	Std.	VE
Lactic Acid	All	—	180
Lasso* (50% Chlorobenzene)		NR	NR
Latex	All	—	—
Laurel Chloride	100	—	180
Lauric Acid	All	—	180
Lead Acetate	All	—	180
Lead Nitrate	All	—	180
Levulinic Acid	All	—	180
Linseed Oil		—	180
Lithium Bromide	All	—	180
Lithium Sulfate	All	—	180

M

Chemical	Concentration % By Weight	Std.	VE
Magnesium Bisulfite	All	—	180
Magnesium Carbonate	All	—	180
Magnesium Chloride	All	100	180
Magnesium Hydroxide	All	NR	180
Magnesium Sulfate	All	100	180
Maleic Acid	All	—	180
Mercuric Chloride	All	100	180
Mercurous Chloride	All	80	180
Methylene Chloride	100	NR	NR
Methyl Ethyl Ketone	100	NR	NR
Methyl Isobutyl Carbitol	100	NR	NR
Methyl Isobutyl Ketone	100	NR	NR
Methyl Styrene	100	NR	NR
Mineral Oils		80	180
Monochloro Acetic Acid	100	NR	NR
Monoethynolamine	100	NR	NR
Motor Oil	—	—	180
Myristic Acid	100	—	180

N

Chemical	Concentration % By Weight	Std.	VE
Naphtha	100	—	180
Naphthalene	100	—	180
Nickel Chloride	All	100	180
Nickel Nitrate	All	100	180
Nickel Chloride	All	100	180
Nickel Nitrate	All	100	180
Nickel Plating 8% Lead .8% Fluoboric Acid .4% Boric Acid		—	180
Nickel Plating 11% Nickel Sulfate 2% Nickel Chloride 1% Boric Acid		—	180
Nickel Plating 44% Nickel Sulfate 4% Ammonium Chloride 4% Boric Acid		—	180
Nickel Sulfate	All	100	180
Nitric Acid	5 20 52	NR NR NR	150 120 NR
Nitric Acid Fumes	—	—	160
Nitrobenzene	100	NR	NR

O

Chemical	Concentration % By Weight	Std.	VE
Oakite Rust Stripper		—	180
Octanoic Acid	100	—	180
Oil, Sour Crude	100	80	180
Oil, Sweet Crude	100	80	180
Oleic Acid	All	NR	180
Oleum (Fuming Sulfuric)		NR	NR
Olive Oil	100	—	180
Oxalic Acid	All	—	180

P

Chemical	Concentration % By Weight	Std.	VE
Perchloretylene	100	NR	100
Perchloric Acid	10 30	NR NR	150 100
Peroxide Bleach 2% Sodium Peroxide 96% .025% Epsom Salts, 5% Sodium Silicate, 42° BE 1.4% Sulfuric Acid, 66°BE		NR	180
Phenol	100	NR	NR
Phenol Sulfonic Acid	100	NR	NR
Phosphoric Acid	All	100	180
Phosphoric Acid Fumes		100	180
Phosphorous Pentoxide	0-54	—	180
Phosphorous Trichloride	100	NR	NR
Phthalic Acid	All	—	180

Chemical	Concentration % By Weight	Maximum Recommended Temperature °F.	
		Std.	VE
Pickling Acids Sulfuric and Hydrochloric		NR	180
Picric Acid/ Alcoholic	10	NR	180
Polyvinyl Acetate Latex	All	—	180
Polyvinyl Alcohol	100	NR	120
Polyvinyl Chloride Latex with 35 parts DOP		—	120
Potassium Alum Sulfate	All	90	180
Potassium Bicarbonate	0-50	NR	150
Potassium Bromide	All	90	180
Potassium Carbonate	All	NR	150
Potassium Chloride	All	100	180
Potassium Dichromate	All	—	180
Potassium Ferricyanide	All	—	180
Potassium Ferrocyanide	All	—	180
Potassium Hydroxide	All	NR	150
Potassium Nitrate	All	100	180
Potassium Permanganate	All	NR	180
Potassium Persulfate	All	—	180
Potassium Sulfate	All	100	180
Propionic Acid	20	—	180
	50	—	160
	100	—	NR
Propylene Glycol	All	—	180
Pyridine	100	—	NR

S

Chemical	Concentration % By Weight	Std.	VE
Salicylic Acid	All	—	160
Sebacic Acid	All	—	180
Selenius Acid	All	—	180
Silver Nitrate	All	—	180
Soaps	All	90	180
Sodium Acetate	All	—	180
Sodium Aluminate	All	NR	120
Sodium Alkyl Aryl Sulfonates	All	—	150
Sodium Benzoate	100	—	180
Sodium Bicarbonate	All	NR	180
Sodium Bifluoride	All	—	120
Sodium Bisulfate	All	80	180
Sodium Bisulfite	All	70	180
Sodium Bromate	10	—	—
Sodium Bromide	All	90	180
Sodium Carbonate	0-25	NR	—
	35	NR	—
Sodium Chlorate	All	NR	180
Sodium Chloride	All	100	180
Sodium Chlorite	All	NR	150
Sodium Chromate	50	—	180

Chemical	Concentration % By Weight	Maximum Recommended Temperature °F.	
		Std.	VE
Sodium Cyanide	All	—	180
Sodium Dichromate	All	—	180
Sodium Di-Phosphate	All	—	180
Sodium Ferricyanide	All	—	180
Sodium Ferrocyanide	All	—	180
Sodium Fluoride	All	—	180
Sodium Fluoro Silicate	All	—	150
Sodium Hexametaphosphates	All	—	120
Sodium Hydroxide	5	NR	150
	10	NR	150
	25	NR	120
	50	NR	160
Sodium Hydrosulfide	All	—	180
Sodium Hypochlorite	0-5	70	180
	5-15	NR	150
Sodium Lauryl Sulfate	All	—	180
Sodium Mono-Phosphate	All	100	180
Sodium Nitrate	All	100	180
Sodium Nitrite	All	100	180
Sodium Persulate	20	—	130
Sodium Silicate	All	NR	180
Sodium Sulfate	All	100	180
Sodium Sulfide	All	NR	180
Sodium Sulfite	All	NR	180
Sodium Tetro Borate	All	—	180
Sodium Thiocyanate	57	—	180
Sodium Thiosulfate	All	—	180
Sodium Tripolyphosphate	All	—	180
Sodium Xylene Sulfonate	All	NR	180
Sorbitol Solutions	All	—	150
Sour Crude Oil	100	80	180
Soya Oil	All	—	180
Stannic Chloride	All	—	180
Stannous Chloride	All	—	180
Stearic Acid	All	100	180
Styrene	100	NR	NR
Sugar, Beet and Cane Liquor	All	—	180
Sugar, Sucrose	All	—	180
Sulfamic Acid	0-25	70	180
Sulfanilic Acid	All	—	180
Sulfated Detergents	All	100	180
Sulfur Dioxide, Dry or Wet		NR	—
Sulfur Trioxide/Air	All	NR	180

Chemical	Concentration % By Weight	Maximum Recommended Temperature °F. Std.	VE
Sulfuric Acid	0-5	100	180
	5-70	—	160
	75	NR	—
	Over 75	NR	NR
Sulfurous Acid	All	NR	—
Superphosphoric Acid 105% H_3PO_3 76% P20s		NR	180

T

Chemical	Concentration % By Weight	Std.	VE
Tall Oil	All	—	—
Tannic Acid	All	—	—
Tartaric Acid	All	NR	180
Tetrachloroethylene	100	NR	NR
Thionyl Chloride	100	NR	NR
Toluene	100	NR	NR
Toluene Solfonic Acid	All	—	180
Transformer Oils:			
Mineral Oil Types		—	180
Chloro-Phenyl Types		NR	NR
Trichlor Acetic Acid	50	NR	180
Trichloroethane	100	NR	—
Trichloroethylene	100	NR	NR
Trichlorophenol	100	NR	NR
Tridecylbenzene Sulfonate	All	—	180
Trimethylene Chlorobromide	100	NR	NR

Chemical	Concentration % By Weight	Maximum Recommended Temperature °F. Std.	VE
Trisodium Phosphate	All	NR	180
Turpentine	100	NR	—
Tween Surfactant	All	—	150

V

Chemical	Concentration % By Weight	Std.	VE
Vegetable Oils		100	180
Vinegar		100	180
Vinyl Acetate	100	NR	NR
Vinyl Toluene	100	NR	—

W

Chemical	Concentration % By Weight	Std.	VE
Water			
Deionized		NR	180
Demineralized		100	180
Distilled		100	180
Fresh		100	180
Salt		100	180
Sea		100	180

X

Chemical	Concentration % By Weight	Std.	VE
Xylene	100	NR	NR

Z

Chemical	Concentration % By Weight	Std.	VE
Zinc Chlorate	All	—	180
Zinc Chloride	All	100	180
Zinc Nitrate	All	100	180
Zinc Sulfate	All	100	180

Appendix G

Deflected Pipe Minimum Inside Diameters

Class SN 18

Nominal Pipe Size (in.)	Pipe O.D. (in.)	Pressure Class					
		PN 25		PN 50		PN 100	
		Min. Dia (in.)		Min. Dia (in.)		Min. Dia (in.)	
		@ 3% defl.	@ 5% defl.	@ 3% defl.	@ 5% defl.	@ 3% defl.	@ 5% defl.
18	19.5	18.21	17.83	18.23	17.85	18.23	17.85
20	21.6	20.20	19.79	20.20	19.79	20.20	19.79
24	25.8	24.15	23.66	24.18	23.68	24.18	23.68
27	28	26.23	25.69	26.25	25.71	26.25	25.71
28	30	28.13	27.55	28.13	27.55	28.15	27.57
30	32	30.01	29.39	30.03	29.41	30.03	29.41
33	34	31.91	31.25	31.91	31.25	31.93	31.27
36	38.3	35.95	35.21	35.97	35.23	35.99	35.25
41	42.9	40.29	39.46	40.31	39.48	40.33	39.50
42	44.5	41.81	40.94	41.83	40.96	41.85	40.98
44	45.9	43.12	42.23	43.14	42.25	43.16	42.27
45	47.7	44.83	43.90	44.85	43.92	44.87	43.94
48	50.8	47.75	46.77	47.77	46.79	47.79	46.81
51	53.9	50.68	49.63	50.70	49.65	50.72	49.67
54	57.1	53.70	52.59	53.72	52.61	53.74	52.63
57	60	56.43	55.27	56.45	55.29	56.47	55.31
60	62.9	59.16	57.94	59.20	57.98	59.23	58.00
63	66	62.09	60.81	62.13	60.85	62.15	60.87
66	69.2	65.11	63.77	65.15	63.81	65.17	63.83
69	72.5	68.23	66.82	68.25	66.84	68.29	66.88
72	75.4	70.96	69.50	71.00	69.54	71.02	69.56
78	81.6	76.81	75.23	76.86	75.27	76.88	75.29
84	87	81.91	80.22	81.95	80.26	81.99	80.30
85	88.6	83.42	81.70	83.46	81.74	83.50	81.78
90	94.3	88.81	86.98	88.85	87.02	88.89	87.06
96	99.5	93.71	91.78	93.75	91.82	93.79	91.86
104	108	101.73	99.63	101.77	99.67	101.81	99.71
110	114	107.39	105.17	107.41	105.19	107.45	105.23
120	126	118.70	116.25	118.72	116.27	118.76	116.31
126	132.5	124.84	122.27	124.86	122.29	124.90	122.33

Class SN 36

Nominal Pipe Size (in.)	Pipe O.D. (in.)	Pressure Class									
		PN 25		PN 50		PN 100		PN 150		PN 200	
		Min. Dia (in.)		Min. Dia (in.)		Min. Dia (in.)		Min. Dia (in.)		Min. Dia (in.)	
		@ 3% defl.	@ 5% defl.	@ 3% defl.	@ 5% defl.	@ 3% defl.	@ 5% defl.	@ 3% defl.	@ 5% defl.	@ 3% defl.	@5% defl.
18	19.5	18.08	17.71	18.08	17.71	18.11	17.73	18.11	17.73	18.13	17.75
20	21.6	20.04	19.63	20.06	19.65	20.06	19.65	20.08	19.67	20.10	19.69
24	25.8	23.99	23.50	23.99	23.50	24.01	23.52	24.01	23.52	24.03	23.54
27	28	26.04	25.51	26.04	25.51	26.06	25.53	26.09	25.55	26.11	25.57
28	30	27.92	27.35	27.92	27.35	27.94	27.37	27.96	27.39	27.98	27.41
30	32	29.78	29.17	29.80	29.19	29.82	29.21	29.84	29.23	29.86	29.25
33	34	31.66	31.01	31.68	31.03	31.70	31.05	31.72	31.07	31.74	31.09
36	38.3	35.69	34.95	35.71	34.97	35.73	34.99	35.75	35.01	35.77	35.03
41	42.9	40.01	39.18	40.01	39.18	40.03	39.20	40.07	39.24	40.09	39.26
42	44.5	41.50	40.64	41.52	40.66	41.54	40.68	41.56	40.70	41.60	40.74
44	45.9	42.82	41.93	42.82	41.93	42.86	41.97	42.88	41.99	42.92	42.03
45	47.7	44.50	43.58	44.52	43.60	44.54	43.62	44.58	43.66	44.60	43.68
48	50.8	47.41	46.43	47.43	46.45	47.45	46.47	47.49	46.51	47.51	46.53
51	53.9	50.31	49.27	50.33	49.29	50.35	49.31	50.39	49.35	50.43	49.39
54	57.1	53.31	52.21	53.31	52.21	53.35	52.25	53.40	52.29	53.44	52.33
57	60	56.03	54.87	56.05	54.89	56.07	54.91	56.11	54.95		
60	62.9	58.74	57.53	58.76	57.55	58.80	57.59	58.84	57.63		
63	66	61.64	60.37	61.66	60.39	61.70	60.43	61.76	60.49		
66	69.2	64.64	63.31	64.66	63.33	64.70	63.37	64.75	63.41		
69	72.5	67.74	66.35	67.76	66.37	67.78	66.39	67.84	66.45		
72	75.4	70.45	69.00	70.47	69.02	70.52	69.06				
78	81.6	76.26	74.69	76.28	74.71	76.33	74.75				
84	87	81.32	79.64	81.34	79.66	81.38	79.70				
85	88.6	82.81	81.10	82.83	81.12	82.89	81.18				
90	94.3	88.16	86.34	88.18	86.36	88.24	86.42				
96	99.5	93.04	91.12	93.06	91.14	93.12	91.20				
104	108	101.00	98.91	101.02	98.93	101.08	98.99				
110	114	106.61	104.41	106.63	104.43	106.69	104.49				
120	126	117.85	115.42	117.89	115.46	117.95	115.52				
126	132.5	123.95	121.39	123.99	121.43	124.05	121.49				

Class SN 46

Nominal Pipe Size (in.)	Pipe O.D. (in.)	Pressure Class									
		PN 25 Min. Dia (in.)		PN 50 Min. Dia (in.)		PN 100 Min. Dia (in.)		PN 150 Min. Dia (in.)		PN 200 Min. Dia (in.)	
		@ 3% defl.	@ 5% defl.	@ 3% defl.	@ 5% defl.	@ 3% defl.	@ 5% defl.	@ 3% defl.	@ 5% defl.	@ 3% defl.	@ 5% defl.
18	19.5	18.02	17.65	18.02	17.65	18.04	17.67	18.06	17.69	18.06	17.69
20	21.6	19.98	19.57	20.00	19.59	20.00	19.59	20.02	19.61	20.04	19.63
24	25.8	23.91	23.42	23.91	23.42	23.93	23.44	23.95	23.46	23.97	23.48
27	28	25.96	25.43	25.98	25.45	25.98	25.45	26.00	25.47	26.02	25.49
28	30	27.84	27.27	27.84	27.27	27.86	27.29	27.88	27.31	27.90	27.33
30	32	29.70	29.09	29.72	29.11	29.72	29.11	29.76	29.15	29.78	29.17
33	34	31.58	30.93	31.58	30.93	31.60	30.95	31.62	30.97	31.66	31.01
36	38.3	35.59	34.85	35.59	34.85	35.63	34.89	35.65	34.91	35.67	34.93
41	42.9	39.89	39.06	39.89	39.06	39.93	39.10	39.95	39.12	39.99	39.16
42	44.5	41.38	40.52	41.40	40.54	41.42	40.56	41.46	40.60	41.48	40.62
44	45.9	42.69	41.81	42.69	41.81	42.71	41.83	42.76	41.87	42.80	41.91
45	47.7	44.36	43.44	44.38	43.46	44.40	43.48	44.44	43.52	44.48	43.56
48	50.8	47.26	46.29	47.28	46.31	47.30	46.33	47.35	46.37	47.39	46.41
51	53.9	50.15	49.12	50.17	49.13	50.21	49.17	50.25	49.21	50.29	49.25
54	57.1	53.15	52.06	53.17	52.08	53.19	52.10	53.23	52.14	53.29	52.19
57	60	55.86	54.71	55.88	54.73	55.90	54.75	55.96	54.81		
60	62.9	58.57	57.37	58.57	57.37	58.61	57.41	58.68	57.47		
63	66	61.46	60.19	61.48	60.21	61.52	60.25	61.58	60.31		
66	69.2	64.44	63.11	64.46	63.13	64.50	63.17	64.56	63.23		
69	72.5	67.54	66.15	67.56	66.17	67.60	66.21	67.66	66.27		
72	75.4	70.23	68.78	70.27	68.82	70.31	68.86				
78	81.6	76.04	74.47	76.06	74.49	76.10	74.53				
84	87	81.07	79.40	81.09	79.42	81.16	79.48				
85	88.6	82.57	80.86	82.59	80.88	82.65	80.94				
90	94.3	87.89	86.08	87.93	86.12	87.97	86.16				
96	99.5	92.75	90.84	92.77	90.86	92.83	90.92				
104	108	100.69	98.61	100.73	98.65	100.79	98.71				
110	114	106.29	104.10	106.33	104.14	106.39	104.20				
120	126	117.50	115.08	117.54	115.12	117.60	115.18				
126	132.5	123.58	121.03	123.62	121.07	123.68	121.13				

Class SN 72

Nominal Pipe Size (in.)	Pipe O.D. (in.)	Pressure Class									
		PN 25 & 50 Min. Dia (in.)		PN 100 Min. Dia (in.)		PN 150 Min. Dia (in.)		PN 200 Min. Dia (in.)		PN 250 Min. Dia (in.)	
		@ 3% defl.	@ 5% defl.	@ 3% defl.	@ 5% defl.	@ 3% defl.	@ 5% defl.	@ 3% defl.	@ 5% defl.	@ 3% defl.	@ 5% defl.
18	19.5	17.92	17.55	17.92	17.55	17.94	17.57	17.96	17.59	17.96	17.59
20	21.6	19.86	19.45	19.88	19.47	19.90	19.49	19.90	19.49	19.92	19.51
24	25.8	23.77	23.28	23.79	23.30	23.79	23.30	23.81	23.32	23.83	23.34
27	28	25.80	25.27	25.82	25.29	25.84	25.31	25.86	25.33	25.88	25.35
28	30	27.66	27.09	27.68	27.11	27.70	27.13	27.72	27.15	27.74	27.17
30	32	29.52	28.91	29.54	28.93	29.56	28.95	29.58	28.97	29.60	28.99
33	34	31.38	30.73	31.40	30.75	31.42	30.77	31.44	30.79		
36	38.3	35.36	34.63	35.40	34.67	35.42	34.69	35.44	34.71		
41	42.9	39.64	38.82	39.66	38.84	39.70	38.88	39.72	38.90		
42	44.5	41.13	40.28	41.15	40.30	41.17	40.32	41.21	40.36		
44	45.9	42.43	41.55	42.45	41.57	42.49	41.61	42.51	41.63		
45	47.7	44.09	43.19	44.14	43.23	44.16	43.24	44.20	43.28		
48	50.8	46.98	46.01	47.00	46.03	47.04	46.07	47.08	46.11		
51	53.9	49.84	48.82	49.88	48.86	49.92	48.90	49.95	48.92		
54	57.1	52.83	51.74	52.87	51.78	52.91	51.82	52.93	51.84		
57	60	55.52	54.37	55.56	54.41	55.60	54.45				
60	62.9	58.21	57.01	58.25	57.05	58.29	57.09				
63	66	61.09	59.83	61.13	59.87	61.17	59.91				
66	69.2	64.05	62.73	64.09	62.77	64.15	62.83				
69	72.5	67.11	65.73	67.17	65.79	67.21	65.83				
72	75.4	69.80	68.36	69.86	68.42						
78	81.6	75.57	74.01	75.61	74.05						
84	87	80.59	78.92	80.65	78.98						
85	88.6	82.06	80.36	82.12	80.42						
90	94.3	87.36	85.56	87.42	85.62						
96	99.5	92.18	90.28	92.24	90.34						
104	108	100.08	98.02	100.16	98.10						
110	114	105.63	103.46	105.72	103.54						
120	126	116.79	114.38	116.87	114.46						
126	132.5	122.83	120.29	122.91	120.37						

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