

MUNICIPAL GASKETED SEWER PIPING SYSTEMS

PRODUCT INFORMATION BULLETIN

IPEX Ring-Tite® & Enviro-Tite® Piping Systems



PVC Sewer Piping Systems manufactured to CSA & ASTM standards

IPEX Ring-Tite® Pipe & Fittings (100mm-1050mm) (4"-42")
CSA B182.2, ASTM D3034, F679

IPEX Enviro-Tite® Pipe (100mm-375mm) (4"-15")
CSA B182.2 (4"-15")
CSA B182.1 (6" DR 28), ASTM F1760

Designed for various municipal applications, IPEX Ring-Tite and Enviro-Tite systems provide advanced protection from cracking, leaking, corrosion and other threats that can compromise the integrity of municipal sewer systems.

IPEX municipal sewer piping systems are made with a high-strength, high-impact PVC compound. More specifically, an innovative co-extrusion process is used for the production of Enviro-Tite, allowing for 50% use of reprocessed PVC while increasing product performance. The combination of reprocessed materials and superior performance truly distinguishes Enviro-Tite as one of the most environmentally friendly sewer pipes available.

Ring-Tite fittings are made from superior quality PVC and are injection molded or fabricated using the most advanced technology available and are as solid and reliable as our PVC pipe.

Proven in tough North American climates for over 50 years, IPEX PVC pipe and fittings systems have an established track record of performance.

Key features include:

Corrosion-proof Performance: IPEX Ring-Tite and Enviro-Tite systems are immune to corrosion from aggressive soils and galvanic action. In addition, H₂S and other aggressive chemicals common in sanitary sewage have no effect.

Tight Joints & Lower Treatment Costs: Eliminate infiltration and exfiltration. Ring-Tite and Enviro-Tite's joints easily outperform concrete and corrugated PE joints.

Third-party certification: IPEX Ring-Tite and Enviro-Tite systems are certified to CSA B182.2. Third party certification is your verification that the product will perform as stated.

Ring-Tite®
Enviro-Tite®



Products are manufactured by IPEX Inc.
and distributed in the United States by IPEX USA LLC.

Ring-Tite® & Enviro-Tite® are trademarks of
IPEX Branding Inc.

Canadian Customers call IPEX Inc.

Toll Free: (866) 473-9462
www.ipexinc.com

US Customers call IPEX USA LLC

Toll Free: (800) 463-9572
www.ipexamerica.com

High flow capacity: IPEX's PVC pipe and fittings are manufactured with smooth inner walls and provide systems with a Manning coefficient of 0.009, allowing for use of smaller diameters of pipe when compared to rough walled pipe.

Ring-Tite & Enviro-Tite Dimensions

	Nominal Size		Average I.D.		Min Wall Thickness		Average O.D.	
	in	mm	in	mm	in	mm	in	mm
SDR35	4	100	3.97	100.94	0.12	3.06	4.21	107.06
	5	135	5.32	135.08	0.16	4.09	5.64	143.26
	6	150	5.92	150.29	0.18	4.55	6.28	159.39
	8	200	7.92	201.16	0.24	6.10	8.40	213.36
	10	250	9.90	251.46	0.30	7.62	10.50	266.70
	12	300	11.79	299.36	0.36	9.07	12.50	317.50
	15	375	14.43	366.42	0.44	11.10	15.30	388.62
	18	450	17.63	447.87	0.53	13.57	18.70	475.01
	21	525	20.79	527.99	0.63	16.00	22.05	559.99
	24	600	23.39	594.00	0.71	18.00	24.80	630.00
	27	675	26.36	669.42	0.80	20.29	27.95	710.00
	30	750	30.17	766.36	0.91	23.22	32.00	812.80
	36	900	36.11	917.22	1.09	27.79	38.30	972.80
42	1050	41.95	1065.72	1.27	32.29	44.50	1130.30	
SDR28	4	100	3.91	99.42	0.15	3.82	4.21	107.06
	5	135	5.24	133.02	0.20	5.12	5.64	143.26
	6	150	5.83	148.01	0.22	5.69	6.28	159.39

(%) Deflection of Ring-Tite & Enviro-Tite (SDR 35 pipe)

ASTM Embedment Material Classification		Manufactured Granular Angular CLASS I	Clean Sand & Gravel CLASS II		Sand & Gravel with Fines CLASS III		Silt & Clay CLASS IV
DENSITY (PROCTOR) AASHTO T-99		90%	90%	80%	90%	85%	85%
E' kPa (psi)		20 700 (3,000)	13 800 (2,000)	7 000 (1,000)	7 000 (1,000)	3 500 (500)	2 760 (400)
1 m	3.3 ft	0.3	0.5	1.0	1.0	1.7	2.1
2	6.6	0.4	0.5	1.0	1.0	1.8	2.2
3	9.8	0.4	0.6	1.2	1.2	2.2	2.6
4	13.1	0.6	0.8	1.6	1.6	2.9	3.5
5	16.4	0.7	1.1	2.0	2.0	3.7	4.4
6	19.7	0.9	1.3	2.4	2.4	4.4	5.3
7	23.0	1.0	1.5	2.8	2.8	5.1	6.1
8	26.3	1.2	1.7	3.2	3.2	5.9	7.0
9	29.5	1.3	1.9	3.6	3.6	6.6	7.9
10	32.8	1.4	2.1	4.0	4.0	7.3	8.8
15	49.2	2.2	3.2	6.0	6.0	11.0	13.1

○ Not recommended

Canadian Customers call IPEX Inc.
Toll Free: (866) 473-9462
www.ipexinc.com

US Customers call IPEX USA LLC
Toll Free: (800) 463-9572
www.ipexamerica.com

MUNICIPAL OPEN PROFILE SEWER PIPE & FITTINGS

IPEX PVC Profile Pipe – Ultra-Rib®

**PVC Gravity Flow Systems manufactured to
CSA and ASTM standards**

**IPEX Ultra-Rib® Pipe and Fittings
(200 mm – 600 mm) (8" – 24")
CSA B182.4 and ASTM F794**

IPEX Ultra-Rib® is a gravity flow PVC sewer pipe with concentric reinforcing ribs that encircle the pipe to provide superior ring stiffness and performance. It is an extruded, seamless pipe made from high grade PVC compound.

Ultra-Rib is available in standard sewer sizes from 200mm to 600 mm (8" – 24"). Its optimized profile design offers strength and reliability, as well as economy and superior flow rates.

Features and Benefits

Ultra-Rib offers many advantages over traditional materials, as well as other plastic sewer pipes. Some of these advantages include:

Tight Joints & Lower Treatment Costs: Eliminate infiltration and exfiltration. Ultra-Rib's 50 psi capable joints easily outperform concrete and corrugated PE joints.

Superior Flow Characteristics: Because of the smooth inside wall of Ultra-Rib, a Manning's coefficient of 0.009 can be used when designing systems using Ultra-Rib pipe. This compares with Manning's coefficients of up to 0.023 for other materials like clay or concrete.

Abrasion Resistance: Ultra-Rib has been proven to be more abrasion resistant than other profile pipes, and has out-performed concrete pipe in testing at California State University.

Chemical Resistance: PVC is virtually immune to chemical attack from any type of sewage. Hydrogen Sulphide attack, which causes millions of dollars of damage to concrete and metal infrastructure, will not affect Ultra-Rib.

Stress Crack Resistance: While some HDPE pipes have been found to crack prematurely under load, Ultra-Rib's tough PVC construction and superior formulation has been proven to be immune to these problems.



Ultra-Rib®



Products are manufactured by IPEX Inc.
and distributed in the United States by IPEX USA LLC.
Ultra-Rib® is a trademark of IPEX Branding Inc.

Canadian Customers call IPEX Inc.
Toll Free: (866) 473-9462
www.ipexinc.com

US Customers call IPEX USA LLC
Toll Free: (800) 463-9572
www.ipexamerica.com

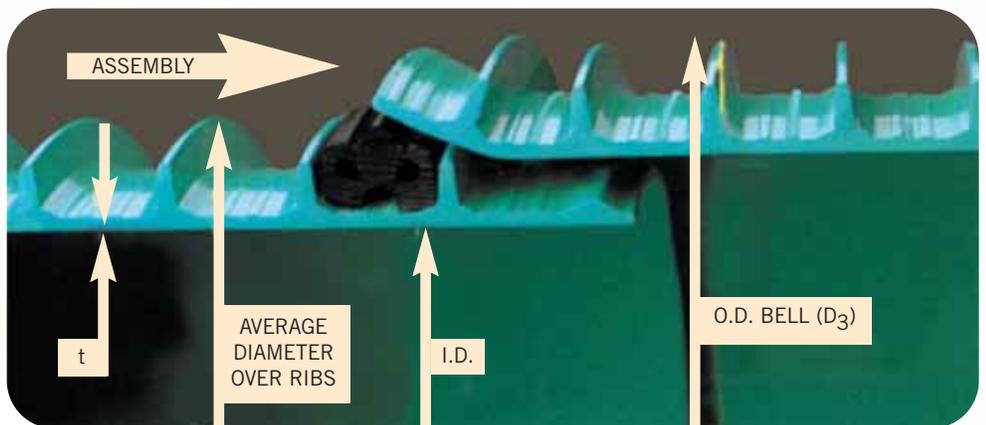
Percent (%) Deflection of ULTRA-RIB pipe

ASTM Embedment Material Classification	Manufactured Granular Angular CLASS I	Clean Sand & Gravel CLASS II		Sand & Gravel with Fines CLASS III		Silt & Clay CLASS IV	
	DENSITY (PROCTOR) AASHTO T-99	90%	90%	80%	90%	85%	85%
E' kPa (psi)	20 700 (3,000)	13 800 (2,000)	7 000 (1,000)	7 000 (1,000)	3 500 (500)	2 760 (400)	
Height of Cover							
m	ft						
1	3.3	0.3	0.5	1.0	1.0	1.7	2.1
2	6.6	0.4	0.5	1.0	1.0	1.8	2.2
3	9.8	0.4	0.6	1.2	1.2	2.2	2.6
4	13.1	0.6	0.8	1.6	1.6	2.9	3.5
5	16.4	0.7	1.1	2.0	2.0	3.7	4.4
6	19.7	0.9	1.3	2.4	2.4	4.4	5.3
7	23.0	1.0	1.5	2.8	2.8	5.1	6.1
8	26.3	1.2	1.7	3.2	3.2	5.9	7.0
9	29.5	1.3	1.9	3.6	3.6	6.6	7.9
10	32.8	1.4	2.1	4.0	4.0	7.3	8.8
15	49.2	2.2	3.2	6.0	6.0	11.0	13.1

Not recommended

Dimensions

Pipe Size		Average I.D. d		Average Diameter Over Ribs D		O.D. at Bell D ₃		Waterway Wall t	
mm	in	mm	in	mm	in	mm	in	mm	in
200	8	200	7.89	224	8.80	248	9.78	2.20	0.087
250	10	251	9.86	280	11.00	311	12.22	2.30	0.091
300	12	298	11.74	333	13.10	371	14.59	2.60	0.102
375	15	365	14.37	408	16.04	453	17.82	2.80	0.110
450	18	448	17.65	497	19.57	553	21.77	3.30	0.130
525	21	527	20.75	579	22.80	638	25.14	4.06	0.160
600	24	597	23.50	650	25.61	717	28.24	4.58	0.180



Canadian Customers call IPEX Inc.
Toll Free: (866) 473-9462
www.ipexinc.com

US Customers call IPEX USA LLC
Toll Free: (800) 463-9572
www.ipexamerica.com

SALES AND CUSTOMER SERVICE

Canadian Customers call IPEX Inc.

Toll free: (866) 473-9462

www.ipexinc.com

U.S. Customers call IPEX USA LLC

Toll free: (800) 463-9572

www.ipexamerica.com

About the IPEX Group of Companies

As leading suppliers of thermoplastic piping systems, the IPEX Group of Companies provides our customers with some of the world's largest and most comprehensive product lines. IPEX products are backed by more than 50 years of experience. With state-of-the-art manufacturing facilities and distribution centers across North America, we have established a reputation for product innovation, quality, end-user focus and performance.

Markets served by IPEX group products are:

- Electrical systems
- Telecommunications and utility piping systems
- PVC, PVC0, CPVC, PP, ABS, PEX, FR-PVDF and PE pipe and fittings (1/4" to 48")
- Industrial process piping systems
- Municipal pressure and gravity piping systems
- Plumbing and mechanical piping systems
- PE Electrofusion systems for gas and water
- Industrial, plumbing and electrical cements
- Irrigation systems

Products are manufactured by IPEX Inc. and distributed in the United States by IPEX USA LLC.

Ultra-Rib®, Ultra-X2, Enviro-Tite and Ring-Tite are trademarks of IPEX Branding Inc.

This literature is published in good faith and is believed to be reliable. However, it does not represent and/or warrant in any manner the information and suggestions contained in this brochure. Data presented is the result of laboratory tests and field experience.

A policy of ongoing product improvement is maintained. This may result in modifications of features and/or specifications without notice.



Installation Guide

Ultra-Rib®

UltraX2™

Enviro-Tite®

Ring-Tite®

M U N I C I P A L S Y S T E M S

PVC SEWER PIPE & FITTINGS

100 mm - 1200 mm (4" - 48")



IPEX

We build tough products for tough environments®

TABLE OF CONTENTS

STARTING THE JOB	4
Receiving and Handling	4
Unloading	4
Cold Weather Handling	6
Stockpiles	6
Weathering Resistance	6
Distribution Along Trench	7
Loading Transfer Trucks	8
Gaskets	8
Excavation	8
Line and Grade	9
Trench Width	9
INSTALLATION	10
Trench Zones	10
Embedment Materials	11
Selection of Embedment Materials	12
Preparation of Trench Bottom	12
Trench Boxes	13
Lowering Pipe Into Trench	13
Dimensions	14
Assembly of Pipe	18
Lubricant	20
Curved Sewers	21
Field Cut Assembly	23
Manhole Connections	24
Service Connections	25
Sewer Laterals	28
Riser Problems Demand Special Attention	28
Backfilling and Tamping	29
Tamping Equipment	30
TESTING OF SEWERS	31
Joint Tightness Testing	31
Deflection Testing	33
Videos	36



SPECIAL APPLICATIONS	36
Installing Pipe Through Casings	36
Deep Burial	39
Shallow Burial	39
Percent (%) Deflection of Ring-Tite, Enviro-Tite DR35, Ultra-Rib and Ultra-X2 Pipe	40
Percent (%) Deflection of IPEX Centurion Pipe	41
Tie-In Connections	42
Repairs	43
Solvent-Weld Pipe & Fittings	44
SOLVENT CEMENTING	45
Principles of Solvent Cementing	45
Solvent Cementing Instructions	46
Handling	46
Storage Conditions	46
Safety Precautions	46
Cold Weather	47
Preparation	47
Initial Set Time Schedule	50
Joint Cure Schedule	51
ADDITIONAL INFORMATION	52
Standards	52
Abbreviations	53
Addresses	54
Unit Conversion	55

IPEX PVC SEWER PIPE INSTALLATION GUIDE FOR RING-TITE, ENVIRO-TITE, ULTRA-RIB AND ULTRA-X2

INTRODUCTION

This book was written especially for the installer and for those who direct the actual handling and installation of IPEX Ring-Tite, Enviro-Tite, Ultra-Rib and Ultra-X2 PVC Gravity Sewer Pipes. This guide is not intended to supply all necessary design information nor to assume the responsibility of the Engineer (or other designer) in establishing procedures best suited to individual job conditions in order to attain satisfactory performance.

Engineers, superintendents, contractors, foremen and pipe laying crews will find this guide contains many helpful suggestions. This guide will also be of help in determining needs when ordering pipe and fittings.



STARTING THE JOB

RECEIVING AND HANDLING

Each pipe and fitting shipment should be inspected with care upon its arrival. The pipe and fittings were carefully loaded at the factory using methods acceptable to the carrier and it is their responsibility to deliver it in good order. ***It is the duty of the receiver to ensure that there has been no loss or damage in transit.***

The tally sheet or bill of lading which accompanies each shipment provides a complete list of all items included. Check the load against the tally sheet and report any errors to the transportation agent immediately. Be sure to have proper notations made on the delivery receipt.

Below is a checklist to follow when receiving shipments from carriers:

1. Make an overall examination of the load. If intact, ordinary inspection while unloading should be enough to make sure the pipe has arrived in good condition.
2. If the load has shifted or shows rough treatment, each piece must then be carefully inspected for damage.
3. Check total quantities of each item against tally sheet (pipe, gaskets, fittings, lube, etc.).
4. Any damaged or missing items must be noted on delivery receipt and returned to the transportation company.
5. Notify the carrier immediately and make claim in accordance with their instructions.
6. Do not dispose of any damaged material. The carrier will notify you of proper procedure to follow.
7. Shortages and damaged material are not automatically reshipped. If replacement material is needed, reorder through your distributor or IPEX representative.

UNLOADING

It is the customer's decision and responsibility on how PVC sewer pipe and fittings are unloaded in the field.

When unloading units, follow these instructions carefully:

- (a) Remove restraints from the top unit loads; typically being 32 mm (1-1/4") straps.
- (b) If needed, remove all 25 mm x 100 mm (1" x 4") boards across the top and down the sides of the units.

- (c) Remove the strapping only on the bundles of pipe being unloaded, and remove one unit at a time.
- (d) Use a forklift (or front end loader with forks) to remove each top unit separately. Remove the rear units first. Do not slide the equipment forks against the underside of pipe in a pallet. This may damage the pipe by abrasion.
- (e) If a forklift is not available, a spreader bar on top and nylon straps capable of handling the load may be used. The straps must be spaced approximately 2.5 m (8.2') apart and be looped under the unit. Cables should be cushioned with a rubber hose or other soft material to prevent abrasion to the pipe.
- (f) During the removal and handling, be sure that the units do not hit anything. Severe impact could cause damage, particularly during very cold weather installations.
- (g) Do not
 - i. Handle units with chains or single cables.
 - ii. Attach cables to unit frames for lifting.
- (h) Units should be:
 - i. Stored and placed on level ground.
 - ii. Stacked no more than two units high.
 - iii. Protected by dunnage (scrap wood) the same way they were loaded on the truck. The dunnage must support the weight of all units so that pipe lengths do not carry the weight of the unit loaded above them.
- (i) To unload lower units, repeat the above process (items A through H).
- (j) For Ultra-Rib pipe, if there are broken ribs for a continuous length of 300 mm (12") or more, that pipe length should not be used.

Preferred unloading is by units. If unloading equipment is not available, the pipe may be removed individually by cutting the bands securing the top tiers to those below. Care should be taken to ensure that the pipe is not dropped or damaged. Since the bands are tightly bound, the pipe may have a tendency to move when a band is cut. Make sure the truck is parked on level ground and that no one is standing near either side of the truck in case a length should roll off. Do not stand on the banded pipe while cutting the band.



COLD WEATHER HANDLING

Extra care should be taken in handling during cold weather. As the temperature drops below freezing, the flexibility and impact resistance of PVC pipe is reduced.

Pipe at the bottom of a bundle may become out of round slightly due to the weight of the pipe stacked above it. At normal temperatures, this situation will correct itself soon after the load is removed. Under freezing conditions, the recovery to initial roundness may take several hours.

STOCKPILES

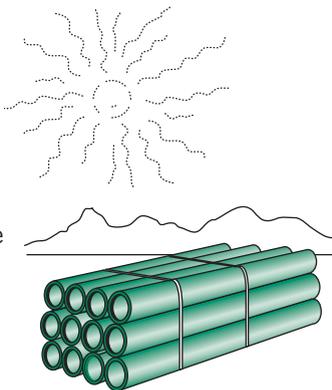
Stockpiles should always be built on a flat base. If mechanical equipment is being used to handle the unit, bearing pieces provide an excellent base. If unloading by hand, secure two timbers for a base. Set them on a flat area spaced the same distance as a factory load. Nail stop blocks at each end. Build up the stockpile in the same manner as it was stacked for shipment, transferring dunnage and chock blocks from the load to the stockpile.

Individual lengths of pipe should be stacked in piles no higher than 1.5 m (5').

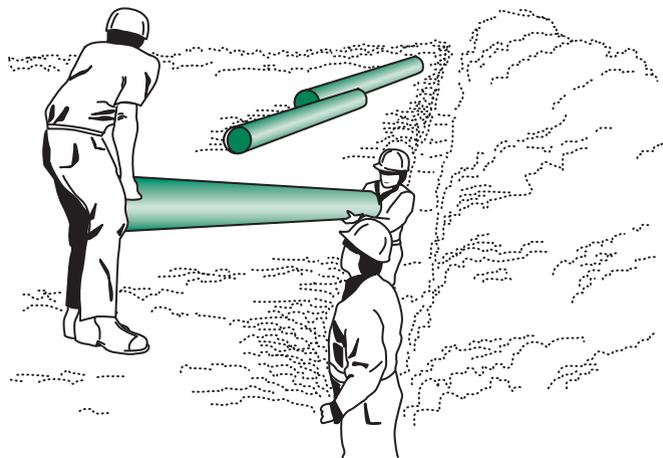
WEATHERING RESISTANCE

It should be noted that when PVC pipe is stored outside and exposed to prolonged periods (i.e. six months or more) of direct sunlight, an exterior discoloration may occur. This process is simply a hardening of the outer thousandths of an inch layer of vinyl. Physical properties such as pipe stiffness and tensile strength of PVC pipe are unaffected by surface discoloration. However, impact resistance may be reduced slightly. As a result, extra care should be used during installation and backfilling. It should be noted that degradation does *not* continue after PVC pipe has been buried.

A method of protecting PVC during extended exposure to sunlight is to cover it with an opaque material such as canvas. Air circulation should be provided under the protective cover. For above ground installations, application of a water-based latex paint will be effective protection against continuous sunlight exposure.



DISTRIBUTION ALONG TRENCH



In stringing out PVC pipe, keep these points in mind:

1. Lay pipe as near the trench as possible to avoid excess handling.
2. If the trench is open, it is advisable to string pipe on the side away from excavated soil wherever possible. This will allow pipe to be moved easily to the edge of the trench for lowering into position.
3. If the trench is not yet open, find out to which side excavated soil will be thrown. Then, string out pipe on the opposite side.
4. Place pipe in such a manner to protect it from traffic and heavy equipment. Also, safeguard it from the effects of any blasting which may be done.
5. Direct sunlight may cause the exposed side of the pipe to heat up creating a bow in the pipe. Should this occur, rotate the cool side towards the sun or place the pipe in the shade to alleviate the curving effect. Leaving the pipe in units will minimize bowing of PVC pipe due to heat from the sun.
6. It is common practice to string pipe with bell ends pointing upgrade.



LOADING TRANSFER TRUCKS

Use trucks with long bodies so that pipe lengths do not overhang more than 600 mm (24"). Make certain that the truck bed is smooth, without cross-strips, bolt heads, or other protrusions which could damage the pipe.

Place the first layer with the bell ends overhanging; avoid sliding the pipe and abrading it. Subsequent layers can be slid into place. All bell ends should overhang the layer below.

Short body trucks may be used if fitted with racks which properly support the pipe in a horizontal position, with supports spaced every metre (3') or less along the pipe lengths. Pad contact areas to avoid damage to the pipe.

GASKETS

IPEX Ring-Tite, Enviro-Tite, Ultra-Rib, Ultra-X2 and Centurion sewer pipes are provided with factory installed rubber gaskets eliminating the need for field installation. For Ring-Tite, Enviro-Tite and Centurion pipe, the gasket is placed inside the bell end to accommodate a smooth-walled spigot for assembly. With Ultra-Rib and Ultra-X2, the gasket is positioned on the spigot exterior for assembly into the smooth-surface interior of the bell.

Gaskets standardly supplied with IPEX PVC sewer pipe are made from the commonly used elastomer, SBR. Other gasket materials such as neoprene or nitrile are available should the gasketed joint require any special chemical resistance. Consult IPEX for recommendations.

EXCAVATION

As a general rule, do not open the trench too far ahead of pipe laying. Avoiding long stretches of opened trench will often reduce your costs by:

- (a) reducing pumping and sheeting requirements
- (b) minimizing the possibility of flooding the trench
- (c) reducing caving caused by ground water
- (d) helping to avoid frozen trench bottom and backfill
- (e) lowering safety hazard risks to workers and traffic

For sewer projects involving extremely deep cuts, Ring-Tite, Enviro-Tite and Ultra-Rib are available in shorter lengths. Contact IPEX for details on availability and delivery for these special orders.

LINE AND GRADE

Abrupt directional changes for sewer lines are often accomplished using manholes. Besides being an access chamber to the line, the manhole acts as a directional junction box for sewer pipe laid in straight lines.

The grade to which the pipe is to be laid is generally specified on the project drawings. Rather than suggesting a minimum grade to be used at all times with IPEX sewer pipe, it is recommended that the grade be sufficient to provide a minimum velocity of 0.6 m/s (2.0 fps). This will ensure that the flow is self-cleansing at all times inside the pipe.

TRENCH WIDTH

The width of the trench at the top of the pipe should allow for proper placement and compaction of the haunching materials. Generally, the minimum trench width should be 300 mm (12") greater than the outside diameter of the pipe, with a minimum value of 450 mm (18") at all times.

For a rigid pipe, keeping the trench width narrow is important since the load imposed upon the pipe is a function of the trench width. However, for flexible pipe, the maximum load on the pipe is the "prism load" which is the weight of the soil column directly above the pipe. Thus, precautions in keeping the trench narrow are unnecessary for a PVC pipe installation. The key is to compact the haunching material out to the undisturbed trench walls. More details on proper installation are contained in the following section.



INSTALLATION

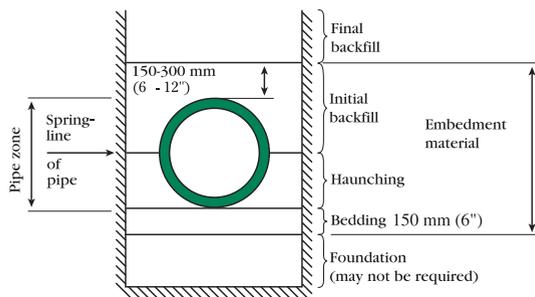
An understanding of flexible conduit terminology is essential for the installer. The soil class and density realized in the bedding, haunching and initial backfill zones are important factors in achieving a satisfactory installation of PVC pipe.

Much of the installation information can also be found in Canadian Standards Association (CSA) Standard B182.11, entitled, "Recommended Practice for the Installation of Thermoplastic Drain, Storm and Sewer Pipe and Fittings" or ASTM Standard D2321, entitled, "Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity Flow Applications."

TRENCH ZONES

The following figure has been prepared to illustrate the various zones used with flexible pipe terminology.

Pipe Zone Terminology



Foundation – A foundation is required when the trench bottom is unstable. Any foundation that will support a rigid pipe without causing loss of grade or structural breakage will be more than adequate for PVC pipes.

Bedding – The bedding directly underneath the pipe is required only to bring the trench bottom up to grade. It should not be so thick or soft that the pipe will settle and lose grade. The sole purpose of the bedding is to provide a firm, stable and uniform support of the pipe. A bedding thickness of 100 mm (4") is most times sufficient. The engineer may wish to increase the bedding to 150 mm (6") for ledge rock foundations.

Haunching – This area is the most important in terms of limiting the vertical deflection of the flexible pipe. Pipe support is obtained in the haunch zone by compacting soil in both directions away from the pipe to the undisturbed trench walls.

Initial Backfill – This zone begins above the springline to a level 150 mm (6") to 300 mm (12") above the top of the pipe. Compaction here will give little additional side support to PVC pipe, but may be required to maintain stability of any above ground surfaces (i.e. roads or sidewalks).

Note: *The particle size recommended for the three zones described above should not exceed 38 mm (1.5") for Ring-Tite, Enviro-Tite, Ultra-Rib, Ultra-X2 and Centurion.*

Final Backfill – The remainder of the trench fill above the initial backfill provides no support for a PVC pipe and should be free of stones 150 mm (6") and larger. Compaction may be required for reasons other than support of the PVC pipe since this zone is very significant in supporting the above ground surfaces (i.e. roads or highways).

EMBEDMENT MATERIALS

Some general rules about all soils to be used in a buried pipeline trench include that they must be free of sharp objects, sticks, large clumps, frozen material, organic materials and boulders.

Most of the soils commonly found can be classified into one of the following categories, which are referenced from ASTM D2487.

Class 1

Angular, 6 mm to 38 mm (1/4" – 1-1/2") graded stone, including a number of fill materials such as coral, slag, cinders, crushed stone or crushed shells.

Class 2

Coarse sands and gravels with a maximum particle size of 38 mm (1-1/2"), including various graded sands and gravels containing small percentages of fines, generally granular and non-cohesive.

Class 3

Fine sand and clayey gravels, including fine sands, sand-clay mixtures and gravel-clay mixtures.

Class 4

Silt, silty clays, and clays including inorganic clays and silts of medium to high plasticity and liquid limits.

Class 5

Includes organic soils such as frozen earth, debris and other foreign materials. These materials are not recommended for use in the bedding, haunch or initial backfill zones.

Note: *The performance of a flexible conduit does not depend only on the class of embedment materials used, but more importantly, on the density achieved in compaction of the haunching material.*



SELECTION OF EMBEDMENT MATERIALS

Soil to be used in the pipe zone should be capable of maintaining the specified soil density. For example, if a coarse material such as Class 1 is used for bedding the pipe, it should also be used in the haunch zone to the springline of the pipe. Otherwise, side support may be lost due to migration of the Class 2, 3 or 4 material into the bedding.

When selecting the embedment materials, ensure that native soil migration from the trench walls cannot occur. A well-graded compacted granular material will prevent this condition from occurring. In trenches subject to inundation, the granular material should be compacted to a minimum of 85% Standard Proctor Density.

PREPARATION OF TRENCH BOTTOM

Preparation of the trench bottom is the starting point for a satisfactory and safe sewer pipe installation. The trench bottom should be smooth and free from large stones, clumps of dirt, and any frozen material as approved by the engineer. It is economical on most sewer installations to undercut the trench bottom by machine and bring it up to grade by use of granular material.

If the bedding material chosen is a loose granular such as sand, the pipe can be laid directly on it. If the bedding is a hard, compacted material, excavation for the bells (bell holes) should be provided so that the pipe is uniformly supported along the entire length.

Coarse sand, crushed stone or shell often is the most economical granular material because compaction is easily obtained. With all types of soil, voids should be eliminated under and around the lower half of the pipe by working in granular materials by shovel slicing.

Native backfill may be used for the trench bottom providing the soil is free of large stones, hard lumps and debris, and can be properly compacted by tamping. Ensure that the fill does not fit the Class 5 description.

In rocky trenches, place a minimum 100 mm (4") layer of select bedding material to provide a cushion for the pipe. The rock foundation must first be excavated to at least 100 mm (4") below the final grade of the pipe bottom. *Any buried pipe, regardless of pipe material, that rests directly on rock may be subject to eventual breakage under the weight of soil and/or live loads.*

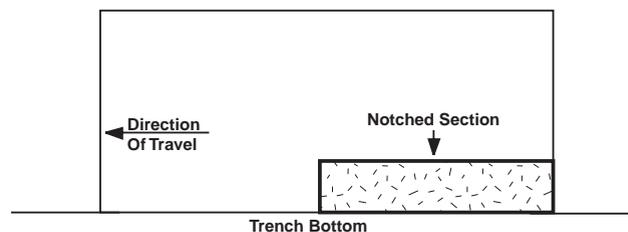
When an unstable trench bottom is encountered and appears to be unable to support the pipe properly, the engineer may insist that the bottom be excavated and refilled to pipe grade with an approved foundation and bedding material. This layer should be compacted to a minimum 85% Standard Proctor Density.

TRENCH BOXES

It is good safety practice to use movable trench boxes whenever possible while installing pipe in a below ground trench. The trench box serves as a lateral support to protect workers from possible cave-ins. They are often a requirement of local labor codes.

In order not to compromise the integrity of a PVC pipe installation, there are essentially two options available when using a trench box:

1. Set the box directly on the trench foundation after having bottom corner sections of the box removed on each side. This will permit proper placement and compaction of bedding material in the pipe zone. The box should be regularly moved along in the direction of the excavation with the cut-away section being at the back end (as shown below).



2. A full profile box may be used but only if it is set on ledges or shelves made in the sidewalls of the trench. These ledges should be located above the springline of the pipe. This will create a subditch condition within the trench, and will ensure optimal compaction around the PVC pipe. A full profile box will also be effective if suspended from the top of the trench by cross beams or side-wheels.

LOWERING PIPE INTO TRENCH

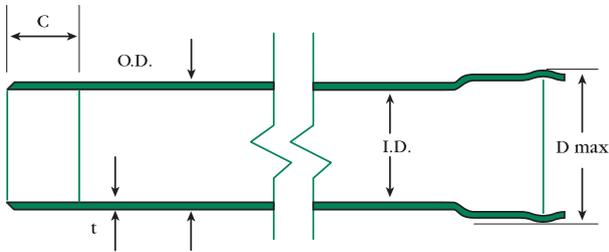
PVC sewer pipe in sizes up to 375 mm (15") diameter are capable of being handled and lowered into the trench by hand. Larger pipe should be lowered using ropes and skids or an excavator bucket with slings. Do not kick or throw PVC pipe into the trench.

Pipe and fittings should be inspected for defects or damage prior to lowering into the trench. Any defective or damaged pipe or fittings should be repaired or replaced. All foreign matter should be removed from the pipe interior before lowering for usage. For Ultra-Rib Pipe, the maximum permitted continuous length of broken ribs is 300 mm (12").



DIMENSIONS

1. Ring-Tite and Enviro-Tite



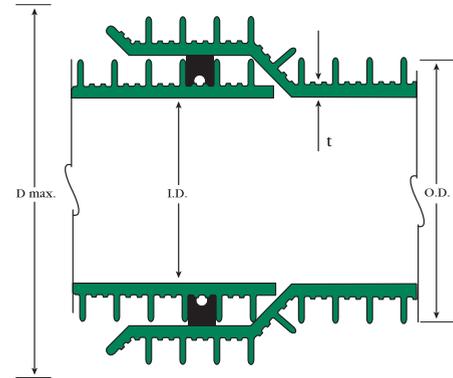
- where, O.D. = average outside diameter
- I.D. = average inside diameter
- t = minimum wall thickness
- Dmax = approximate outside diameter of the bell
- C = insertion depth distance

Note: Bell profiles are for information only.
Actual profiles may vary

Enviro-Tite available in DR35 from 100 - 375 mm.

Pipe Size		O.D.		I.D.		t		Dmax		C	
mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.
DR28											
100	* 4	107.1	4.22	99.0	3.90	3.8	0.15	135	5.31	71	2.8
125	* 5	143.3	5.64	132.5	5.22	5.1	0.20	173	6.81	72	2.8
150	* 6	159.4	6.28	147.3	5.80	5.7	0.22	191	7.52	89	3.5
DR35											
100	4	107.1	4.22	100.7	3.96	3.1	0.12	133	5.24	71	2.8
125	5	143.3	5.64	134.6	5.30	4.1	0.16	171	6.73	72	2.8
150	6	159.4	6.28	149.6	5.89	4.6	0.18	189	7.44	89	3.5
200	8	213.4	8.40	200.4	7.89	6.1	0.24	245	9.65	100	3.9
250	10	266.7	10.50	250.5	9.86	7.6	0.30	310	12.20	115	4.5
300	12	317.5	12.50	298.1	11.74	9.1	0.36	364	14.33	125	4.9
375	15	388.6	15.30	365.1	14.37	11.1	0.44	442	17.40	145	5.7
450	18	475.0	18.70	448.1	17.56	13.6	0.53	550	21.65	286	11.3
525	21	560.0	22.05	528.3	20.71	16.0	0.63	640	25.20	317	12.5
600	24	630.0	24.80	594.4	23.36	18.0	0.71	700	27.56	343	13.5
675	27	710.0	27.95	669.9	26.26	20.3	0.80	800	31.50	343	3.5
750	30	812.8	32.00	763.8	30.07	23.2	0.91	926	36.46	356	4.0
900	36	972.8	38.30	914.4	36.00	27.8	1.09	1108	43.62	406	6.0
1050	42	1130.3	44.50	1062.0	41.81	32.3	1.27	1265	49.80	406	16.0

2. Ultra-Rib

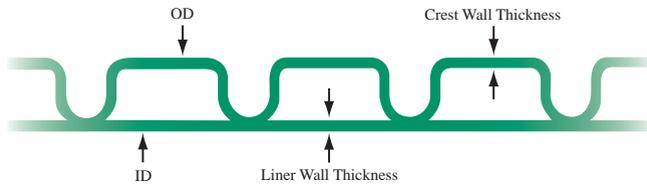


- where, O.D. = average outside diameter of barrel
- I.D. = average inside diameter
- t = minimum waterway wall thickness
- Dmax = approximate outside diameter of bell

Pipe Size		O.D.		I.D.		t		Dmax	
mm	in.	mm	in.	mm	in.	mm	in.	mm	in.
200	8	224	8.8	200	7.87	2.20	0.09	248	9.8
250	10	280	11.0	251	9.88	2.30	0.09	311	12.2
300	12	333	13.1	298	11.73	2.60	0.10	371	14.6
375	15	408	16.1	365	14.37	2.80	0.11	453	17.8
450	18	497	19.6	448	17.64	3.30	0.13	556	21.9
525	21	584	23.0	527	20.75	4.06	0.16	665	26.2
600	24	660	26.0	597	23.50	4.58	0.18	724	28.5

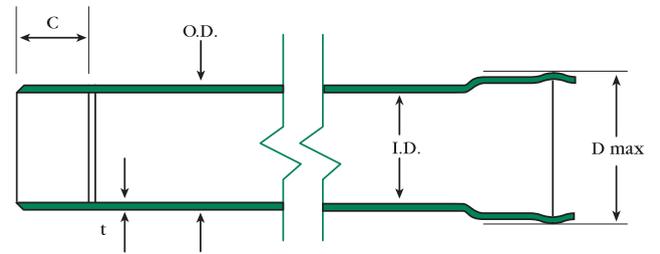


3. Ultra-X2



Nominal Pipe Size		OD		ID		Crest Wall Thickness		Liner Wall Thickness		Insertion Force
mm	in	mm	in	mm	in	mm	in	mm	in	
750	25.53	816.6	32.15	749.2	29.50	3.7	0.15	5.6	0.22	985 lbf
900	35.43	984.6	38.76	901.4	35.49	3.3	0.13	4.6	0.18	1000 lbf

4. IPEX Centurion



where, O.D. = average outside diameter
 I.D. = average inside diameter
 t = minimum wall thickness
 Dmax = approximate outside diameter of the bell
 C = insertion depth distance

Note: Bell profiles are for information only.
 Actual profiles may vary.

Pipe Size		OD		ID		t		Dmax		C	
mm	in	mm	in	mm	in	mm	in	mm	in	mm	in
DR41											
600	24	655	25.8	623	24.5	16.0	0.63	753	29.6	330	13.0
750	30	813	32.0	773	30.4	19.8	0.78	918	36.1	368	14.5
900	36	973	38.3	925	36.4	23.7	0.93	1089	42.9	393	15.5
1050	42	1130	44.5	1075	42.3	27.5	1.09	1255	49.4	406	16.0
1200	48	1290	50.8	1227	48.3	31.5	1.24	1424	56.1	432	17.0
DR51											
600	24	655	25.8	630	24.8	12.8	0.50	745	29.3	330	13.0
750	30	813	32.0	781	30.7	15.9	0.63	909	35.8	368	14.5
900	36	973	38.3	935	36.8	19.1	0.75	1080	42.5	393	15.5
1050	42	1130	44.5	1086	42.8	22.2	0.87	1240	48.8	406	16.0
1200	48	1290	50.8	1240	48.8	25.3	1.00	1409	55.5	432	17.0

Note: The installation recommendations presented in this booklet for Ring-Tite and Enviro-Tite are generally valid for IPEX Centurion pipe used for gravity sewer applications. For specific recommendations, contact your local IPEX sales office.



ASSEMBLY OF PIPE

Ring-Tite, Enviro-Tite, Ultra-Rib, Ultra-X2 and Centurion pipe are assembled in the form of a bell and spigot gasketed joint. For Ring-Tite, Enviro-Tite pipe and Centurion pipe, the gasket is in place in the interior of the bell while the spigot is factory-beveled for easy insertion. Ultra-Rib and Ultra-X2 differ by having the gasket positioned on the spigot exterior, between the second and third ribs, for insertion into a smooth-interior bell. Assembly procedures are virtually identical.

Assembly Steps

1. Ensure that the bell interior and spigot exterior are clean and free from foreign material that could prevent an effective seal between the bell and spigot.

Note: All Ring-Tite, Enviro-Tite and Centurion PVC pipe is shipped with a chamfer on the end of the spigot. If there is no chamfer, follow the example of a factory-made spigot and machine a suitable chamfer using a beveling tool, hand rasp, disk cutter or router.

2. Apply IPEX lubricant to the pipe as follows:

(a) Ring-Tite, Enviro-Tite and Centurion Pipe – Apply lube to the spigot end only. The coating of lube should extend back 50 to 75 mm (2 to 3") from the spigot edge and should cover the entire circumference. The bell interior need not be lubricated.

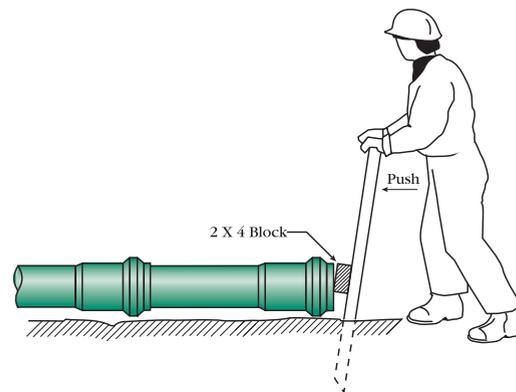
(b) Ultra-Rib and Ultra-X2 Pipe – Lube should be applied to the entire circumference of the bell interior to half of the bell depth. A thin layer of lube should also be applied to the gasket exterior on the spigot end.

The lube may be applied using a brush, cloth, glove, sponge or pad.

3. Insert the spigot end into the bell until the Ring-Tite, Enviro-Tite or Centurion spigot comes in contact with the rubber ring, or for Ultra-Rib and Ultra-X2, until the spigot gasket contacts the bell end.
4. While keeping the lengths in proper alignment, brace the bell and push the spigot into the bell. **The spigot should be inserted until the reference mark on the pipe barrel is even with the edge of the bell.**

Note: If undue resistance is felt to the assembly, the joint should be disassembled, cleaned and remade in accordance with the above methods. Dislodged gaskets can be re-installed on the spigot of Ultra-Rib, Centurion and Ultra-X2 or in the bell of

all IPEX Ring-Tite, Enviro-Tite and Centurion except for pipe with the pinched O-ring gasket. If excessive resistance still exists upon reassembly, **do not attempt to force the assembly.** Contact IPEX immediately for assistance.



Pipe can normally be assembled by hand or by bar and block for sizes up to 375 mm (15"). For larger sizes, it may be necessary to install the pipe using methods such as lever pullers, hydraulic jacks or the backhoe bucket.

When such mechanical means are used, the assembly effort should not be applied directly to the edge of the pipe. A two-by-four or a plank should be placed between the backhoe bucket and the pipe edge. The use of the excavator bucket has the disadvantage that the machine operator is unable to clearly see the pipe installation. A helper should assist by observing the reference mark and signalling the operator when the assembly is complete.

Note: Insertion depths may vary among different pipe manufacturers. As a result, care should be taken when assembling IPEX pipe with another brand of PVC pipe. The insertion depth of the other brands bell should be measured and marked on the IPEX spigot. If assembling the spigot of another brand of pipe into an IPEX bell, refer to Dimension C on page 14 for proper insertion depths of the IPEX bells.

CAUTION: Over-assembly of a PVC sewer pipe joint may cause one or both of the problems below:

- (a) Joint flexibility may be lost which may cause a leak in the case of uneven settlement.
- (b) The inside diameter may be reduced enough to appear as an over-deflection on a deflection mandrel test.



LUBRICANT

To assemble IPEX PVC sewer pipe, the installer should only use IPEX lubricant. The correct amount of lubricant can be calculated using the chart below. If adverse conditions are encountered, such as extreme cold or high water table, extra lubricant must be used.

LUBRICANT USAGE Joints Per Container

Pipe Size		Average Number of Joints per Container					
Metric mm	Nominal (in)	250 g (9 Oz)	516 g (Pint)	1 kg (Quart)	4 kg (Gallon)	11 kg (2½ Gallon)	23 kg (5 Gallon)
100	(4)	17	34	70	280	805	1,610
125	(5)	14	28	56	225	645	1,290
150	(6)	10	20	40	160	460	920
200	(8)	7	14	28	110	320	640
250	(10)	5	10	20	80	230	460
300	(12)	3	7	14	55	160	320
375	(15)	2	4	8	32	87	175
450	(18)	1	2	4	16	45	90
500	(20)	1	2	3	12	35	70
525	(21)	1	2	3	12	35	70
600	(24)	1	1	2	8	22	45
675	(27)	1	2	6	17	35	35
750	(30)			1	4	12	25
900	(36)				3	7	15
1050	(42)				2	5	10
1200	(48)				1	3	7

How to use the chart:

$$\frac{\text{\# of metres of pipe (per diameter)}}{\text{lay length of pipe (m)}} = \text{\# of joints}$$

or

$$\frac{\text{\# of feet of pipe (per diameter)}}{\text{lay length of pipe (ft)}} = \text{\# of joints}$$

$$\frac{\text{\# of joints}}{\text{joints per container}} = \text{\# of containers}$$

CURVED SEWERS

As a cost-saving alternative to manholes, gradual changes in direction for IPEX PVC sewer pipe may be achieved using one of the following:

- bending the pipe (IPEX Ring-Tite and Enviro-Tite only)
- deflecting the gasketed joint
- using IPEX PVC fittings

A. Bending the Pipe Barrel

Smaller diameters of IPEX PVC Ring-Tite and Enviro-Tite Pipe up to 300 mm (12") diameter may be subjected to limited bending to follow the outline of a curved trench.

This practice should not be attempted with Ultra-Rib, Ultra-X2 and Centurion Pipe.

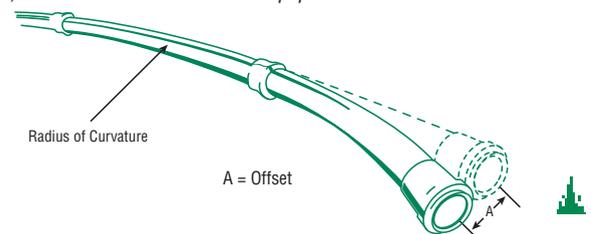
The recommended procedure is as follows:

- Make a concentric assembly in the usual way. Keep the spigot in straight alignment with the bell.
- Place compacted backfill around the assembled joint to restrict its movement while the curvature is being made.
- Place compacted backfill at the inside of the curve, at the mid-point of the pipe length, to form a fulcrum.
- Using only **manual** effort, move the leading bell of the pipe length to be curved by no more than the offset distance shown in the following table.

Below is a table showing the minimum radius of curvature achieved by bending IPEX Ring-Tite and Enviro-Tite Pipe, and the resultant maximum offset for standard 4 m (13') lengths.

Pipe Size		Min. Radius of Curvature		Max. Offset, A	
mm	in.	m	ft.	mm	in.
100	4	13	43	600	23
125	5	18	57	450	18
150	6	19	64	400	16
200	8	26	86	300	12
250	10	33	107	240	9
300	12	39	128	200	8

Note: Bending is not recommended for Ring-Tite and Enviro-Tite pipe sizes greater than 300 mm (12") or for any size of Ultra-Rib, Ultra-X2 and Centurion pipe.



B. Deflecting the Joint

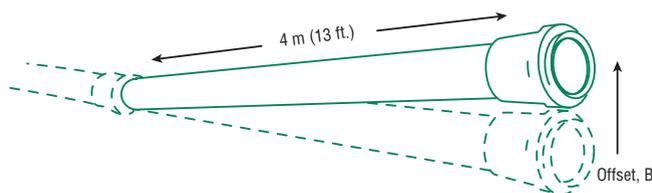
The gasketed joints of IPEX PVC sewer pipe and fittings are flexible enough to permit deviation in the assembled joint for directional changes. Below is the recommended procedure for curving a pipeline using joint deflection:

1. Make a concentric assembly, but push the spigot into the bell only to a point about 13 mm (1/2") short of the reference line. This incomplete assembly permits more movement of the end of the pipe at the neck of the bell.
2. Shift the loose bell end of the assembled length by not more than indicated in the following table.
3. This procedure should not be used in conjunction with Method A (bending the pipe barrel).

Below is a table illustrating the maximum allowable angle of deviation at the bell of IPEX PVC sewer pipe, as well as the resultant maximum offset for a standard 4 metre (13') length.

Pipe Size		Angle At One Bell	Maximum Offset, B		Radius Of Curvature	
mm	in.	degrees (°)	mm	in.	m	ft.
Ring-Tite and Enviro-Tite – 4m (13ft) lengths						
100 - 300	4 - 12	5	350	13.6	46	150
375 - 600	15 - 24	3	210	8.2	76	250
675 - 1050	27 - 42	1.5	100	4.1	150	490
Ultra-Rib – 4m (13ft) lengths						
200 - 600	8 - 24	5	350	13.6	46	150
Ultra-X2						
750 - 900	30 - 36	3	210	8	76	249
IPEX Centurion – 6.1m (20ft) lengths						
600 - 1200	24 - 48	1.5	160	6.3	230	750

Note: If half lengths of pipe are used, the above offset values must be divided by two.



C. Using PVC Fittings

IPEX offers standard elbows and short or long radius sweeps in 11-1/4°, 22-1/2°, 45° or 90°. PVC elbows can also be fabricated to any other angle configuration for all sizes of Ring-Tite, Enviro-Tite, Centurion, Ultra-Rib or Ultra-X2 pipe. These fittings are assembled in the same manner as the pipe.

FIELD-CUT ASSEMBLY

Before assembly is being made using field-cut PVC sewer pipe, follow the instructions below:

- (a) Ring-Tite, Enviro-Tite and Centurion Pipe** – The spigot end must be chamfered to a thickness of about 50% of the pipe wall at a bevel angle of 15°. Next, a reference line for insertion should be applied to minimize possibility of over-insertion. Dimension C in the table entitled, “Pipe Dimensions” (page 14), in this booklet may be used as a guide. Alternatively, the installer may determine the correct insertion line position from an uncut length of the same diameter pipe.
- (b) Ultra-Rib Pipe** – A gasket must be field installed between the second and third ribs of the spigot end. An insertion line can be marked using the table below as a guide.

Pipe Size		Stop Mark (between ribs)
mm	in	
200	8	4 and 5
250	10	5 and 6
300	12	5 and 6
375	15	5 and 6
450	18	5 and 6
525	21	6 and 7
600	24	6 and 7

- (c) Ultra-X2 Pipe** – A gasket must be field installed on the second valley of the spigot end. An insertion line can be marked using the table below as a guide.

Pipe Size		Stop Mark (from end of spigot)	
mm	in	mm	in
750	30	265	10.5
900	36	280	11



MANHOLE CONNECTIONS

Very often, connections of PVC sewer pipe to concrete manholes and other rigid structures require a watertight connection. Some options to obtain such a connection are described below.

Ring-Tite and Enviro-Tite

- 1. Gasketed Outlet** – Manhole suppliers normally offer a precast concrete base manhole with a gasketed outlet to accommodate smooth-walled Ring-Tite and Enviro-Tite PVC pipe. (IPEX Centurion's ODs must be specified prior to order.) The installer must simply specify the appropriate outside diameter of the pipe to ensure a properly sized gasket will be cast into the manhole. The Ring-Tite and Enviro-Tite pipe should be chamfered and lubricated before insertion.
- 2. Grout Adapters** – These fittings are manufactured from a stub of Ring-Tite, Enviro-Tite and Centurion pipe that has been coated externally with a sand, epoxy, cement mortar mixture. A watertight connection can be made by placing the adapter into a manhole outlet followed by filling the annular space around the adapter with a non-shrink grout. The special coating is required because grout will not form a watertight bond with bare PVC pipe.

Ultra-Rib/Ultra-X2

- 1. Smooth-Walled Adapter** – IPEX offers a Bell x Spigot PVC adapter that will transform Ultra-Rib to smooth-walled Ring-Tite and Enviro-Tite outside diameter. Connection to the manhole can then be achieved exactly as described in Method 1 for Ring-Tite and Enviro-Tite pipe. The adapter will be factory chamfered.
- 2. Grout Adapter** – The concept here is identical to the grout adapter used for Ring-Tite and Enviro-Tite pipe, except that the bell end of the grout adapter is made to accept an Ultra-Rib spigot. The procedure involves the application of a non-shrink grout to create a seal between the adapter and the concrete manhole wall. Some manhole manufacturers offer these type of adapters grouted into place in precast factory-made manholes for convenience to the pipeline installer.
- 3. Straight Connection** – Although non-shrink grout will not bond to PVC, it will adhere to elastomeric gaskets. Thus, a watertight grout-sealed connection can be made to the Ultra-Rib providing there is an Ultra-Rib gasket on the pipe spigot. An even better seal can be obtained if two (2) gaskets are placed consecutively on the Ultra-Rib spigot.

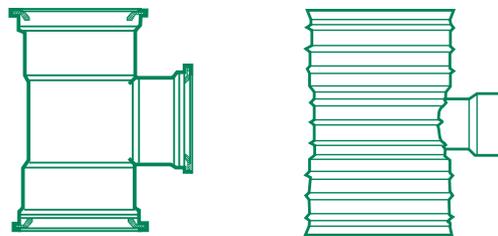
Manhole Installation Notes

- To minimize the effects of possible manhole settlement over time, shorter sections [typically 1 metre or (3')] of PVC sewer pipe should be used when entering and exiting the manhole.
- It is good practice to compact the foundation below the manhole to prevent excessive settlement.
- The area directly underneath the PVC pipe at the manhole should be supported by compacted soil or sand to assist in load bearing capacity.
- Manhole connections other than those listed above may be acceptable to the designer for varying water and soil tightness requirements.

SERVICE CONNECTIONS

IPEX offers four methods of connecting service lines or tie-ins to PVC sewer pipe. PVC fittings are the preferred method for service connections for newly installed lines up to 375 mm (15"), while saddles and Inserta-Tees are advantageous for larger sizes and for tie-ins to existing sewer mainlines of all diameters. Solvent weld fittings are not compatible with fabricated gasketed fittings because the spigot is too short to engage the gasket in a fabricated fitting.

- 1. PVC Fittings** – IPEX manufactures gasketed moulded PVC fittings up to 375 mm (15"), and fabricated PVC fittings up to 1200 mm (48") in all configurations. Custom configurations can also be made to suit design needs.



Joint assembly methods are the same as for pipe joints except the fittings may have different insertion depths. The insertion line on a factory-made pipe spigot should be disregarded when installing fittings on that spigot. A correct insertion distance may be determined by measuring the bell depth of the fitting with a measuring tape prior to assembly.



2. Inserta-Tees – These devices are available for use on Ring-Tite, Enviro-Tite, Ultra-Rib and Ultra-X2 PVC sewer pipe. Inserta-Tees can be installed on mainlines up to 1050 mm (42") diameter, with outlet sizes ranging from 100 mm (4") to 300 mm (12"). Follow the instructions below for proper installation:

Outlet Size		Hole Diameter	
mm	in.	mm	in.
100	4	114	4-1/2
150	6	165	6-1/2
200	8	222	8-3/4
250	10	276	10-7/8
300	12	327	12-7/8

(a) Core the appropriate sized hole with a hand-held drill with holesaw attachment. A tie-down coring machine is recommended for 250 mm (10") and 300 mm (12") Inserta Tee sizes. **

(b) Insert the rubber sleeve into the hole with the gold vertical line on the rubber sleeve facing perpendicular to the direction of mainline flow. The upper lip should be positioned against the wall exterior, while the lower lip should be against the inner pipe wall.

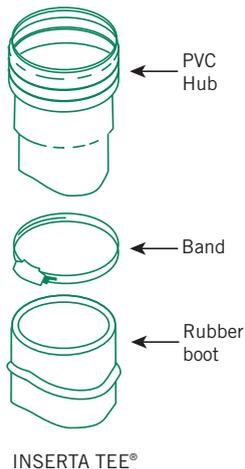
(c) Apply Inserta-Tee solution to the rubber sleeve interior and the PVC hub exterior. **Do Not use an oil-based lubricant.**

(d) Place the PVC hub into the rubber sleeve while aligning the **vertical red** line on the PVC hub with the gold line on the rubber sleeve.

(e) Tap the PVC hub into the sleeve using a hammer and block of wood. The hub should only be inserted until the **horizontal red** line on the hub is even with the outer edge of the rubber sleeve.

(f) Place the stainless steel band around the top of the rubber sleeve and tighten. The lateral pipe can now be inserted into the PVC hub to complete the service connection.

Note: Ensure that the Inserta-Tee used is designed for the type and size of pipe being used (i.e. for Ring-Tite, Enviro-Tite, Ultra-Rib or Ultra-X2).



** The following precautions should be observed when hole-cutting through Ultra-Rib pipe:

- use a variable speed drill
- to prevent binding, and possible injury, initially operate hole cutter in the reverse direction
- after establishing a groove, complete the hole in either the forward or reverse direction.

3. Strap-On Gasketed PVC Saddles – These devices are available as either tees or wyes. Mainline connections can be made to pipe as large as 1050 mm (42") with outlet sizes up to 150 mm (6") standardly available. **This method is for use on Ring-Tite and Enviro-Tite PVC pipe only.** The procedure below should be followed to ensure proper installation:

(a) Place saddle in position on pipe. Use the saddle as a template and marker guide for the hole cut-in. Remove the saddle from the pipe.

(b) Using the hole guide mark, cut a hole through the pipe wall outside the mark by the thickness of the saddle stem [more than 6 mm (1/4")]. Use a hand, keyhole or power jig saw to cut the hole. For wye saddles, cut or bevel the downstream side of the hole at a 45° angle to obtain a better fit for the saddle stem.

(c) Clean and dry both the underside of the saddle and the mating surface of the pipe.

(d) Position the saddle over the hole. Place the two (2) stainless steel hose clamps around the pipe and through the slots at each end of the saddle skirt. Check to see that the saddle stem is recessed into the hole for stability and that the straps are at right angles to the pipe surface.

(e) Tighten the straps alternately with a large screwdriver until the maximum torque has been reached by hand. The minimum applied torque should be 6.8 joules (5.0 ft/lbs).

(f) Place and tamp the select backfill around the pipe and saddle to provide firm and continuous support for both.

Note: If saddles are not properly positioned, the rubber gasket may not be touching the pipe wall which may result in a leak. When performing any of the above service connection methods, every effort should be made to:

- Ensure no foreign matter enters the main line through the connection outlet.
- Keep the outlet plugged until the service lateral pipe is installed.
- Keep the lateral service pipe capped at its terminating point until the house sewer line is later installed.



SEWER LATERALS

In general, service laterals should be taken off at an angle of no greater than 45 degrees from the horizontal. This will minimize the effects of side-soil friction imposing excessive downward loads on the service connection.

When connecting laterals, use a long sweep PVC bend wherever possible to facilitate changes in slope more gradually. Good compaction is **imperative** beneath the long sweep bends as well as below the branch of the service connection in order to maintain proper soil support. The PVC long sweep bends from IPEX are made to a radius of curvature of six (6) times the nominal diameter of the bend.

RISER PROBLEMS DEMAND SPECIAL ATTENTION

When vertical risers cannot be avoided, consult the design engineer as more special precautions may be required.

Service lines from the property to the street sewer demand special design considerations when the collection sewer is deeper than 4 m (13') regardless of the piping material used. Service risers from main sewers buried more than 4 m (13') should be taken off at an angle not less than 45° from the vertical. The service should then be moved to the vertical position by an appropriate elbow and vertical section of pipe. In sanitary sewer systems, drop laterals and drop manholes are the most common examples of areas requiring this special attention.

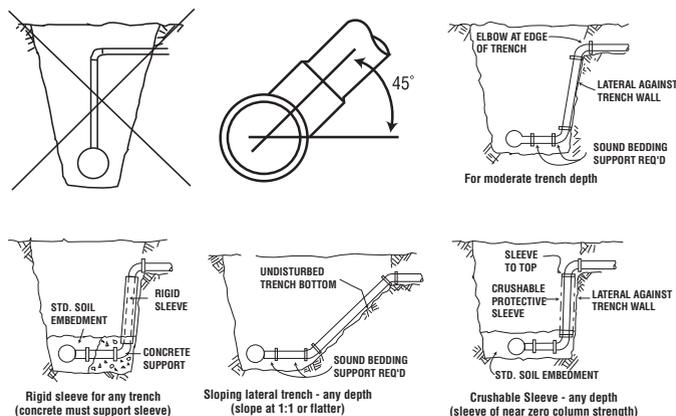
Drop laterals may create undue stresses on the buried pipe and fitting assembly. Horizontal portions of a lateral laid over disturbed uncompacted materials may experience a loss of bedding support if the foundation settles. This can lead to loss of grade and ultimately beam or shear failure in the pipe or fitting. As the soil adjacent to the pipe settles with the foundation, it attempts to drag the pipe with it, magnifying the load on the fittings.

It is critical to provide proper support beneath the mainline, service fitting, lateral, elevation fittings and their adjacent fill. Since this is usually difficult, the best approach is to turn the lateral down immediately when entering the trench and keep it against the trench wall thus eliminating any unsupported portion.

Keeping the drop portion (and the upper elbow) immediately adjacent to the trench wall can reduce drag down effects and can control beam bending during backfill. Even then, the elbow at the bottom must be both strong enough and bedded on a sound foundation to react to the loads. As depths increase, settlement loads can ultimately fail the system or buckle the riser.

Designs employing sleeves or concrete encasement of the drop portion of the lateral are effective if the designer provides an adequate means of supporting the loads at the bottom.

Sleeving the lateral with a crushable sleeve such as corrugated polyethylene drainage tubing can also solve the problem. As the fill adjacent to the lateral settles, the sleeve folds up and moves down with it. This accordion-like effect displaces the load from the lateral. It should be noted that when this method is used, the annular space between the sleeve and the lateral should not be filled with backfill.



BACKFILLING AND TAMPING

Backfilling should follow pipe assembly as closely as possible. This protects pipe from falling rocks, eliminates possible lifting of the pipe off grade due to flooding, avoids shifting pipe out of line by cave-ins, and lessens the possibility that backfill material will freeze.

The two purposes for proper haunching and proper initial backfilling of PVC pipe are:

- to provide the side soil support, which is necessary to enable the pipe and soil to work together to meet the designed load requirements within the allowable deflection limit.
- to provide protection for the pipe from impact damage due to large rocks, etc., contained in the final backfill.

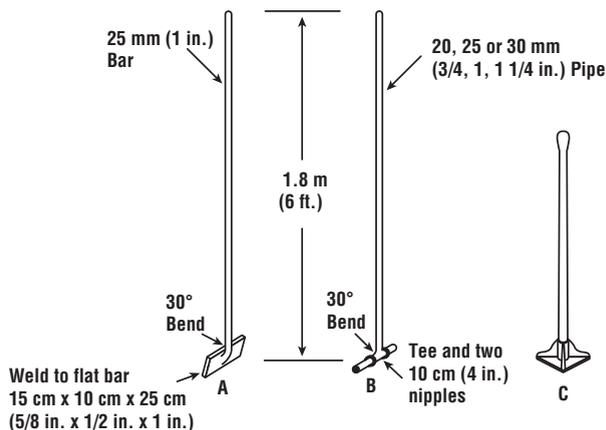
After initial backfilling has been completed, the balance of the backfill can be done by machine.



TAMPING EQUIPMENT

The following are some forms of tamping equipment commonly used.

Tamping Bars – If manual tamping is to be done directly beside or above PVC pipe, tamping bars are preferred. Two types of tamping bars should be available for a good tamping job. First, a bar with a narrow head should be used. (See A or B below) These are used to tamp under the pipe. The second type of tamping bar should have a flat head. It is used to compact the soil along the sides of the pipe to the trench walls. (See C below) The flat tamper will not do the work of the tamping bar and vice-versa.



Tampers – These devices are well-suited for use in the Bedding, Haunch, Initial Backfill, or Final Backfill zones. A minimum cover of 300 mm (12") is recommended for jumping jacks to avoid excessive impacts, while flat plate tampers may be used with as little as 150 mm (6") of backfill over the pipe.

Mechanical Compactors – This category refers to such machines as hoe-pacs and vibratory rollers. They should only be used in the Final Backfill zone and must always have a minimum cover of 1 metre (3.3') above the pipe.

Flood or water tamping may be used as a method of compaction only in trenches that are excavated in soils from which water drains quickly. Care should be taken not to float the pipe. The introduction of water under pressure (i.e. water-jetting) should never be used to compact embedment soils of PVC pipe.

TESTING OF SEWERS

JOINT TIGHTNESS TESTING

To ensure the integrity of the assembled gasketed joints of a PVC sewer pipeline, the designer will often require testing after installation is complete. This testing is frequently a requirement for sanitary sewer lines and is a growing trend for storm sewer systems as well.

There are two options that may be specified by the designer to test joint tightness – air testing or water testing. Air testing is preferable where possible because of its accuracy, simplicity and minimal time consumption. Water testing tends to be more expensive than with air, but is advantageous in some situations.

1. Air Testing

Here, the installer must plug both ends of a section of sewer to be tested before subjecting that section of pipe to low pressure air. The air must be maintained at a minimum pressure of 24.0 kPa (3.5 psi) for the specified time period for each diameter shown in the table below. Duration times vary with changes in pipe size and length of test sections. A maximum pressure drop of 3.5 kPa (0.5 psi) is permitted within the specified time duration. If a maximum pressure drop of 7.0 kPa (1.0 psi) is specified, the time values in the table should be doubled.

Should the pressure drop be greater than 3.5 kPa (0.5 psi) within the specified time duration, the installer must locate and repair any deficiencies at his own expense. Re-testing must be performed until a successful test is achieved. Sources of leaks may be dirt in an assembled gasketed joint, incorrectly tightened service saddles or improper plugging or capping of sewer lateral piping. If there is no leakage (i.e. zero pressure drop) after one hour of testing, the section should be passed and presumed free of defects.

If there is groundwater present at a level higher than the pipe invert during the air-test, the test pressure should be increased to a value of 24.0 kPa (3.5 psi) greater than the water head at the bottom of the pipe [to a maximum air test pressure of 34.0 kPa (5.0 psi)].



Time Required for a 3.5 kPa (0.5 psi) Pressure Drop per Diameter and Length of PVC Sewer Pipe

Pipe Size		Minimum Time	Length for Minimum Time		Time for Longer Meter Length	Time for Longer Feet Length
mm	in.	min:sec	m	ft.	sec	sec
100	4	1:53	182.0	600	0.62 L	0.19 F
125	5	2:31	137.0	450	1.10 L	0.34 F
150	6	2:50	121.3	400	1.40 L	0.43 F
200	8	3:47	90.8	300	2.49 L	0.76 F
250	10	4:43	72.8	240	3.89 L	1.19 F
300	12	5:40	60.7	200	5.61 L	1.71 F
375	15	7:05	48.5	160	8.76 L	2.67 F
450	18	8:30	40.5	133	12.62 L	3.85 F
525	21	9:55	34.7	114	17.17 L	5.24 F
600	24	11:20	30.2	100	22.43 L	6.84 F
675	27	12:45	26.8	88	28.38 L	8.65 F
750	30	14:10	24.4	80	35.04 L	10.68 F
900	36	17:00	20.1	66	50.47 L	15.38 F
1050	42	19:54	17.4	57	68.71 L	20.94 F
1200	48	22:47	15.2	50	89.74 L	27.35 F

where L = length of test section in metres

F = length of test section in feet

example – If there is 0.5 metres (1.65 ft.) of water above the invert of a buried PVC sewer line, what must the air-test pressure be?

solution – The static head of the groundwater at the pipe invert will be:

$$0.5 \text{ m} \times (9.73 \text{ kPa} / \text{m}) = 4.87 \text{ kPa}$$

therefore, the total air-test pressure should be:

$$4.87 \text{ kPa} + 24.0 \text{ kPa} = 28.87 \text{ kPa}$$

or

$$1.64 \text{ ft.} \times (.43 \text{ psi} / \text{ft.}) = .71 \text{ psi}$$

therefore, the total air-test pressure should be:

$$.71 \text{ psi} + 3.5 \text{ psi} = 4.21 \text{ psi}$$

Since this value is less than 34.0 kPa (5.0 psi), the installer may proceed with the air test using this start pressure.

Knowing the density of water to be 1000 kg/m³ (62.4 lb/ft³), the maximum head of groundwater permitted above the invert of a PVC sewer pipe for an air test is 1 metre (3.3').

2. Water Testing

Infiltration – The allowable infiltration for any pipe section should be measured by a weir or current meter placed in an appropriate manhole. This is an acceptable method of leakage testing only when the ground-water level is above the top of the pipe throughout the section of line being tested. It is especially useful when the water table is well above the top of the pipe. Usually the designer will give explicit instructions for conducting the test.

Exfiltration – This test is suitable for very dry areas, or where the water table is suitably low that test pressures can easily exceed the static head of the water table. Test pressures should be a minimum of 5.9 kPa (0.9 psi) above the water table head. The test section of pipe shall be filled with water and the leakage rate measured.

For sizes 100 mm - 375 mm (4" - 15"), the allowable leakage rate shall be 4.63 liters per mm of pipe diameter per kilometer per 24 hours (50 USgal./inch/mile/day). For sizes 450 mm (18") and larger, the allowable rate for testing shall be 0.93L/mm/km/day (10 USgal./inch/mile/day). Should the allowable leakage rate be exceeded for either an infiltration or exfiltration test, the installer must locate and repair any deficiencies at his own expense until a successful test is conducted. Tests are typically conducted from manhole to manhole.

DEFLECTION TESTING

Deflection is the way a flexible pipe reacts to vertical soil loads when buried in a trench. It illustrates how the pipe and surrounding soil work together to easily withstand common, and even extreme soil loads.

The maximum deflection of plastic pipe or fittings can be accurately predicted by the designer by knowing the pipe stiffness, soil stiffness and the height of cover. For the majority of underground PVC sewer pipe applications, with proper compaction, the deflection will be well within the recommended maximum allowable of 7.5%. However, if the designer has reason to believe that excessive deflection may be present, a deflection test may be necessary.

There are two commonly used methods of performing deflection tests on PVC sewer pipe:

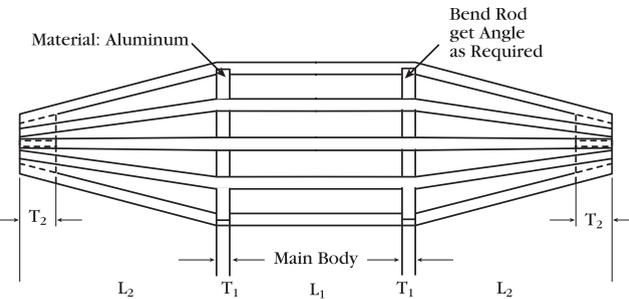
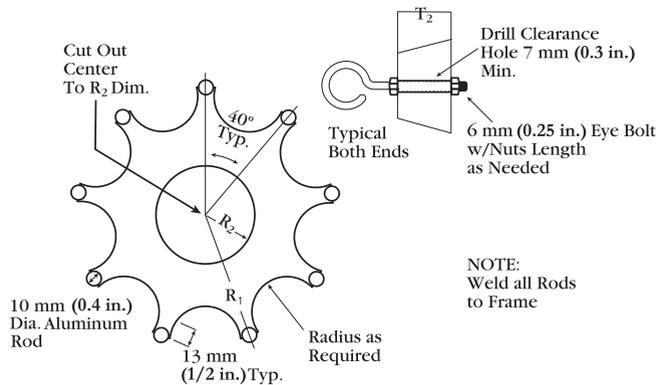
1. Go/No-Go Device
2. Physical Measurement



1. Go/No-Go Device

The most popular method of the two is the rigid Go/No-Go mandrel. This gage can accurately determine whether the deflection is within specified limits. The test involves the pulling of a mandrel through an installed sewer line. The mandrel will simply get stuck if the actual deflection is beyond the specified limit (normally 7.5%). The mandrel must be designed to have dimensions which exactly match the clearance inside the pipe, at the deflection limit.

Below is a detailed drawing of a suggested mandrel design for 7.5% deflection, along with tables of appropriate dimensions for Ring-Tite, Enviro-Tite and Ultra-Rib Pipes.



Ring-Tite and Enviro-Tite – Mandrel Dimensions

Pipe Size		Base I.D.		L1, L2		R2		R1	
mm	in.	mm	in.	mm	in.	mm	in.	mm	in.
200	8	194.7	7.67	150	6	35	1.4	90.0	3.54
250	10	242.9	9.56	200	8	40	1.6	112.3	4.42
300	12	288.6	11.36	200	8	45	1.8	133.5	5.26
375	15	353.0	13.90	230	10	50	2.0	163.3	6.43
450	18	431.2	16.98	300	12	55	2.2	199.4	7.85
525	21	508.1	20.00	300	12	60	2.4	235.0	9.25
600	24	571.0	22.48	350	14	65	2.6	264.1	10.40
675	27	643.3	25.33	350	14	70	2.8	297.5	11.71

Ultra-Rib – Mandrel Dimensions

200	8	196.1	7.7	150	6	35	1.4	91.2	3.6
250	10	245.2	9.7	200	8	40	1.6	114.0	4.5
300	12	291.8	11.5	200	8	45	1.8	135.7	5.3
375	15	357.3	14.1	230	10	50	2.0	166.1	6.5
450	18	438.7	17.3	300	12	55	2.2	204.0	8.0
525	21	515.8	20.3	300	12	60	2.4	239.8	9.4
600	24	584.2	23.0	350	14	65	2.6	271.7	10.7

Notes:

- T1 = 10 mm (0.4") and T2 = 25 mm (1") for all sizes of mandrels
- For pipes larger than 675 mm (27"), physical measurement is recommended.
- Two times dimension R1 is critical passing dimension for deflection mandrels.

2. Physical Measurement

To begin this process, measure the vertical inside diameter at a particular point in a PVC sewer pipe before it is installed (D1). Next, measure the inside diameter at that same point after the pipe has been installed and completely backfilled (D2). Now, the deflection at that point can be computed as follows:

$$\text{Deflection} = \frac{D1 - D2}{D1} \times 100\%$$

For accurate results, a micrometer should be used.



VIDEOS

The use of video cameras to inspect the interior of newly installed sewer pipe is very common today. The idea of videotaping the inside of sewer lines was first conceived to fulfill the need to evaluate the decaying condition of older sewers made from traditional pipeline materials such as clay, brick or concrete. The only practical benefit of videos with regard to newly installed PVC sewer pipe is in detecting glaring installation deficiencies such as leaking joints or excessive deflections. Although videos are able to pinpoint the location of a deficiency, they are unable to quantify the magnitude of a problem or whether the deficiency is within allowable limits.

SPECIAL APPLICATIONS

INSTALLING PIPE THROUGH CASINGS

When the direction of pipe laying intercepts a heavily travelled, protected or landscaped area, it may be advantageous to install the pipe through a protective casing. A casing may be required for one of the following reasons:

1. To make the pipeline accessible without excavating the surface.
2. For installation savings compared to jacking PVC sewer pipe directly through the unexcavated area.
3. To absorb the effects of extreme impact load situations (i.e. railway loading with shallow burial).

There are four major precautions to observe in the design and installation of PVC pipe in casings. To ensure proper installation always:

1. Select the appropriate casing size
2. Install spacers or skids on the PVC pipe
3. Minimize the friction force during the pull to avoid over-insertion
4. Install a water-permeable seal at the casing ends

Casing Size

The casing size should be large enough to readily accommodate the maximum outside diameter of the pipe bells and the projections of the supporting skids. The bell OD's for Ring-Tite, Enviro-Tite, Ultra-Rib and Ultra-X2 are presented in the Pipe Dimensions section found on pages 14 to 17.

On the following page is a summary of the recommended casing sizes for each diameter of PVC sewer pipe.

Pipe Size		Minimum Casing Size	
mm	in.	mm	in.
100	4	250	10
125	5	300	12
150	6	300	12
200	8	400	16
250	10	450	18
300	12	500	20
375	15	660	26
450	18	750	30
525	21	810	32
600	24	865	34
675	27	965	38
750	30	1220	48
900	36	1270	50
1050	42	1400	56
1200	48	1550	62

Casing Material Choices

Various options are available for the casing pipe including steel, corrugated metal, concrete or large diameter PVC pipe. Factors such as soil conditions, corrosion resistance, and required pull or push forces should all be considered. If the casing can be installed in an open-cut excavation, PVC pipe would be an ideal choice. IPEX can offer a suitable PVC casing pipe up to 1200 mm (48") in diameter. Minimum cover for PVC casings with H-20 traffic loads should be 300 mm (12").

Skids

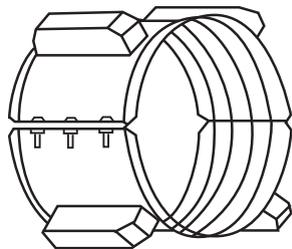
The pipe should not rest on the bells after installation in the casing. Runners or skids should be attached to the pipe with steel straps for a sufficient distance along the barrel to prevent any portion of the pipe from touching the casing. Pipe sizes 300 mm (12") and under should have 4 skids arranged at 90° intervals around the pipe. Pipes over 300 mm (12") should have 6 skids positioned 60° apart. To help avoid over-belling as the pipe is being pushed or pulled through the casing, place one set of runners with their ends even with the insertion lines on the pipe spigot.

If this method is used, ensure that the wood has not been treated with creosote which could harm PVC over its lifetime. To check the compatibility of any other wood preservatives with PVC, consult the IPEX Chemical Resistance Guide or call your local IPEX representative.



Mechanical Casing Spacers

Moulded plastic spacers can be used on Ring-Tite, Enviro-Tite and Ultra-Rib and Ultra-X2 pipes. These moulded pipe spacers are available to provide insulating protection between the carrier pipe and the casing. These spacers are manufactured from polyethylene, stainless



steel or carbon steel and come complete with runners to provide clearance for the bell and spigot assemblies. The casing spacer manufacturer should be contacted for direct information on the location and number of casing spacers required.

Pulling Pipe Through Casings

A common method used for pulling pipe through a casing requires the feeding of a cable through the casing and the first length of pipe, then attaching it to a wooden cross-piece over the face of the bell-end. The length of pipe is then pulled back through the casing and repeated for the next lengths.

Each length must be inserted into the bell-end of the previous length as is done in regular assembly. The pull should be slow and steady while avoiding any jerking movements. Place a protective wrap around the spigot end of the first length to minimize any possible abrasion against the casing.

Non-petroleum based lubricants applied to the casing interior or skid exteriors will make the sliding easier.

Sealing the Casing

IPEX does not recommend the use of cement grouting between the pipe wall and the casing. The grout will transfer the external load from the casing directly onto the pipe. After the pipeline has been tested and accepted, the space between the pipe and casing should be sealed with a permeable grouting material at the entry and exit points only. The chosen material should be selected so that backfill cannot enter the casing, while water is permitted to escape. If the installer is obliged to use a grout, the grout pressure must not exceed 80 kPa (12 psi) at 23°C (73°F) or lower. If warmer temperatures will be encountered the grouting pressure must be decreased. Contact IPEX for further information.

If pressure grouting is to be used, the following precautions should be observed:

1. Support the pipe with either skids or casing spacers.
2. Fill the pipe section to be grouted with water.
3. Use a lightweight grout to minimize buoyancy forces.
4. Gravity flow the grout into the annular space.
5. Do not exceed maximum grouting pressures.

Maximum Recommended Grouting Pressure

DR	Max Grouting Pressure	
	(kPa)	(psi)
51	25	not recommended
41 / Ultra-X2	50	not recommended
35 / Ultra-Rib	82	12
28	164	24

These maximum pressures are based on the temperature in the wall of the pipe not exceeding 23°C (73°F). Maximum grouting pressures must be reduced with increased wall temperatures.

DEEP BURIAL

The successful performance of PVC pipe is principally governed by limiting its deflection. The prism load method is typically used to evaluate the load on PVC pipe. This equals the maximum actual load the pipe will have to withstand.

The tabular values presented on the following two pages are long-term deflections after final consolidation of the backfill in the pipe zone. IPEX recommends that the maximum long-term deflection for PVC pipe should be set at 7.5%. Since the critical deflection value for PVC is 30%, the designer is provided with a 4 to 1 safety factor (30/7.5) against any possible leakage or structural problems.

The first table of deflections is presented for the Ring-Tite, Enviro-Tite, Ultra-Rib and Ultra-X2 products. The second table is for deflection of IPEX Centurion DR41 and DR51 Pressure Pipe. This pipe is becoming very popular for gravity sewers in 600 mm (24") and larger sizes due to its larger inside diameter, even tighter joints and cost savings versus Ring-Tite and Enviro-Tite DR35.

SHALLOW BURIAL

When subjected to live traffic loading (H-20), the minimum cover for DR28, DR35, Ultra-Rib and Ultra-X2 pipe is **300 mm (12")**. The installation must be done to yield a minimum soil stiffness (E') of 7 000 kPa (1 000 psi) in the haunch zone around the pipe.

For DR41 and DR51 pipe, the minimum cover for H-20 loading shall be **600 mm (24")**. The same minimum E' of 7 000 kPa (1 000 psi) should be obtained at this depth. 

PERCENT (%) DEFLECTION OF RING-TITE, ENVIRO-TITE DR35, ULTRA-RIB AND ULTRA-X2 PIPE

ASTM EMBEDMENT MATERIAL CLASSIFICATION	DENSITY (PROCTOR) AASHTO T-99	E' kPa (psi)	DEPTH OF COVER													
			metres	.6	1	2	3	4	5	6	7	8	9	10	15	
Manufactured Granular Angular	90%	20 700 (3 000)	0.7	0.5	0.3	0.4	0.4	0.4	0.6	0.7	0.9	1.0	1.2	1.3	1.4	2.2
			1.1	0.7	0.5	0.5	0.6	0.8	1.1	1.3	1.5	1.7	1.9	2.1	3.2	
Clean Sand & Gravel	90%	13 800 (2 000)	2.0	1.4	1.0	1.0	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0	6.0	
			2.0	1.4	1.0	1.0	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0	6.0	
Sand & Gravel with Fines	90%	7 000 (1 000)	n/r	2.5	1.7	1.8	2.2	2.9	3.7	4.4	5.1	5.9	6.6	7.3	11.0	
			85%	3 500 (500)	n/r	3.0	2.1	2.2	2.6	3.5	4.4	5.3	6.1	7.0	7.9	8.8
Silt & Clay	85%	2 760	n/r	3.0	2.1	2.2	2.6	3.5	4.4	5.3	6.1	7.0	7.9	8.8	13.1	

1. Deflection values shown include effect of H-20 live load and dead load.
2. External loading based upon a prism load of soil weight of 1900 kg/m³ (120 lbs. per cubic foot)
3. Bedding classifications correspond to ASTM D2321.
4. The deflection lag factor is 1.0 for a prism load.
5. Recommended maximum deflection of 7.5% provides a 4 to 1 factor of safety.
6. Deflection values for DR28 will be slightly less than those above.

PERCENT (%) DEFLECTION OF IPEX CENTURION

ASTM EMBEDMENT MATERIAL CLASSIFICATION	DENSITY (PROCTOR) AASHTO T-99	E' kPa (psi)	DEPTH OF COVER												
			metres	.6	1	2	3	4	5	6	7	8	9	10	15
Manufactured Granular Angular	90%	20 700 (3 000)	DR	2	3.3	6.6	9.8	13.1	16.4	19.7	23.0	26.3	29.5	32.8	49.2
			51	0.5	0.4	0.4	0.4	0.6	0.7	0.9	1.0	1.2	1.3	1.5	2.2
Clean Sand & Gravel	90%	13 800 (2 000)	41	0.5	0.3	0.4	0.4	0.6	0.7	0.9	1.0	1.2	1.3	1.5	2.2
			51	0.7	0.5	0.5	0.7	0.9	1.1	1.3	1.5	1.8	2.0	2.2	3.3
Sand & Gravel with Fines	80%	7 000 (1 000)	41	0.7	0.5	0.5	0.6	0.9	1.1	1.3	1.5	1.7	1.9	2.2	3.2
			51	1.5	1.0	1.1	1.3	1.7	2.2	2.6	3.0	3.5	3.9	4.3	6.5
Silt & Clay	85%	2 760 (400)	41	1.4	1.0	1.0	1.3	1.7	2.1	2.5	2.9	3.4	3.8	4.2	6.3
			51	1.5	1.0	1.1	1.3	1.7	2.2	2.6	3.0	3.5	3.9	4.3	6.5
Clean Sand & Gravel	90%	13 800 (2 000)	41	1.4	1.0	1.0	1.3	1.7	2.1	2.5	2.9	3.4	3.8	4.2	6.3
			51	n/r	2.0	2.1	2.5	3.3	4.2	5.0	5.9	6.7	7.5	8.4	12.6
Sand & Gravel with Fines	85%	7 000 (1 000)	41	n/r	1.9	2.0	2.4	3.1	3.9	4.7	5.5	6.3	7.1	7.9	11.8
			51	n/r	2.4	2.6	3.1	4.1	5.2	6.2	7.2	8.3	9.3	10.3	15.5
Silt & Clay	85%	2 760 (400)	41	n/r	2.3	2.4	2.9	3.8	4.8	5.7	6.7	7.7	8.6	9.6	14.4

1. Deflection values shown include effect of H-20 live load and dead load.
2. External loading based upon a prism load of soil weight of 1900 kg/m³ (120 lbs. per cubic foot)
3. Bedding classifications correspond to ASTM D2321.
4. The deflection lag factor is 1.0 for a prism load.
5. Recommended maximum deflection of 7.5% provides a 4 to 1 factor of safety.



TIE-IN CONNECTIONS

For the installer, one of the more favorable aspects of PVC sewer pipe, is the ease and simplicity of tie-ins. Specific instructions are described below.

Ring-Tite, Enviro-Tite and Centurion

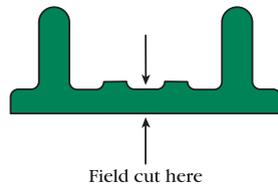
1. To cut saw and Enviro-Tite Pipe, a miter box, regular hand or abrasive wheel saw should be used. The cut should be square to ensure proper assembly.

Note: If an abrasive wheel saw is used to cut PVC pipe, protective goggles must be worn by the operator. When cutting in a confined space, a dust mask should be worn over the nose and mouth.

2. Next, the spigot end should be chamfered at an angle of 15° to a wall thickness of 50% of the original at the edge. Beveling can be done using a sander, hand-file, router or side of an abrasive wheel saw blade. Ensure that all sharp edges are removed to prevent damage to the gasket during assembly.
3. An insertion line should then be marked circumferentially on the pipe spigot to act as a guide for correct insertion depth. Dimension, C, from the table entitled, "Pipe Dimensions" found on pages 14 and 17 will indicate the insertion line position if assembly is to be made into a pipe bell or the bell of an IPEX fabricated fitting. If assembly is to be made to an injection moulded PVC fitting, the installer should physically measure the bell depth before applying an appropriate insertion line on the cut pipe.

Ultra-Rib & Ultra-X2

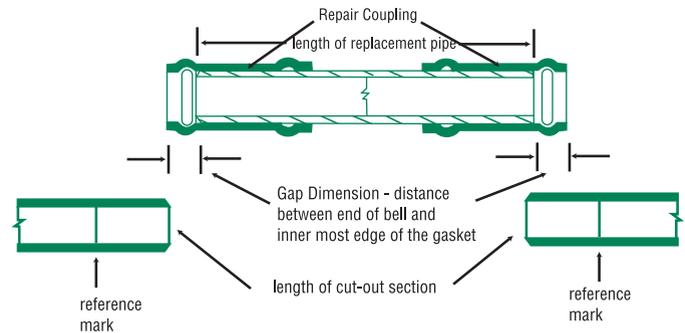
1. The same tools may be used to cut the Ultra-Rib and Ultra-X2 as were suggested for Ring-Tite and Enviro-Tite pipe. The center groove between ribs should be used as a guide for proper square-end cuts.
2. To create a spigot for Ultra-Rib: A gasket is field applied to the plain end between the second and third ribs.
Ultra-X2: A gasket is field applied to the second valley of the spigot end.
3. Insertion into another length of Ultra-Rib and Ultra-X2 or the bell-end of a fitting is done using the table presented in the section entitled, "Field Cut Assembly".



REPAIRS

Repairs can be made for Ring-Tite, Enviro-Tite, Centurion, Ultra-Rib or Ultra-X2 pipe in a similar fashion. One would simply insert a replacement section of pipe into the damaged area, and join it to the existing pipe by means of two repair couplings. If one of the ends of the existing pipe is a bell-end, only one repair coupling is required.

Should it be necessary to replace a section of pipe, IPEX provides a repair coupling to simplify and speed up the repair operation. The replacement section can consist of a length of pipe with two spigot ends and two double bell repair couplings or a length of pipe with an integral bell and one spigot end and one double bell repair coupling.

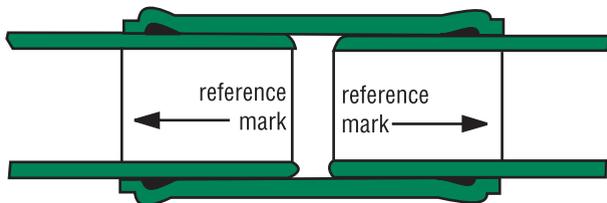


When cutting out the section to be repaired, ensure that no damaged areas remain (i.e. no hairline fractures). A minimum pipe length of 0.6 m (2") will give sufficient work space for a repair.

1. Determine the length of the replacement section as shown above. Cut the pipe to the proper length.
2. Bevel the ends of the pipeline and the repair section. Locate the reference marks on all ends.
3. Mount the couplings as shown above or on the pipeline ends instead of the replacement section.
4. Insert the replacement section into the pipeline and slide the couplings into position as shown below. The couplings should be centered over the gap and midway between the reference marks.



When using a section with an integral bell, additional pipe length may need to be exposed. This will enable the pipeline to be deflected to allow proper alignment of the replacement joint. When determining the length of the replacement section, take care to allow for the gap dimension on one end only. Complete the integral bell joint first then slide the double bell coupling into place.



SOLVENT-WELD PIPE & FITTINGS

Many times, pipe other than gasketed joint PVC is used for underground drainage or sewage. Some of the IPEX products that would fall into this category include PVC Drainline, System 15 DWV, Series PVC, PVC or CPVC Schedule 40 and 80, BlazeMaster CPVC or ABS-DWV. Here are some notes regarding the use of these products underground:

1. Assemble the pipe using the appropriate cement and primer for the pipe material and application. Solvent-welding procedures should conform to the recommendations below.
2. Trench zone recommendations for solvent-welded pipes are exactly the same as those for Ring-Tite, Enviro-Tite, Ultra-Rib and Ultra-X2 pipe, as described in this booklet.
3. The joints of a solvent welded pipe system are rigid, and thus have no capability to offer flexibility or deviation at the joint. However, the pipe barrel may be bent within specified limits. Contact IPEX for details.

SOLVENT CEMENTING

Many solvent cementing techniques have been published, covering step-by-step procedures on how to make a solvent-cemented joint. What follows is a review of these basic principles along with the techniques needed to suit particular applications, temperature conditions and variations in sizes and fits of pipe and fittings.

PRINCIPLES OF SOLVENT CEMENTING

To make consistently tight joints, the following points should be clearly understood:

1. The joining surfaces must be softened and made semi-fluid.
2. Sufficient cement must be applied to fill the gap between pipe and fittings.
3. Assembly of pipe and fittings must be made while the surfaces are still wet and fluid.
4. Joint strength develops as the cement dries. In the tight part of the joint, surfaces tend to fuse together; in the loose part, the cement bonds to both surfaces.

Penetration and softening can be achieved by the cement itself, by a suitable primer, or by the use of both primer and cement. A suitable primer will usually penetrate and soften the surfaces more quickly than cement alone. In addition, the use of a primer provides a safety factor for the installer. For example, in cold weather, more time and additional applications of the solvent are required.

Apply generous amounts of cement to fill the loose part of the joint. In addition to filling the gap, adequate cement layers will penetrate the surfaces and remain wet until the joint is assembled. To prove this, apply two separate layers of cement on the top surface of a piece of pipe. First, apply a heavy layer of cement; then beside it, a thin, brushed-out layer. Test the layers every 15 seconds by gently tapping with your finger. You will note that the thin layer becomes tacky and then dries quickly (probably 15 seconds). The heavy layer will remain wet much longer. Check for penetration a few minutes after applying these layers by scraping them with a knife. The thin layer will have little or no penetration, while the heavy layer will have more penetration.

If the cement coatings on the pipe and fittings are wet and fluid when assembly takes place, they tend to flow together, becoming one cement layer. Also, if the cement is set, the



surfaces beneath the pipe and fittings will still be soft. These softened surfaces in the tight part of the joint will fuse together. As the solvent dissipates, the cement layer and the softened surfaces will harden with a corresponding increase in joint strength. A good joint will withstand the required working pressure long before the joint is fully dry and final strength is obtained. In the tight (fused) part of the joint, strength will develop quicker than in the looser (bonded) part of the joint.

SOLVENT CEMENTING INSTRUCTIONS

HANDLING

Solvent cements should be used as received in original containers. Adding thinners to change viscosity is not recommended. If the cement is jelly-like and not free-flowing, it should not be used. Containers should be kept tightly covered when not in use to stop the evaporation of the solvent.

STORAGE CONDITIONS

Solvent cements should be stored at temperatures between 4°C and 43°C (40°F and 110°F) away from heat or open flame. Cements should be used before the expiry date stamped on the container. If new cement is subjected to freezing temperatures, it may become extremely thick. If the cement is not jelly-like, it can be placed in a warm area where it will soon return to its original, usable condition. However, if hardening is due to actual solvent loss (when a container is left open too long during use or not sealed properly after use), the cement will not return to its original condition. Cement in this condition has lost its formulation and should be discarded in an environmentally safe manner.

SAFETY PRECAUTIONS

Solvent cements are extremely flammable and should not be used or stored near heat or open flame. In confined or partially enclosed areas, a ventilating device should be used to remove vapors and minimize inhalation. Containers should be kept tightly closed when not in use, and covered as much as possible when in use. Avoid frequent contact with the skin. In case of eye contact, flush repeatedly with water. Keep out of the reach of children.

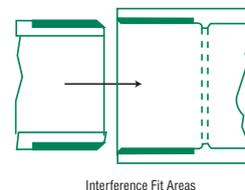
COLD WEATHER

Although normal installation temperatures are between 4°C and 43°C (40°F and 110°F), high strength joints have been made at temperatures as low as -26°C (-15°F) with good cements. To do this, the installer must ensure he has adequately softened the joining surfaces as outlined in the following steps of this manual. In addition, cement must be kept warm to prevent excessive thickening and gelation in cold weather.

PREPARATION

1. Use a handsaw and miter box or mechanical saw to cut squarely. A diagonal cut reduces the bonding area in the most effective part of the joint.
2. Plastic tube cutters may also be used for cutting plastic pipe. However, some cutters produce a raised bead at the end of the pipe. Remove any raised beads with a file or reamer, as it will wipe the cement away when pipe is inserted into the fitting.
3. Remove all burrs from both the inside and outside of the pipe with a knife, file or reamer. Burrs can scrape channels into pre-softened surfaces or create hang-ups inside surface walls.
4. Remove dirt, grease and moisture; a thorough wipe with a clean dry cloth is usually sufficient. Moisture will retard cure, and dirt or grease can prevent adhesion. Solvent cementing should not be attempted in the rain.
5. Check pipe and fittings for fit (dry) before cementing.

For proper interference fit, the pipe must go easily into the fittings one-third to three-quarters of the way. Too tight a fit is not desirable. You must be able to fully bottom the pipe in the socket during assembly with cement. If the pipe and fittings are not out of round, a satisfactory joint can be made if there is a "net" fit, i.e. the pipe bottoms in the fitting socket with no interference, but without excess movement.



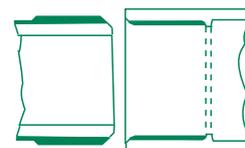
6. Use the right applicator for the size of pipe or fittings being joined:
 - a. For pipe sizes 7.5 mm through 25 mm (3/8" through 1"), use the 20 mm (3/4") dauber
 - b. For sizes 20 mm through 50 mm (3/4" through 2"), use the 25 mm (1") brush
 - c. For sizes 20 mm through 75 mm (3/4" through 3"), use the 38 mm (1-1/2") dauber
 - d. For sizes 75 mm through 600 mm (3" through 24"), use a roller or paintbrush with a width equal to about one half the pipe diameter being cemented.

It is important that the correct size applicator be used to ensure that sufficient layers of cement are applied.

7. The purpose of the primer is to penetrate and soften the pipe and fitting surfaces so that they can be fused. The use of the primer and the checking of its softening effect provides assurance that the surfaces are prepared for fusion in a wide variety of conditions. Also, always check the penetration or softening on a piece of scrap pipe before you start the installation and if the weather changes during the installation process. Use a knife or sharp scraper and draw the edge over the coated surface. Proper penetration has been made if you can scrape away a few thousandths of an inch of the primed surface. As weather conditions affect priming and cementing action, repeated applications to one or both surfaces may be necessary. In cold weather, more time is required for proper penetration.
8. Using the correct applicator (as outlined in step 6), apply primer freely to the fitting socket, keeping the surface and applicator wet until the surface has been softened. This will usually take 5 - 15 seconds. More time is needed for hard surfaces and cold weather conditions. Redip the applicator in primer as required. When the surface is primed, remove any puddles of primer from the socket of the fitting.
9. Apply the primer to the spigot end equal to the depth of the fitting socket. Use the same method of application used on the fitting socket.
10. A second application of the primer in the socket is recommended.
11. Immediately after reapplying the primer, and while the surfaces are still wet, apply the appropriate cement. The correct cement for the job can be quickly determined by reading the container labels. Be sure that the cement is in a

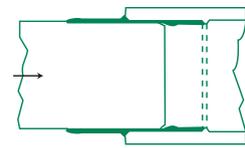
fluid condition. If it is thicker than normal or appears gel-like, it should not be used.

12. Stir the cement and apply it, using the correct applicator (outlined in step 6). Apply a thick, even layer of cement on the spigot, equal to the depth of the socket. Flow the cement on with the applicator. **DO NOT** brush it out to a thin layer which will dry in a few seconds.
13. Apply a medium layer of cement to the fitting socket; avoid puddling the cement in the socket. On bell-ended pipe, do not coat beyond the socket depth or allow cement to run down in the pipe beyond the bell.
14. Apply a second thick, even layer of cement on the spigot. There must be more than sufficient cement to fill any gap in the joint. Large-sized pipe and fittings may require two or more workers to apply the primer and cement, and assemble the pipe and fitting.



Cement Coatings of Sufficient Thickness

15. Attach the pipe to the fitting without delay. Cement must be wet. Use sufficient force to ensure that the spigot bottoms into the fitting socket. If possible, twist the spigot one-eighth to one-quarter turn as it is inserted.
16. Hold the pipe and fitting together for a short time (5 - 30 seconds) to eliminate pushout. Larger sizes with tight fits may require more time. Since the fitting sockets are made with a taper, the pipe may move back out of the fittings just after assembly.
17. A joint will have a ring or bead of cement completely around the juncture of the pipe and fitting after assembly. If voids in this ring are present, insufficient cement was applied and the joint may be defective.
18. Using a cloth, remove all excess cement from the pipe and fitting, including the ring or bead, as it will needlessly soften the pipe and the fitting, and does not add to joint strength.



Assembly of Surfaces While They are Wet and Soft

19. Handle newly assembled joints carefully until the initial set has taken place. Recommended setting time allowed before handling or moving is related to temperature and found on the next page.



20. Joint strength development is very rapid within the first 48 hours. Short cure periods are satisfactory for high ambient temperatures with low humidity, small pipe sizes and interference-type fittings. Longer cure periods are necessary for low temperatures, large pipe sizes, loose fits and relatively high humidity.

Note: For solvent cementing 200 mm (8") and larger pipe and fittings, the following is recommended:

- Two operators are needed, simultaneously applying primer and cement to the pipe and fittings.
- A heavy-bodied, medium setting cement such as IPS Weld-On 711 or an extra-heavy, high-strength cement such as IPS Weld-On 719 are recommended. They provide thicker layers and have higher gap-filling properties. They also allow slightly more open time before assembly.
- A mechanical device may be needed to pull the joint together. This may be as simple as a 2 x 4 and a bar, or another method is to use two "come-alongs" or lever pullers. Sufficient chain with a choker strap is laid out on either side of the joint. The "come-alongs" are then laid out on either side of the joint, adjusted to the correct length which is equivalent to the insertion depth. The primer and cement are applied; the "come-alongs" are immediately hooked up, and the joint pulled together.

INITIAL SET TIME SCHEDULE

Initial Set Schedule for PVC Solvent Cements*

Temperature Range		Pipe Size					
		100-200	4-8	250-375	10-15	> 375	>15
C	F	mm	in	mm	in	mm	in
15 to 38	60 to 100	30 minutes		2 hours		4 hours	
4 to 15	40 to 60	2 hours		8 hours		16 hours	
-18 to +4	0 to 40	12 hours		24 hours		48 hours	

Note: Initial set schedule is the necessary time to allow before the joint can be carefully handled.

* These figures are estimates based on our laboratory tests. Due to the many variables in the field, these figures should be used as a general guide only.

After the initial set time, the joints will withstand the stresses of a normal installation. (A misaligned installation will cause excessive stresses in the joint.) For long runs of pipe, care should be taken not to disturb joints for 1/2 to 1-1/2 hours before handling or burying.

JOINT CURE SCHEDULE

The following cure schedules may be used to determine the necessary time required after assembly before testing the system or before line pressure can be applied.

Joint-Cure Schedule for PVC Solvent Cements** (for Relative Humidity 60% or Less)

Temperature Range		Pipe Size					
		100-200	4-8	250-375	10-15	> 375	>15
C	F	mm	in	mm	in	mm	in
15 to 38	60 to 100	90 minutes		2 days		3 days	
4 to 15	40 to 60	4 hours		4 days		6 days	
-18 to +4	0 to 40	3 hours		8 days		8 days	

Note: Joint cure schedule is the necessary time to allow before pressurising the system. In damp or humid weather, allow 50% more cure time.

**These figures are estimates based on our laboratory tests. Due to the many variables in the field, these figures should be used as a general guide only.



ADDITIONAL INFORMATION

The list below identifies some industry standards in use today regarding manufacturing quality control and proper installation of PVC sewer pipe. To order a copy of any of these standards, please contact the appropriate organization using the addresses presented at the bottom of the list.

Standards

AASHTO M278	Class PS46 Polyvinyl Chloride (PVC) Piping Systems for Subsurface Drainage of Transportation Facilities
AASHTO M304	Polyvinyl Chloride (PVC) Ribbed Drain Pipe and Fittings Based on Controlled Inside Diameter
ASTM D2321	Underground Installation of Flexible Thermoplastic Sewer Pipe
ASTM D3034	Type PSM Polyvinyl Chloride (PVC) Sewer Pipe and Fittings
ASTM F679	Polyvinyl Chloride (PVC) Large Diameter Plastic Gravity Sewer Pipe and Fittings
ASTM F794	Polyvinyl Chloride (PVC) Ribbed Gravity Sewer Pipe and Fittings Based on Controlled Inside Diameter
AWWA C605	Underground Installation of Polyvinyl Chloride (PVC) Pressure Pipe & Fittings for Water
AWWA C905	Polyvinyl Chloride (PVC) Pressure Pipe & Fittings 14" through 48" (350 mm through 1200 mm)
BNQ 3624-130	Piping – PVC Plastic Rigid Pipe & Fittings, 150 mm in Diameter or Smaller for Underground Sewage Application
BNQ 3624-135	Piping – PVC Plastic Rigid Pipe & Fittings, 200 mm in Diameter or Greater, for Underground Sewage Application
BNQ 3624-250	Piping – PVC Plastic Rigid Pipe & Fittings, for Conveyance and Distribution of Water Under Pressure

CSA B137.3	Rigid Polyvinyl Chloride (PVC) Pipe for Pressure Applications
CSA B181.2	PVC Drain, Waste and Vent Pipe & Pipe Fittings
CSA B182.1	Plastic Drain and Sewer Pipe and Fittings
CSA B182.11	Recommended Practice for the Installation of Thermoplastic Drain, Storm & Sewer Pipe and Fittings
CSA B182.2	PVC Sewer Pipe and Fittings
CSA B182.4	Profile (Ribbed) PVC Sewer Pipe & Fittings
UNI-B-6	Recommended Practice for Low-Pressure Air Testing of Installed Sewer Pipe
UNI-PUB-6	Installation Guide for PVC Sewer Pipe
UNI-PUB-7	External Corrosion of Underground Water Distribution Piping Systems
UNI-TR-1	Deflection: The Pipe/Soil Mechanism
UNI-TR-6	PVC Force Main Design

Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ASTM	American Society for Testing and Materials
AWWA	American Water Works Association
BNQ	Bureau de Normalisation du Quebec
CSA	Canadian Standards Association
UNI-Bell	Uni-Bell PVC Pipe Association



Addresses**CSA International**

178 Rexdale Boulevard
 Toronto, Ontario, M9W 1R3
 Ph: (416) 747-4000
 Fx: (416) 747-4149

American Society for Testing and Materials

100 Barr Harbor Drive
 West Conshohocken, PA, USA 19428-2959
 Ph: (610) 832-9500
 Fx: (610) 832-9555

Uni-Bell PVC Pipe Association

2711 LBJ Freeway, Suite 1000
 Dallas, Texas, USA 75234
 Ph: (972) 243-3902, Fx: (972) 243-3907

American Association of State Highway & Transportation Officials

444 North Capitol St., N.W., Ste. 249
 Washington, DC, USA 20001
 Ph: (202) 624-5800
 Fx: (202) 624-5806

American Water Works Association

6666 West Quincy Avenue,
 Denver, Colorado, USA 80235
 Ph: (303) 794-7711
 Fx: (303) 794-7310

Bureau de Normalisation du Québec Parc Technologique du Québec Métropolitain

333, Rue Franquet
 Sainte-Foy (Québec) G1P 4C7
 Ph: (418) 652-2238
 Toll Free: (800) 386-5114
 Fx: (418) 652-2292

UNIT CONVERSION

Parameter	S.I.	x	Factor	=	U.S.
Length	mm		.0394		inch
	cm		.3937		inch
	m		3.2808		feet
Mass	kg		2.2046		lb.
	kg/m		.6720		lb./ft.
Volume	L		.2642		U.S. Gal.
Pressure	kPa		.3346		ft. H-20
	kPa		.2924		in. Hg
	kPa		.1450		psi
Energy	J		.7376		ft.-lb.
	kg-m		7.2230		ft.-lb.
Torque	N-m		.7376		ft.-lb.
Force	N		.2248		lb.
<hr/>					
Temperature: deg. C = (.5556) x (deg. F - 32)					
deg. F = (1.8 x deg. C) + 32					
<hr/>					



Volume II: Sewer Piping Systems Design

Municipal Technical
Manual Series



IPEX

FOURTH EDITION

Ring-Tite® & Enviro-Tite® Sewer Pipe & Fittings

Ultra-Rib®, Ultra-X2™ & Perma-Loc™ Profile Pipe & Fittings

PVC Manholes & Access Chambers

Vortex Flow™ Inserts for Corrosion & Odor Control

Inlet Control Devices

Lifesaver™ Manhole & Catch Basin Adjustment Units

We Build Tough Products for Tough Environments®

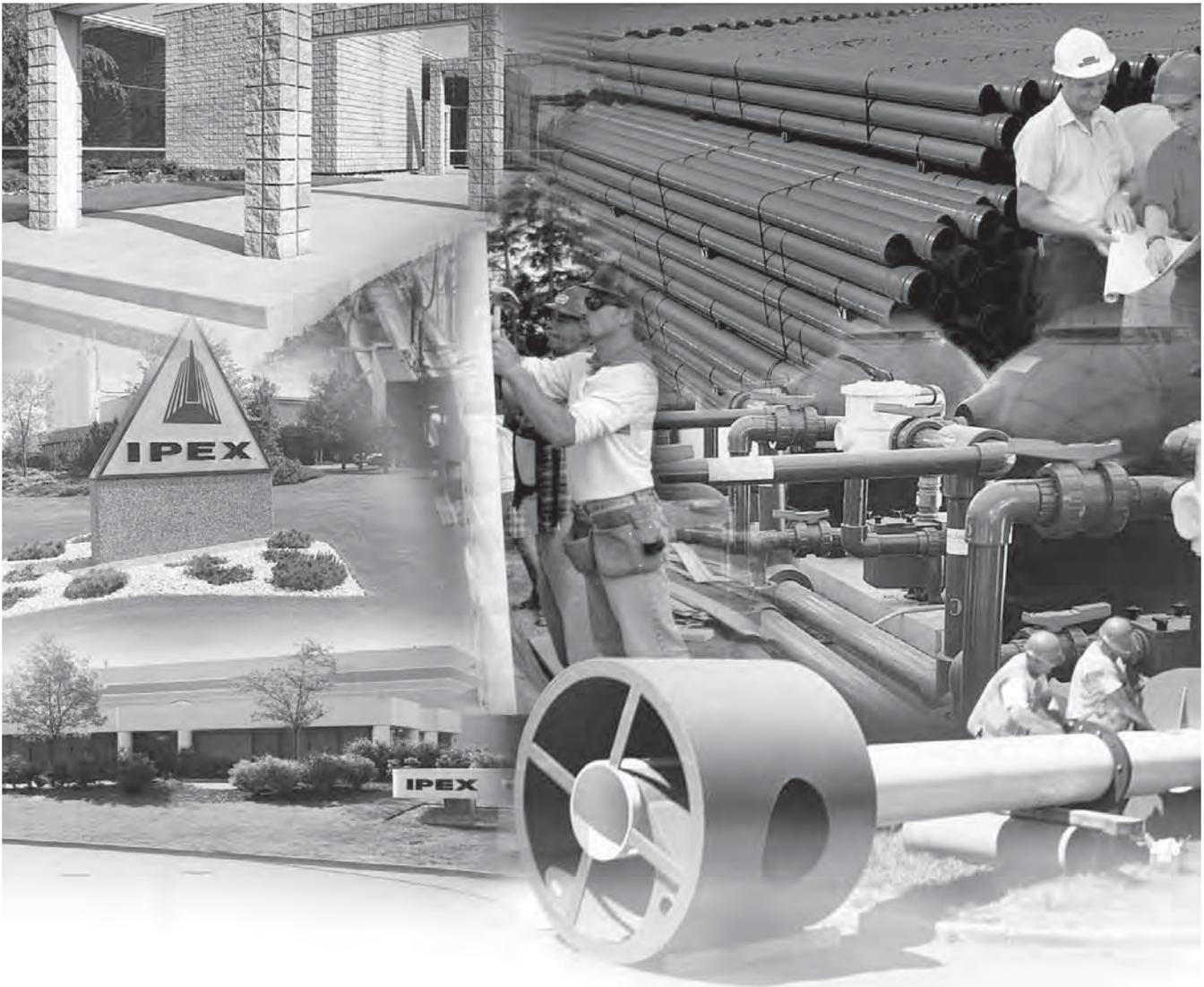
IPEX Sewer Piping Systems Design

Municipal Technical Manual Series

Vol. II, 3rd Edition

© 2008 by IPEX. All rights reserved. No part of this book may be used or reproduced in any manner whatsoever without prior written permission. For information contact: IPEX, Marketing, 2441 Royal Windsor Drive, Mississauga, Ontario, Canada, L5J 4C7.

The information contained here within is based on current information and product design at the time of publication and is subject to change without notification. IPEX does not guarantee or warranty the accuracy, suitability for particular applications, or results to be obtained therefrom.



ABOUT IPEX

At IPEX, we have been manufacturing non-metallic pipe and fittings since 1951. We formulate our own compounds and maintain strict quality control during production. Our products are made available for customers thanks to a network of regional stocking locations throughout North America. We offer a wide variety of systems including complete lines of piping, fittings, valves and custom-fabricated items.

More importantly, we are committed to meeting our customers' needs. As a leader in the plastic piping industry, IPEX continually develops new products, modernizes manufacturing facilities and acquires innovative process technology. In addition, our staff take pride in their work, making available to customers their extensive thermoplastic knowledge and field experience. IPEX personnel are committed to improving the safety, reliability and performance of thermoplastic materials. We are involved in several standards committees and are members of and/or comply with the organizations listed on this page.



CONTENTS

Sewer Piping Systems Design Manual

About IPEX

Overview *i*

Section One: Product Information

Introduction 1

Designing Sewers with IPEX Systems 1

Ring-Tite® and **Enviro-Tite®** 2

IPEX **Ultra-Rib®** Profile Pipe & Fittings 5

Ultra-X2™ Profile Pipe 8

Perma-Loc™ Profile Pipe 10

PVC Manholes and Access Chambers 12

Vortex Flow™ Inserts for Odor and Corrosion Control 18

Inlet Control Devices for Storm Water Systems 22

Lifesaver™ Manhole & Catch Basin Adjustment Units 24

Section Two: Design Information

High Load Carrying Capabilities 27

Deflection is Not a Bad Thing 27

The Modulus of Soil Reaction, E' 29

Predicting Long Term Deflection 30

Longevity & Durability of PVC Pipe Systems 31

Chemical and Abrasion Resistance 32

Chemical Attack 32

Abrasion 32

Infiltration and Exfiltration 32

Root Intrusion 32

Gravity Flow Systems 33

Installation of PVC Sewer Systems 34

Trench Zones 34

Embedment Materials 34

Selection of Embedment Materials 35

Preparation of Trench Bottom 35

Curved Sewers 35

Sewer Laterals 36

Riser Problems Demand Special Attention 36

Testing of Sewers 37

Deflection Testing 38

Videos 39

Section Three: Appendices

Appendix A: References	41
Appendix B: Calculation Results	42
Appendix C: Reference Tables and Conversion Charts	44
Appendix D: Useful Formulas	49
Appendix E: Abbreviations	52

OVERVIEW

IPEX Inc. is one of the largest manufacturers of plastic piping systems in North America. IPEX manufactures piping systems for many different applications, including sewer and water supply, electrical and telecommunications systems, plumbing, industrial as well as radiant heating systems.

This design manual covers the technical aspects of designing sanitary and storm sewers and other gravity flow systems with PVC pipes and fittings. In addition, there is information on non-corroding PVC manholes, odor controlling drop structures as well as inlet control devices for stormwater systems.

The manual is organized into two sections:

Section 1 deals with specific products and includes detailed information on applications, dimensions and applicable standards for each system.

Section 2 deals with general design issues associated with flexible conduits and buried PVC pipe systems such as load and deflection calculations, hydraulics, chemical resistance and other key topics for designers. The latest research on each topic is outlined and properly referenced for further study.

This manual is designed for Engineers, Technologists and other municipal infrastructure professionals who require a deeper understanding of municipal piping systems than can be gleaned from the more general overview literature available from IPEX.





SECTION ONE: PRODUCT INFORMATION

INTRODUCTION

This section contains detailed information on the following products:

Ring-Tite® and **Enviro-Tite®** smooth wall PVC sewer pipe and fittings

PVC Profile Sewer pipe including **Ultra-Rib®**, **Ultra-X2™** and **Perma-Loc™**

Corrosion proof manholes and access chambers

Vortex Flow™ Inserts for odor and corrosion control

Inlet Control Devices for stormwater management

Lifesaver™ Manhole and Catch Basin adjustment units

DESIGNING SEWERS WITH IPEX SYSTEMS

It is now possible to construct virtually every part of a sewer system using tough, non-corroding PVC pipes, fittings and appurtenances. While PVC pipes and fittings have been used for over 70 years for municipal applications¹, the technology has progressed to the point that a recycled PVC pipe is available with identical material properties and quality as virgin product. There are now PVC manholes and access chambers designed to eliminate infiltration and corrosion in key areas of the system. Specially designed vortex drop structures combat odour and corrosion and actually improve wastewater quality. For stormwater applications, custom designed inlet control devices help to conserve system capacity during storm events by allowing temporary surface storage of run off. Thermoplastics even help to extend the life of roads and concrete manholes and catchbasins – Lifesaver manhole and catchbasin adjustment units cushion the blow from wheel loads on manholes and catchbasins, while eliminating infiltration and undermining of the road bed.

With PVC pipe now available up to 1200mm (48") in diameter, even trunk sewers can be built with corrosion proof PVC. Corroded and leaking sewer systems can be made a thing of the past – Specify PVC for all sewer systems up to 1200mm (48").

¹ Hulsman, Nowack; "70 Years of Experience with PVC Pipe", Conference Paper, Plastic Pipes XII

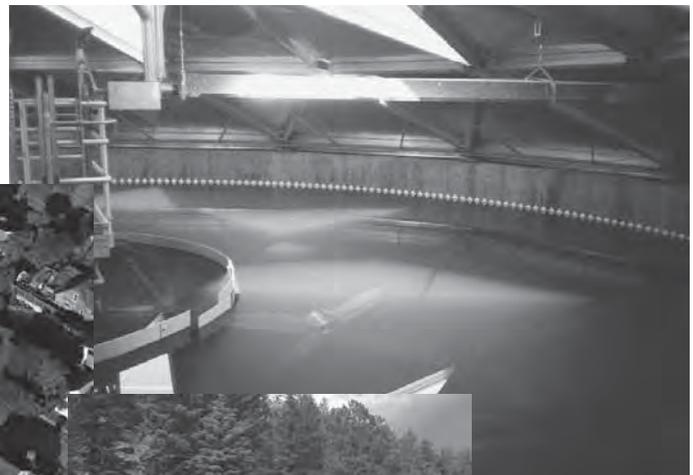
RING-TITE® AND ENVIRO-TITE® PVC SEWER PIPE AND FITTINGS

Ring-Tite and Enviro-Tite piping systems are SDR35 and SDR28 sewer pipes manufactured to demanding ASTM and CSA standards. The two products are identical except for Enviro-Tite having a minimum recycled material content of 50%. Both products have tight joints that can withstand well in excess of both the ASTM and CSA requirements.



Applications:

Gravity flow sanitary sewers, storm sewers, sewer laterals, industrial effluent lines.



Standards:

Ring-Tite Standards:

Certified CSA B182.2

Certified to NQ 3624-130/135

Conforms to ASTM D3034 and ASTM F679



Enviro-Tite Standards:

Certified to CSA B182.7

Certified to NQ 3624-130/135

Conforms to ASTM F1760



Joint Tightness

Ring-Tite and Enviro-Tite pipe joints have been third party tested to withstand a 345 kPa (50) psi hydrostatic pressure. Injection molded fittings have also been laboratory tested to withstand a 345 kPa (50) psi pressure in an undeflected straight alignment. This does not mean that installations should be tested to these pressures in the field, as these pressures could damage manholes, laterals or other appurtenances that are not tested to the same standards as the pipe and fittings. We recommend the testing procedures outlined in our Installation Guide, which is available upon request or can be downloaded from www.ipexinc.com.

Short Form Specifications

General

Main line sewers will be PVC SDR35 sewer pipe and shall be in compliance with ASTM D3040 or ASTM F1760 and third party certified to CSA B182.2 or CSA B182.7. Sewer laterals will be PVC SDR28 sewer pipe and shall be third party certified by CSA as above.

Joints

Sealing gaskets must meet the requirements of ASTM D3034 or ASTM F1760, CSA B182.2 or CSA B182.7. In addition, the pipe joints must be able to withstand a minimum hydrostatic pressure of 345 kPa (50 psi) without leakage.

Pipe Stiffness

The minimum ring stiffness shall be 320 kPa (46 psi) for SDR35 pipe and 625 kPa (90 psi) for SDR 28. This stiffness will be determined using the test methods prescribed by ASTM D3034 and ASTM F1760.

Fittings

Injection-molded gasketed PVC fittings shall meet the requirements of ASTM 3034 and ASTM F1336 and shall be certified to CSA B182.1 or CSA B182.2. Fabricated fittings must conform to ASTM F1336 and CSA B182.2



Dimensions:

Size Ranges

Ring-Tite (SDR35) 100mm – 1050mm (4"-42")

Enviro-Tite (SDR35) 100mm – 375mm (4"-15")

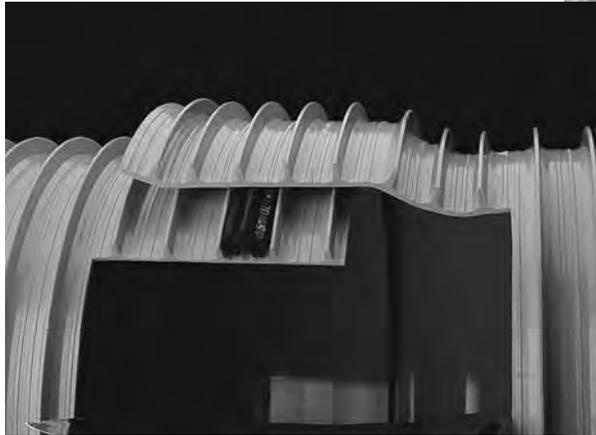
Ring-Tite		DR35						DR28					
Size		Avg. ID		Min. Wall Thickness		Avg. OD		Avg. ID		Min. Wall Thickness		Avg. OD	
in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm
4	100	3.97	100.94	0.12	3.06	4.21	107.06	3.91	99.42	0.15	3.82	4.21	107.06
5	135	5.32	135.08	0.16	4.09	5.64	143.26	5.24	133.02	0.20	5.12	5.64	143.26
6	150	5.92	150.29	0.18	4.55	6.28	159.39	5.83	148.01	0.22	5.69	6.28	159.39
8	200	7.92	201.16	0.24	6.10	8.40	213.36	-	-	-	-	-	-
10	250	9.90	251.46	0.30	7.62	10.50	266.70	-	-	-	-	-	-
12	300	11.79	299.36	0.36	9.07	12.50	317.50	-	-	-	-	-	-
15	375	14.43	366.42	0.44	11.10	15.30	388.62	-	-	-	-	-	-
18	450	17.63	447.87	0.53	13.57	18.70	475.01	-	-	-	-	-	-
21	525	20.79	527.99	0.63	16.00	22.05	559.99	-	-	-	-	-	-
24	600	23.39	594.00	0.71	18.00	24.80	630.00	-	-	-	-	-	-
27	675	26.36	669.42	0.80	20.29	27.95	710.00	-	-	-	-	-	-
30	750	30.17	766.36	0.91	23.22	32.00	812.80	-	-	-	-	-	-
36	900	36.11	917.22	1.09	27.79	38.30	972.80	-	-	-	-	-	-
42	1050	41.95	1065.72	1.27	32.29	44.50	1130.30	-	-	-	-	-	-

Ring-Tite fittings are injection molded in most configurations up to 375mm (15") nominal diameter. Larger sizes are fabricated from sections of pipe.

Enviro-Tite		SDR35						SDR28						Schedule 40					
Size		Avg. ID		Min. Wall Thickness		Avg. OD		Avg. ID		Min. Wall Thickness		Avg. OD		Avg. ID		Min. Wall Thickness		Avg. OD	
in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm
4	100	3.97	100.94	0.121	3.06	4.215	107.06	3.91	99.42	0.150	3.82	4.215	107.06	3.99	101.34	0.237	6.02	4.500	114.30
5	135	-	-	-	-	-	-	5.21	133.02	0.201	5.12	5.640	143.26	-	-	-	-	-	-
6	150	5.89	150.29	0.179	4.55	6.275	159.39	5.80	148.01	0.224	5.69	6.277	159.39	-	-	-	-	-	-
8	200	7.89	201.16	0.240	6.10	8.400	213.36	-	-	-	-	-	-	-	-	-	-	-	-
10	250	9.86	251.46	0.300	7.62	10.500	266.70	-	-	-	-	-	-	-	-	-	-	-	-
12	300	11.74	299.36	0.357	9.07	12.500	317.50	-	-	-	-	-	-	-	-	-	-	-	-
15	375	14.37	366.42	0.437	11.10	15.300	388.62	-	-	-	-	-	-	-	-	-	-	-	-

IPEX ULTRA-RIB® PVC PROFILE PIPE AND FITTINGS

Profile wall pipes are newer designs than standard smooth wall pipe. The outside wall of the pipe is modified with concentric ribs that increase the stiffness of the ring cross section. Ultra-Rib is manufactured with an open profile. This means that the pipe is extruded as a smooth wall pipe, then special molds form concentric ribs into the outside wall of the pipe.



PRODUCT INFORMATION

Applications:

Sanitary and Storm sewers, Industrial lines.



Standards:

IPEX Profile Pipe and Fittings

Certified to CSA B182.4

Certified to BNQ 3624-135

Conforms to ASTM F794

Conforms to AASHTO M304



ASTM
MEMBER

Pipe Stiffness

IPEX Ultra-Rib is manufactured with a minimum 320 kPa (46 psi) ring stiffness to comply with ASTM and CSA standards.

Joint Tightness

IPEX Ultra-Rib profile pipe joints can easily withstand a 50 psi hydrostatic pressure. This is important as most jurisdictions require that any sewer pipe laid in close proximity (ie: less than 2.5 metres or 8 feet) to a water pipe must have a joint that can withstand at least 50 psi.

Short Form Specifications

General

IPEX Ultra-Rib PVC Pipe is available in sizes 200mm, 250mm, 300mm, 375mm, 450mm, 525mm and 600mm (8" - 24")

Product

The pipe shall be extruded with a smooth interior and with solid reinforcing ribs on the exterior at right angles to the pipe. The space between any two ribs serves as a gasket race for perfect sealing.

Ultra-Rib PVC pipe and fittings shall be certified to CSA B182.4 "Profile (Ribbed) PVC Sewer Pipe and Fittings", and shall meet the requirements of ASTM F794 "Standard Specification for Poly (Vinyl Chloride) (PVC) Ribbed Gravity Sanitary Pipe and Fittings Based on Controlled Inside Diameter.

Material

Ultra-Rib PVC Pipe shall be made of PVC compound having a cell classification of 12454B as defined in ASTM D1784.

Pipe Stiffness

Pipe stiffness must be 320 kPa (46 lbs/in of sample length/inch of deflection) at 5% vertical deflection when tested according to ASTM D2412.

Molded Fittings

Injection-molded gasketed PVC fittings of ribbed construction shall be certified to CSA B182.1 or CSA B182.2 and used for direct connection to Ultra-Rib pipes in available sizes.

Fabricated Fittings

Fittings fabricated for use with Ultra-Rib pipe shall be certified to CSA B182.4 or ASTM F794 and may include legs of PVC pipe meeting CSA B182.1, B182.2 or ASTM D3034 or F679.

Joints

Gaskets for use with Ultra-Rib pipe are manufactured from EPDM and are designed specifically for use with Ultra-Rib pipe. This unique design is also available in Nitrile.

Sealing gaskets shall meet the requirements of CSA B182.4 and ASTM F477, with the additional requirement that joints shall be able to withstand 345 kPa (50 psi) hydrastatic pressure.

The joint will not leak at 74 kPa (10.8 psi) or 7.5m (25') of head with -74.2 kPa (22") Hg vacuum with spigot under 5% ring deflection and joint at full axial deflection.

Lubricant

Assembly of Ultra-Rib pipe and fittings shall be done in accordance with the manufacturer's directions using only IPEX PVC pipe lubricant. Substitute lubricants shall not be used. IPEX lubricant shall be applied to the inside of the bell to be joined, to a uniform thickness for a distance inside the bell equivalent to three ribs from outside edge.

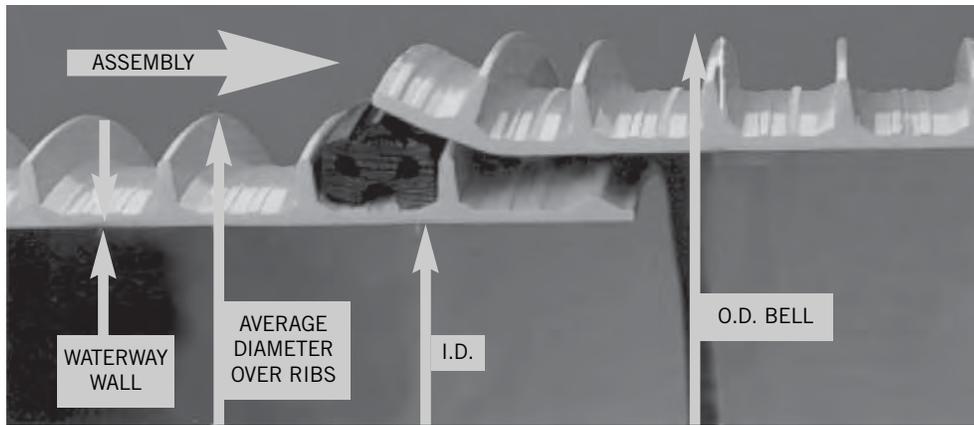
Color Coding

Pipe shall be color coded green.

Dimensions:

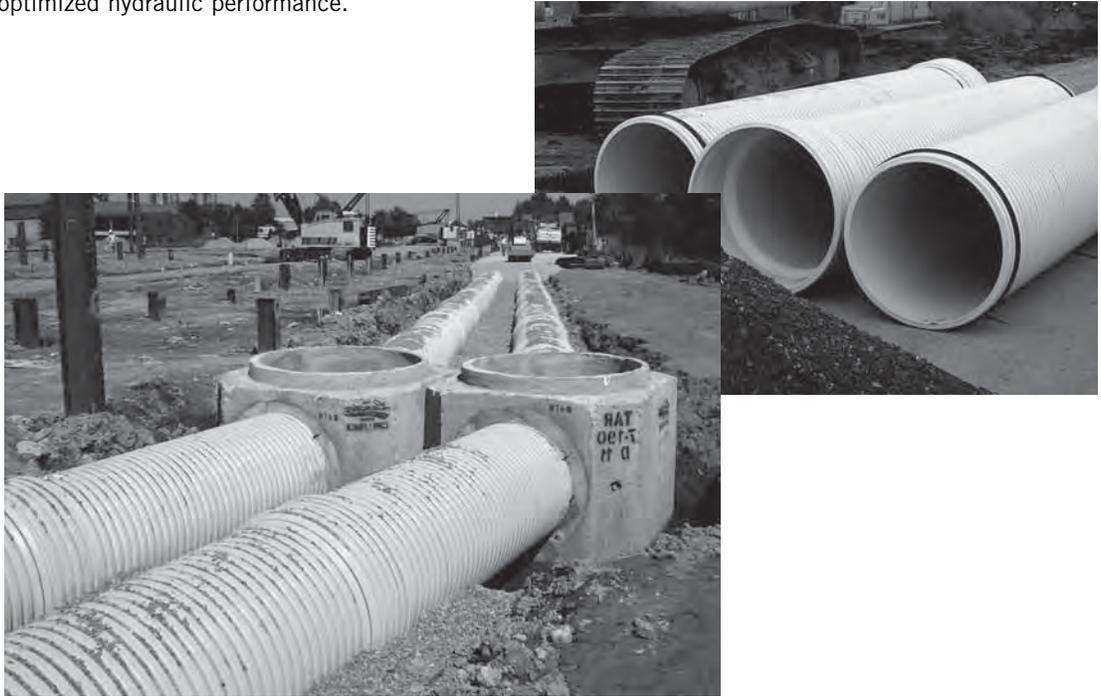
Size Range of 200mm – 600mm (8" - 24")

Size		Avg. ID		Avg. Diameter over Ribs		OD at Bell		Waterway Wall	
in	mm	in	mm	in	mm	in	mm	in	mm
8	200	7.89	200	8.80	224	9.78	248	0.087	2.20
10	250	9.86	251	11.00	280	12.22	311	0.091	2.30
12	300	11.74	298	13.10	333	14.59	371	0.102	2.60
15	375	14.37	365	16.04	408	17.82	453	0.110	2.80
18	450	17.65	448	19.57	497	21.77	553	0.130	3.30
21	525	20.75	527	22.80	579	25.14	638	0.160	
24	600	23.50	597	25.61	650	28.24	717	0.180	4.58



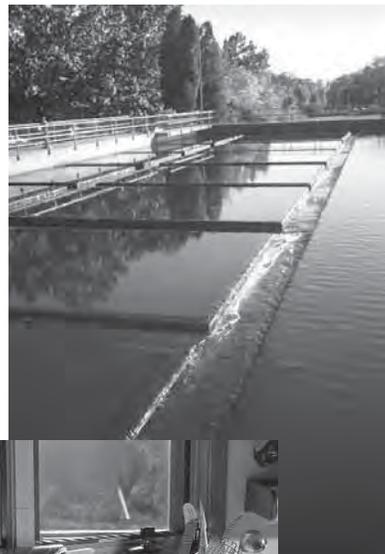
ULTRA-X2™ PROFILE PIPE

Ultra-X2 is a dual wall profile pipe. It is manufactured with a corrugated outer wall which is heat fused to the smooth inner wall. Ultra-X2's construction provides ring stiffness and a low "n" value for optimized hydraulic performance.



Applications:

Storm drainage, sanitary drainage, highway and culvert and gravity industrial lines.



Standards

Certified to CSA B182.4
 Conforms to ASTM F794



Joint Tightness and Infiltration

Ultra-X2 has extremely tight joints. Even though it is designed as a non-pressure drainage pipe, its joints can withstand a hydrostatic pressure of 15 psi. This allows it to perform even in the toughest conditions – surcharged sewers or high groundwater conditions.

Dimensions

Nominal Pipe Size		OD		ID		Crest Wall Thickness		Liner Wall Thickness		Insertion Force
mm	in	mm	in	mm	in	mm	in	mm	in	
750	25.53	816.6	32.15	749.2	29.50	3.7	0.15	5.6	0.22	985 lbf
900	35.43	984.6	38.76	901.4	35.49	3.3	0.13	4.6	0.18	1000 lbf

Short Form Specifications

General

IPEX Ultra-X2 PVC Pipe is available in sizes 750mm and 900mm (30" & 36")

Product

Ultra-X2 PVC pipe and fittings shall be certified to CSA B182.4 “Profile PVC Sewer Pipe and Fittings”, and shall meet the requirements of ASTM F794 “Standard Specification for Poly (Vinyl Chloride) (PVC) Profile Gravity Sanitary Pipe and Fittings Based on Controlled Inside Diameter.

Material

Ultra-X2 PVC Pipe shall be made of PVC compound having a cell classification of 12454 as defined in ASTM D1784.

Pipe Stiffness

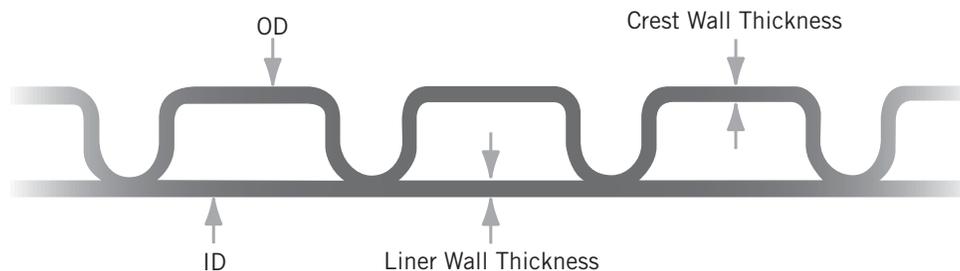
Pipe stiffness must be 320 kPa (46 lbs/in of sample length/inch of deflection) at 5% vertical deflection when tested according to ASTM D2412.

Lubricant

Assembly of Ultra-X2 pipe shall be done in accordance with the manufacturer’s directions using only IPEX PVC pipe lubricant. Substitute lubricants shall not be used. IPEX lubricant shall be applied to the inside of the bell to be joined, to a uniform thickness for a distance inside the bell equivalent to three corrugated profiles from the outside edge.

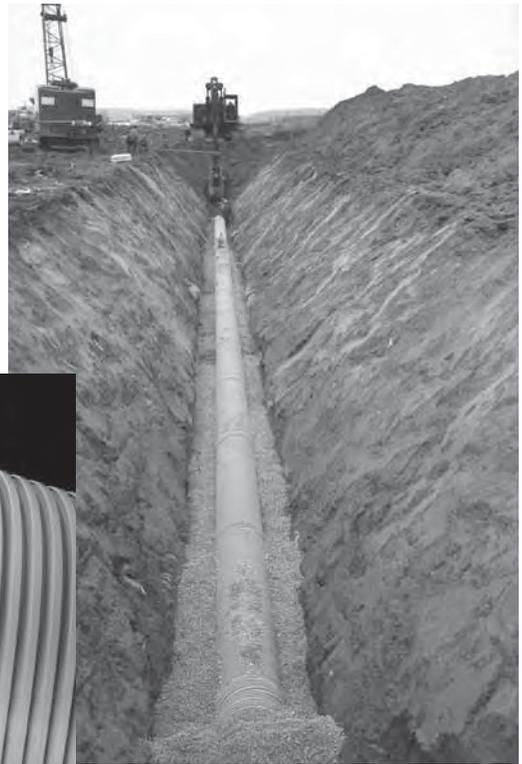
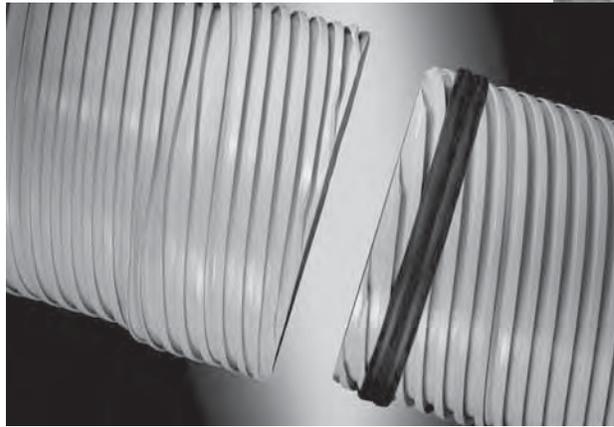
Color Coding

Pipe shall be color coded green.



PERMA-LOC™ PROFILE PIPE

In Western Canada and the U.S., IPEX offers Perma-Loc pipe and fittings up to 900mm (36") in diameter. Perma-Loc is a spiral-wound PVC profile sewer pipe that is fusion welded at the seam to provide a high quality bond. This high-tech welding process is then checked by low pressure air testing of each length of pipe at the factory.



Applications:

Sanitary and storm sewers, industrial waste lines.



Standards

Class V is certified to CSA B182.4

Class IV and V conform to ASTM F794



Pipe Stiffness

Class IV Perma-Loc has a ring stiffness of 70 kPa (10 psi)
 Class V Perma-Loc has a ring stiffness of 320 kPa (46 psi)

Joint Tightness and Infiltration

The close tolerances of Perma-Loc dimensions allow tight seals between the factory installed gaskets and the pipe pipe bells and serve to virtually eliminate infiltration and exfiltration. Test allowances can be specified as low as 2.3 litres/mm/km/day (25 U.S. gal/inch/mile/day). Class V Perma-Loc is recommended for applications where testing is required.

Short Form Specifications

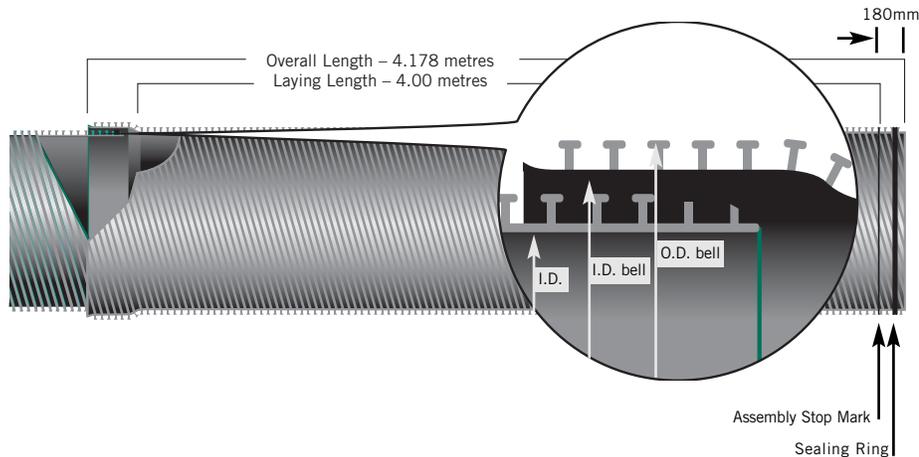
Pipe Stiffness

Perma-Loc Class IV and V have minimum pipe stiffness (P.S.) values of 70 kPa (10 psi) and 320 kPa (46 psi) respectively as per ASTM D2412 test methods.

Class V will be used for all installations requiring acceptance testing.

Dimensions

Size		Perma-Loc IV						Perma-Loc V					
		ID		ID Bell		OD Bell		ID		ID Bell		OD Bell	
in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm
21	525	21.3	541.3	22.6	575.1	24.5	618.7	20.8	527.1	22.6	575.1	24.5	618.7
24	600	24.2	614.7	25.7	652.8	27.0	686.3	23.5	596.9	25.7	652.8	27.7	704.1
27	675	27.2	691.9	28.9	734.1	30.8	782.8	26.5	673.1	28.9	734.1	31.1	789.9
30	750	30.4	773.2	32.2	816.9	33.7	855.0	29.5	749.3	32.2	816.9	34.6	878.6
36	900	36.6	930.7	38.7	983.2	40.5	1,028.6	35.5	901.7	38.7	983.2	41.7	1,058.4



PVC MANHOLES AND ACCESS CHAMBERS

IPEX manholes and access chambers are non-corroding, non-infiltrating manholes and chambers designed to maximize system access while minimizing maintenance requirements. The factory made benching is made of a tough FRP material, while the barrel and chimney are manufactured from IPEX Centurion™ pipe. The 1050mm and 1200mm (42" and 48") manholes can be equipped with special stainless steel steps, while the 600mm (24") access chamber is designed to allow inspection equipment or flushing equipment easy access to the sewer system. In all cases, the pre-cast concrete base acts as an anchor to prevent flotation and to stabilize the structure. Since the concrete is never in contact with the effluent or the sewer atmosphere, corrosion is eliminated.



Applications:

Industrial sewer systems, high water table areas, aggressive effluents, vacuum sewer systems.



Access Chambers vs. Manholes

With today's emphasis on occupational health and safety, most municipalities are focused on minimizing the degree of confined space work occurring in their underground systems. This is where access chambers come in.

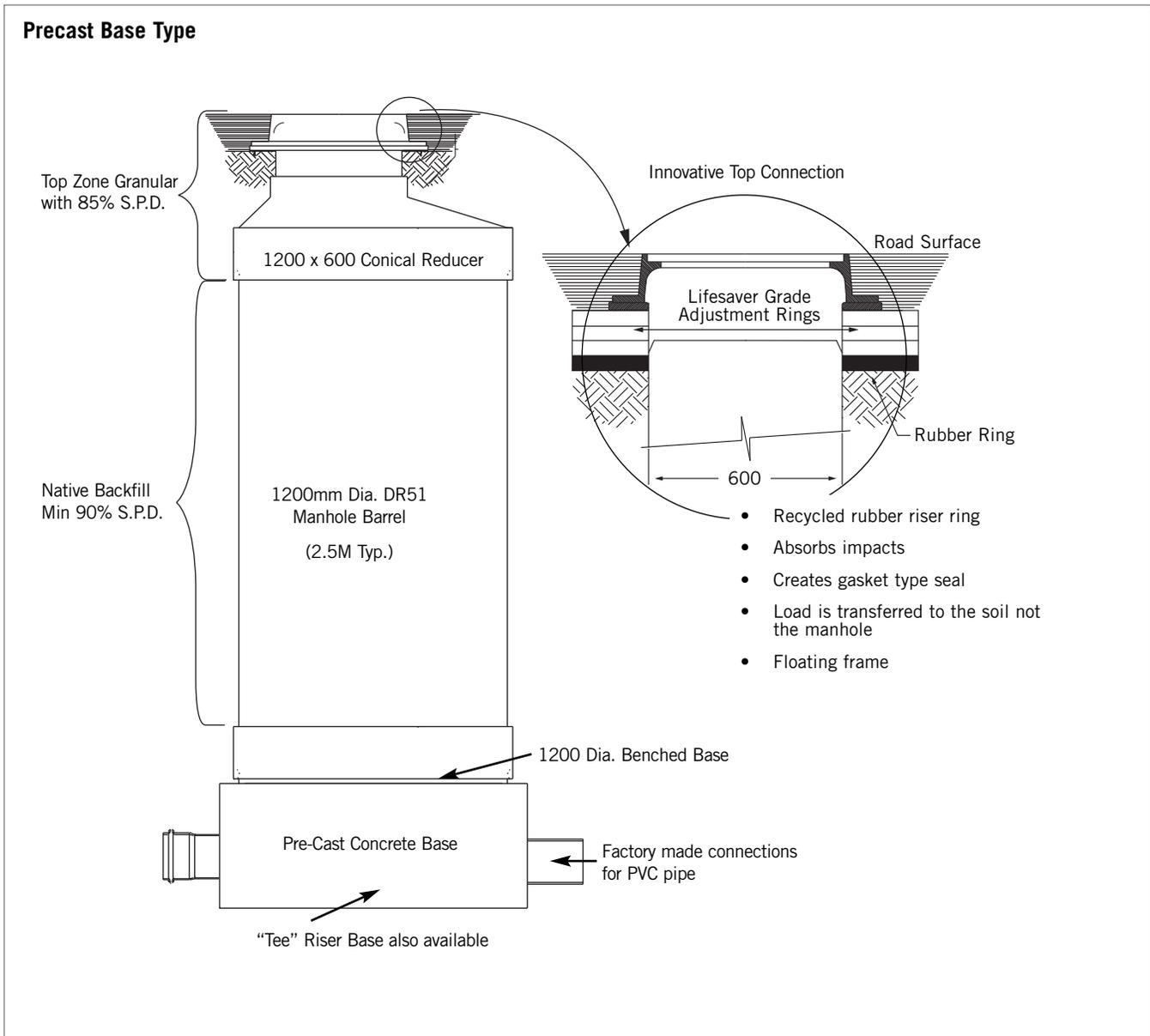
An access chamber differs from a manhole in that it is too small to allow man entry into a sewer. It is typically from 450mm (18") to 600mm (24") in diameter and is large enough to allow the insertion of cameras or flushing equipment into the system. The major advantage is that they allow improved access to the system while minimizing the maintenance concerns associated with concrete manholes. In addition, they are cost efficient to install.

The best choice for a given system depends on a number of factors, including:

- Degree of man access required
- Size of piping system
- Number of direction changes

Ultimately, a combination of manholes and access chambers can be used for a system, with access chambers used for straight connections and full size manholes for any changes of direction

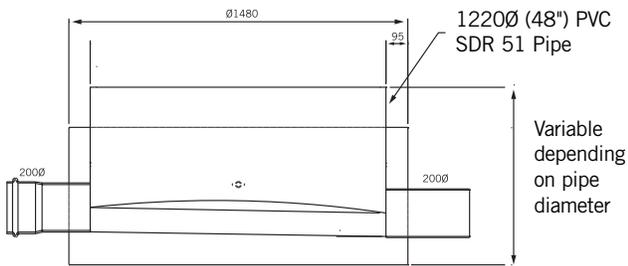
PVC Manhole Installation



Available Manhole Bases (2 types)

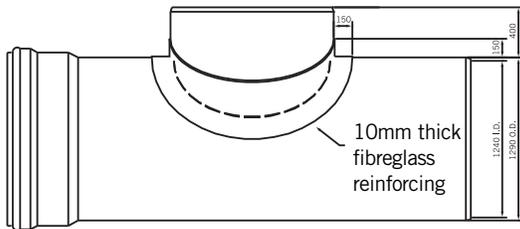
Precast Base Adapter

- Available with fiberglass lined base

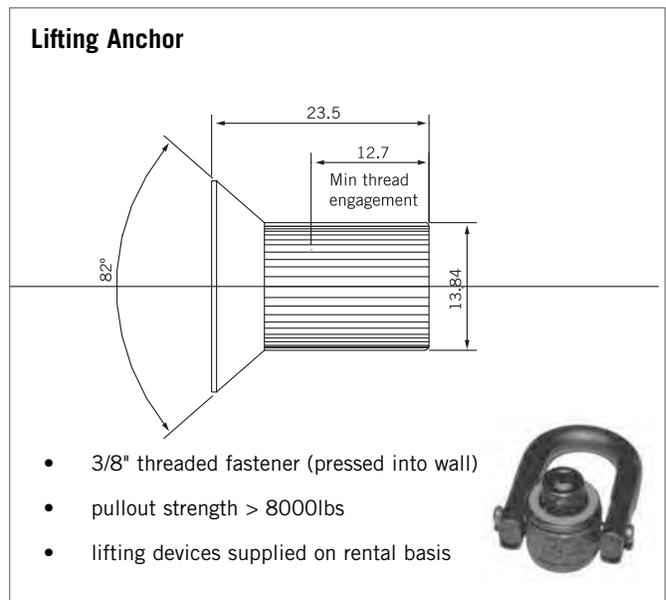
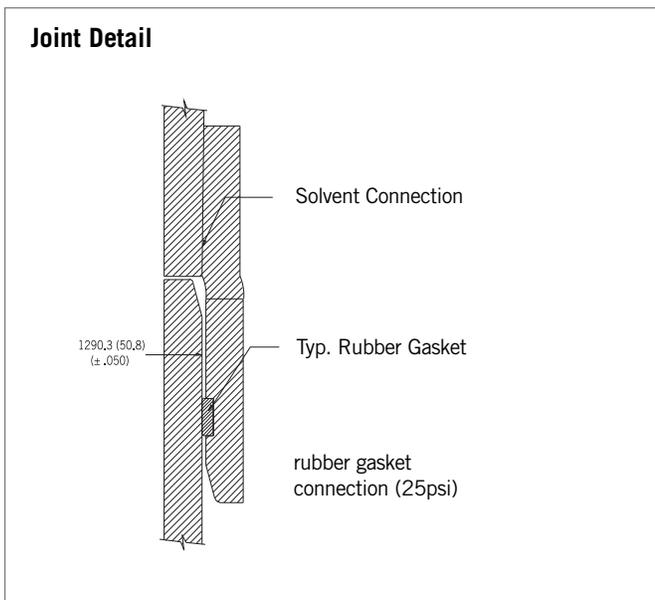
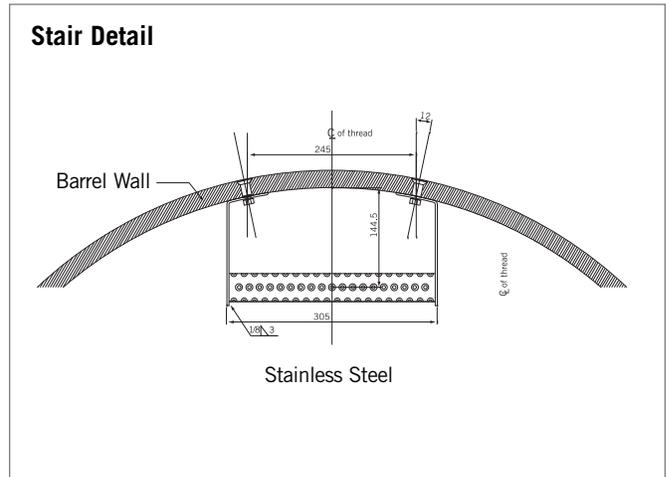
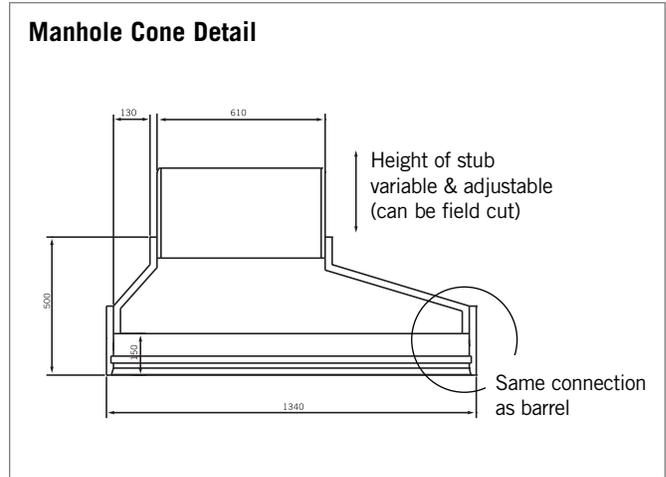
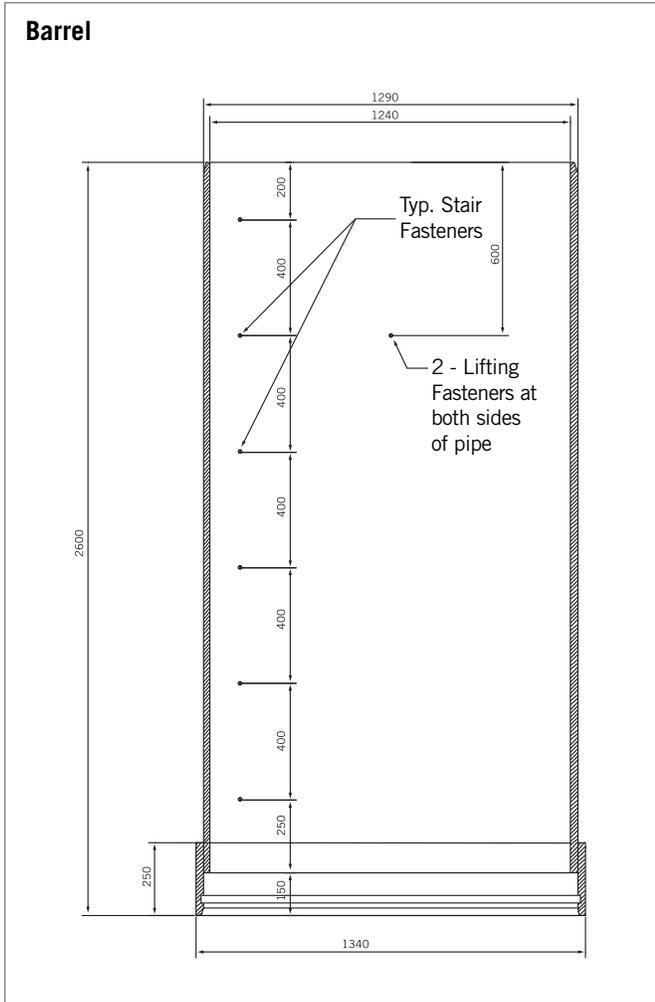


PVC Tee Riser

- For mainlines 600mm diameter and larger
- Fabricated PVC fitting
- Bell x Spigot



Manhole Details



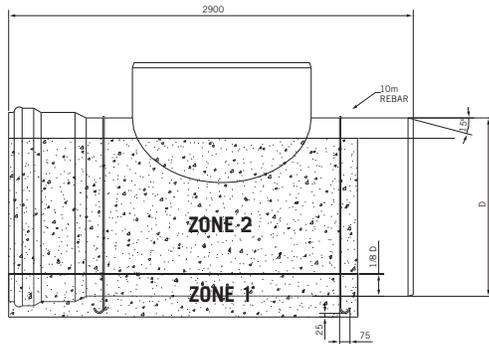
Receiving and Unloading

While it is the customers' decision and responsibility on how PVC manholes are unloaded in the field, we offer these recommendations:

1. Use only IPEX approved lifting devices for unloading. These devices are available for a nominal deposit. Strapping on all shipped goods should not be cut or removed until after unloading to a stable, flat surface.

Standard Concrete Base Installation (Mainline less than 600mm diameter)

1. Over-excavate trench bottom by 100mm.
2. Install 100mm granular material and compact to 95% S.P.D.
3. Install the base, ensuring granular surface is level.
4. In unstable ground conditions consult a qualified Geotechnical Engineer.
5. Install and compact granular material to the top of the pipe.



Vertical Tee-Riser Installation (Mainline 600mm diameter or larger)

The tee-riser must be supported with concrete bedding in order to be properly installed. What follows is a brief description of IPEX's recommendations to ensure a successful installation.

1. Over-excavate trench bottom by 100mm and place blocks to support tee-riser, and maintain clearance for the subsequent concrete pour.
2. Assemble the bell end of the tee-riser to the previously laid PVC sewer pipe. Use the procedures outlined in IPEX's installation guides for sewer or pressure pipe.
3. In order to ensure that the concrete bedding is properly placed, make a form using wood or metal. The form should be shaped so that the horizontal pipe spigot is outside the zone of concrete bedding, otherwise, the concrete will interfere with subsequent pipe assembly.
4. Check again that the tee-riser is evenly supported by the blocks.
5. Install 10m rebars as shown in the drawing.
6. Complete the first pour of 20 Mpa concrete (Zone 1).
7. Ensure that the wood bracing as supplied inside the tee-riser is in place to resist external lateral pressures from the second concrete pour.
8. Allow the concrete installed step 6 to cure. Then pour 20 Mpa concrete in Zone 2 as shown in the drawing.



Barrel Installation

1. Use IPEX approved lifting devices in both lifting fasteners factory installed in barrel exterior (device may be hand-tight only).
2. Lubricate vertical pipe spigot of tee-riser with IPEX 'Ring-Tite™' lubricant.
3. Place barrel bell-end over vertical spigot and apply pressure to top of barrel section for assembly.
4. Should mechanical equipment be required, force should be applied gently using a timber to protect the PVC barrel.
5. Place and compact bedding material as indicated on plans ensuring the compaction equipment does not come in direct contact with barrel.



Conical Top Installation

1. Use IPEX approved lifting devices in both lifting fasteners (device may be hand-tight only).
2. Place conical section bell-end over vertical barrel spigot for assembly in same manner as indicated above for barrel.
3. Ensure compacting equipment is kept a minimum distance of 150mm from conical PVC section surface.



Frame and Cover Installation

1. Measure the distance required to achieve clearance noted on the drawings and mark the stub of the conical top to indicate the finished level.
2. Compact and smooth the granular material as specified to this level.
3. Place the IPEX Rubber Ring over the exposed stub of the conical section.
4. Install the frame and cover (IPEX approved) over the stub on top of the rubber ring as shown in drawing 5.
5. Inside the frame, ensure there is at least 50mm of vertical clearance between the cover and the top of the PVC manhole stub.



VORTEX FLOW™ INSERT (VFI) FOR ODOR AND CORROSION CONTROL

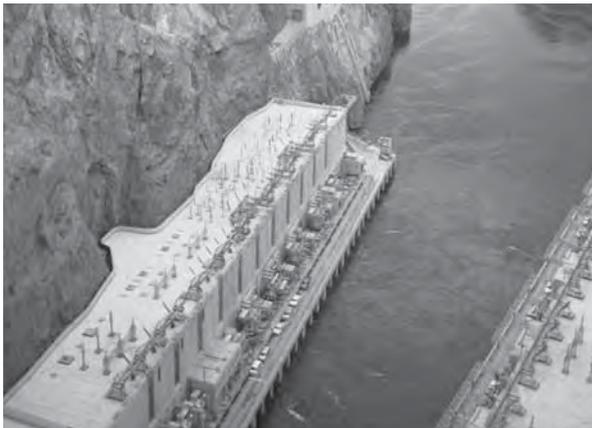
Vortex Flow inserts are specially designed energy dissipating drop structures that virtually eliminate hydrogen sulphide emissions and the associated odor and corrosion problems. This is done by using the flow energy of the sewage to suppress turbulence and aerate the sewage flow. This innovative approach to controlling sewer odor and corrosion was recognized by the American Public Works Association in 1999 with a Technical Innovation Award.

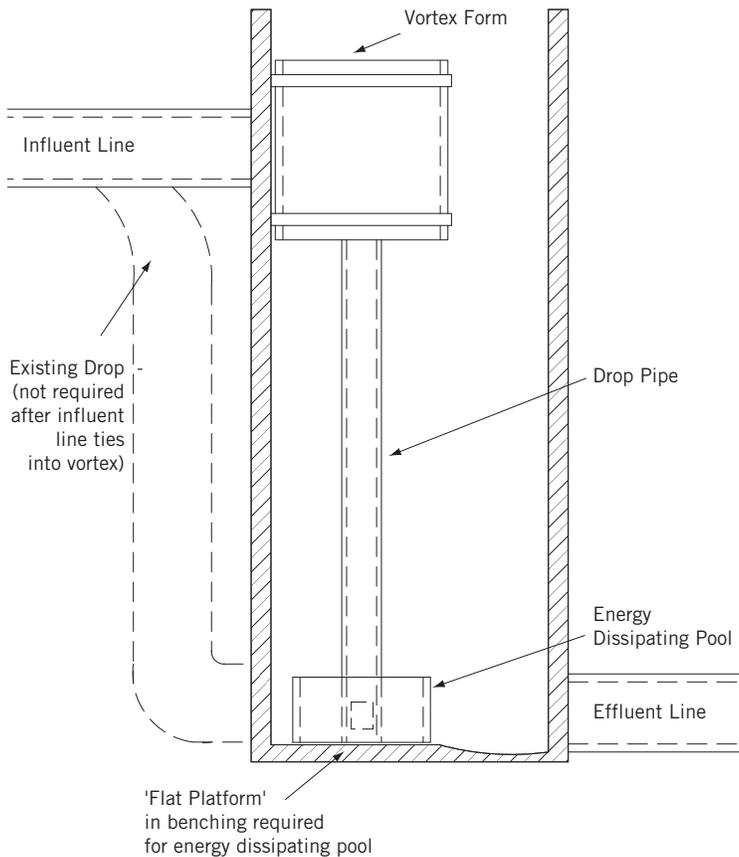


Winner of the 1999 American Public Works Association Innovation Award

Applications:

Drop structures in sanitary sewage manholes, pumping stations, energy dissipation of high velocity flows in sewer systems and dam outfalls.





Odor and Corrosion in Sanitary Collection Systems

The sulphate ion (SO_4) occurs in varying amounts in water and wastewater. Anaerobic bacteria in wastewater metabolize the SO_4 ion, stripping out the oxygen for respiration and excreting hydrogen sulphide (H_2S). Hydrogen sulphide is not particularly soluble in water, and it comes out of solution very quickly where the flow is turbulent or through air stripping in a sanitary sewer flow.

Forcemain discharges are notorious for H_2S emissions because the sewage is coming from an anaerobic environment (a pipe flowing full), and it is being dumped into a gravity sewer. The flow is usually very turbulent, and air-stripping also occurs. As a result, large quantities of H_2S gas are liberated from the sewage flow.

Once the gas comes out of solution into the atmosphere of a manhole or pipe, the gas can attack and corrode metal directly. The gas is also metabolized by bacteria that live on the inside surfaces of manholes and pipes. The bacteria excrete H_2SO_4 , which is commonly known as sulphuric acid. This acid attacks the Portland cement matrix of the concrete, quickly causing deterioration.

The most common method for solving this problem in the past was to inject various chemicals into the sanitary flow in order to oxidize the H_2S in solution. For airborne H_2S , biofilters are typically used to scrub the H_2S from the air. This approach has a number of drawbacks, in that the chemicals used are often expensive, hazardous to handle, or both. Biofilters are quite effective, but require periodic maintenance to ensure proper operation.

The Vortex Flow drop structure can in many cases eliminate the need for both chemical injection and biofilters, and can do so with virtually no maintenance required.

The Design

The Vortex Flow Insert (VFI) was invented by Dr. Eugene Natarius, a noted fluid mechanics expert who devised the VFI to combat a troublesome odor problem from a drop manhole in Minneapolis. While chemical injection was effective in mitigating the problem, the cost of the chemicals was approximately \$5,500 per month. The VFI solved the odor problem, and actually outperformed the chemical injection system with respect to H_2S reduction in solution. Dr. Natarius subsequently patented his invention and IPEX is the worldwide licensee of the VFI.

The VFI works by suppressing flow turbulence, effectively dissipating flow energy and by aerating the flow.

The sewage flow is directed into the top form which has a sloped floor designed to increase the flow velocity to super critical velocity (Froude number >1). The form is designed with a spiral form of decreasing radius which directs the flow into the smaller diameter drop pipe. The velocity and the centrifugal forces built up in the top form ensure that a stable vortex is formed in the drop pipe, and that an "air core" will form in the pipe down to the bottom of the structure's energy dissipating pool.

The air core that forms in the drop pipe has a slight negative pressure as a result of the fluid flow, and as a result it draws any airborne H_2S gas to the bottom of the structure. At the same time, frictional forces on the flow "hugging" the pipe inside wall dissipate the flow energy while minimizing turbulence.

In the energy dissipating pool at the bottom of the structure, the air that was drawn down through the air core is mixed with the effluent. Because the flow exit is submerged, the air cannot simply vent out the bottom of the structure – it must travel through the effluent. As a result, effective aeration occurs, significantly increasing the dissolved oxygen (DO) content of the effluent exiting the structure. The DO oxidizes the dissolved H_2S , to again form the separate H^+ and SO_4 ions, which are much more stable dissolved in water.

Real World Results

The VFI is not simply a theoretical concept – it is a proven method for dealing with odor and corrosion that has been successfully employed around the world. Some of the successful installations include:

Minneapolis MN

A forcemain discharge in a residential area had been a problem for many years, drawing odor complaints from surrounding residents as well as damaging the adjacent gravity sewer pipe as a result of hydrogen sulfide attack. The problem was solved by installing a chemical injection system with a 5000 gallon underground storage tank. Unfortunately, while the sulfide problem was gone, chemical feed costs averaged \$5,500 per month. The VFI was installed in an effort to cut down on chemical use, however it was found that the VFI eliminated the need for the chemical feed system, and in many cases outperformed the chemical feed system with respect to sulfide reduction and oxygenation. The results of this project were presented at WEFTEC 2000, and the presentation paper is available from your IPEX representative.

Sarnia, Ontario, Canada

A large manhole that included a 20" forcemain discharge was found to have severe deterioration as a result of hydrogen sulfide attack. The manhole was replaced and the forcemain discharge was equipped with a VFI. The results were immediately apparent as the familiar "rotten egg" smell had disappeared with the installation of the VFI. Furthermore, the benefits of the oxygenation provided by the VFI were immediately noticed at a downstream pumping station, where a persistent H₂S problem previously caused by the forcemain discharge was eliminated.



Hunter Water Corporation, Australia



The picture shows a VFI installed in a barometric loop, which is essentially an area where a forcemain is brought up out of the ground to improve the hydraulic profile of the system.

Hunter Water Corporation (HWC) performed hydrogen sulfide gas concentration monitoring above two working VFI units and carried out liquid sampling in the pumping station wet wells immediately downstream of the units.

According to the HWC data the average hydrogen sulfide gas concentration for one week of continuous monitoring was 1.29 ppm on discharge of the pumping system 1, and 2.27 ppm on discharge of the pumping system 2. For a long force main discharge with a flow drop an average H₂S gas concentration is typically at least ten times higher. The dissolved hydrogen sulfide concentrations from samples were 0.34-0.70 mg/l and 4.2-4.5 mg/l downstream of the system 1 and system 2 discharges accordingly. The HWC compared the levels of dissolved H₂S and found them significantly lower than those recorded at non-vortex barometric loops.



Compared to similar HWC force main systems with barometric loops, odorous gas emission was significantly lower in the VIA installations. HWC concluded that the VIA is effective in reducing H₂S gas emission. VIA implementation allowed reduction of chemical feed dosing rates.

The Vortex Flow Insert Can Reduce Excavation Costs

Conventional drop structures can be maintenance problems, and can cause odor and corrosion in a sewer system. As a result, some municipalities have prohibited the use of drop structures for connecting sewers at different elevations. This has resulted in small collector sewers being installed at extremely deep depths of burial so that they can connect to a trunk sewer without the use of a drop. These deep burial installations cost developers (and eventually homeowners) millions of dollars in extra excavation costs.

The VFI actually improves wastewater quality by increasing dissolved oxygen and oxidizing hydrogen sulfide. By installing VFI units on all collector sewer drops as well as on trunk sewers, excavation can be minimized, and odor and corrosion reduced or eliminated.

The Vortex Flow Insert for Pumping Stations

Another problem area for odor and corrosion is pumping station wet wells, where excessive turbulence can increase H₂S emissions significantly. The VFI has been successfully used in pumping stations to reduce odors and properly aerate the flow.

While the drop depths in wet wells are typically less than in manhole drop structures, the VFI effectively suppresses turbulence and oxygenates the wastewater, thereby eliminating odor and corrosion.



Installation

Vortex Flow units can be installed in virtually any drop chamber. Conditions vary among installations, but the unit is typically lifted into place using a backhoe, and then secured to the manhole structure using stainless steel straps. In some cases installation can be accomplished without interrupting or bypassing the sewer flow.

How to Specify a Vortex Flow Insert

In order to complete a preliminary design and estimate a price for a VFI unit, we need to know:

- The minimum flow and the peak flow, including any future growth, of the line under consideration.
- The elevation difference between the incoming line and the outlet
- The dimensions and configuration of the sewer lines, and of the manhole if the structure will be put in an existing manhole.

With this information, a preliminary estimate can be prepared. Exact flow volumes and system layout information is not required at this stage, just the general guidelines.

Specifications

All sanitary sewer drops of 3 feet or more in manholes or pumping stations shall be equipped with Vortex Flow Drop structures as manufactured by IPEX Inc..

Vortex units must be fabricated using AWWA C900 or AWWA C905 pipe, as well as PVC sheet conforming to ASTM D1248

Vortex drop structures must be supplied with shop drawings approved by the Project Engineer, as well as installation instructions. The hydraulic capacity of the unit (both minimum and maximum flows) must be clearly indicated in the submission.

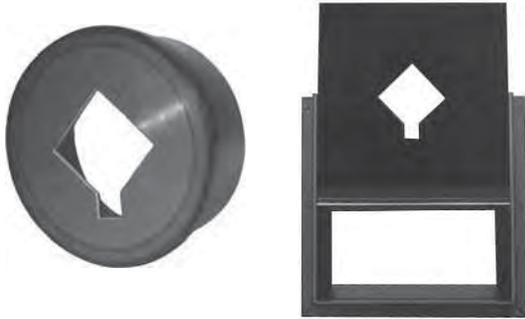
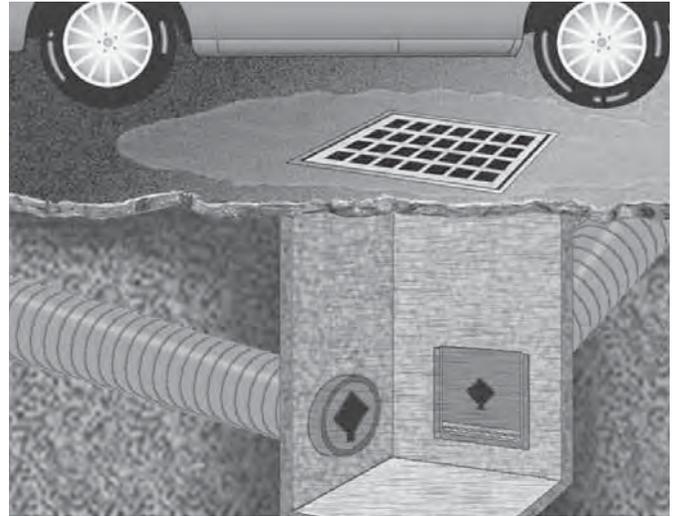
Dimensions

The dimensions of the VFI are dictated by the design flow capacity required. Small units can be designed for collector sewers and may have a top section as small as 14 or 16 inches in diameter. Larger units with capacities up to 100 MGD may be up to 10 feet in diameter. Each unit is custom designed and fabricated for each application.

INLET CONTROL DEVICES FOR STORMWATER SYSTEMS

The IPEX Inlet Control Device (ICD) is used to control flow into storm sewers during peak flow events. It is designed to allow a specified flow volume out of a catchbasin at a specified head. This causes the excess stormwater to be temporarily stored above ground. This approach conserves pipe capacity so that catchbasins upstream do not become uncontrollably surcharged, which could lead to flooding.

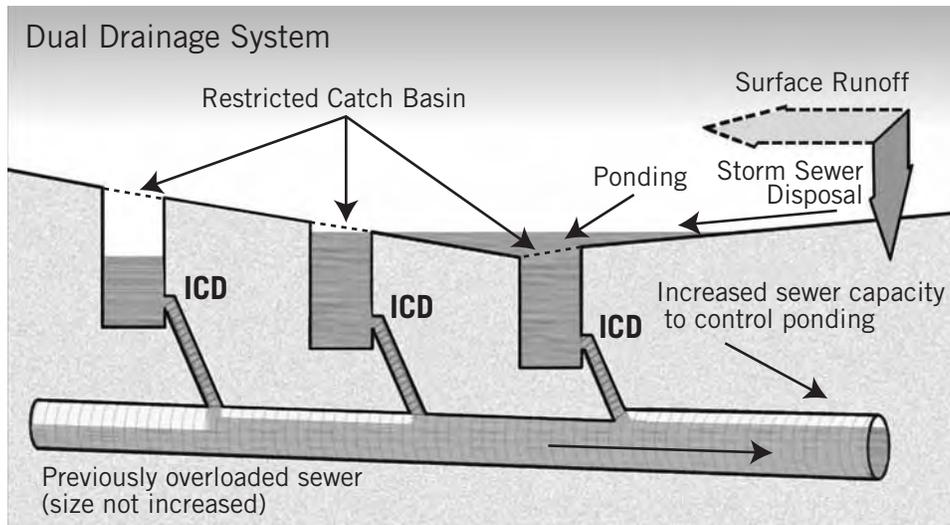
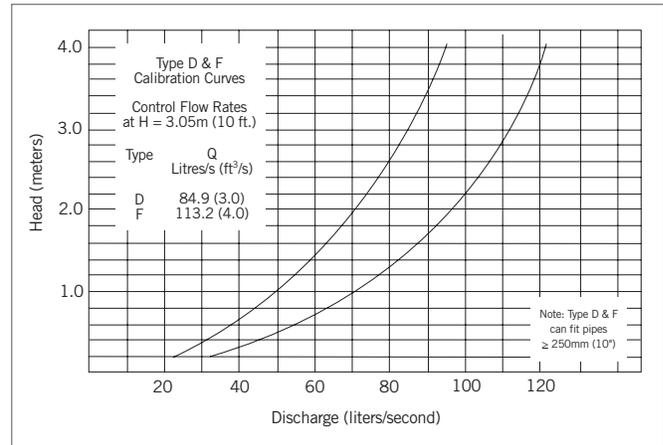
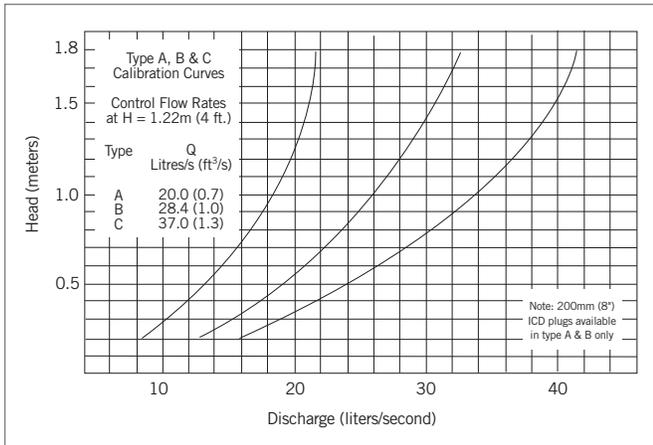
IPEX ICD's incorporate a special design that prevents clogging, which can be a problem for some orifice plates, particularly during low flow conditions.



Applications:

Storm water flow control for parking lots, roads and other areas where main line storm sewer capacity must be managed.





Specifications

IPEX Inlet Control Devices are manufactured from Polyvinyl Chloride (PVC) to be supplied according to the type (i.e. A, B, C, D, or F) as shown in the above graphs.

IPEX Plug ICDs are to be machined to provide a friction fit into the outlet pipe.

Framed ICDs are to be bolted in position over appropriate outlet pipe in the catchbasin/maintenance hole.

Dimensions

ICD's are available both as standard (Types A, B, C, D, & F) and custom designed configurations. In addition, there are specific designs for different types of pipe, including smooth wall PVC, profile wall and concrete pipe.

The main advantage of specifying standard ICD's is that they are readily available and can be delivered immediately. However, there are definite advantages to specifying custom sized units as they allow tremendous design flexibility because the allowable flow can be matched directly to the topography of the pavement surface.

LIFESAVER™ MANHOLE AND CATCH BASIN ADJUSTMENT UNITS

Lifesavers are high impact HDPE adjustment units designed to bring manhole and catchbasin castings up to the exact height of the asphalt or concrete surface of a roadway. These units cushion the impact loads between the cast iron casting and the concrete manhole or catchbasin structure, while eliminating infiltration and undermining. This extends the life of the surrounding roadway.



Applications:

Grade adjustments for manholes, catchbasins as well as electrical, telephone and other utility vaults. Recommended for high traffic areas.





Why use Lifesavers?

Concrete adjusting units are difficult to install, impossible to seal and are relatively fragile. They typically do not stand up to repeated impact loads and tend to crack, allowing infiltration of both water and fines, which causes undermining of the surrounding pavement structure. In addition, accurate slope adjustments are difficult because they must be done by sliding shims under the rings, then waiting for the mortar to cure.



Lifesavers eliminate all these problems because:

- Their lightweight, high impact HDPE construction makes them easy to handle. While concrete units can weigh up to 100 lbs or more, a single Lifesaver ring weighs less than 5 lbs.
- The manhole units are sealed using caulk, as opposed to field mixed (and often poor quality) mortar. This eliminates infiltration of both water and fines. In addition, bedding material can be compacted around the adjusting units immediately, while with concrete units the mortar must cure first.
- The catchbasin units, when properly wrapped with filter cloth will allow infiltration into the catchbasin, but will screen out all fines.
- Lifesavers are completely unaffected by chlorides from road salt and hydrogen sulphide from sanitary sewers. Both of these substances attack concrete units

Finally, Lifesavers have been used for many years in some of the most demanding applications in North America, and have been proven to significantly increase the life of the surrounding pavement structures.

Standards

Lifesavers are molded from high density polyethylene conforming to ASTM D1248.

Dimensions

Flat Manhole Adjusting Ring

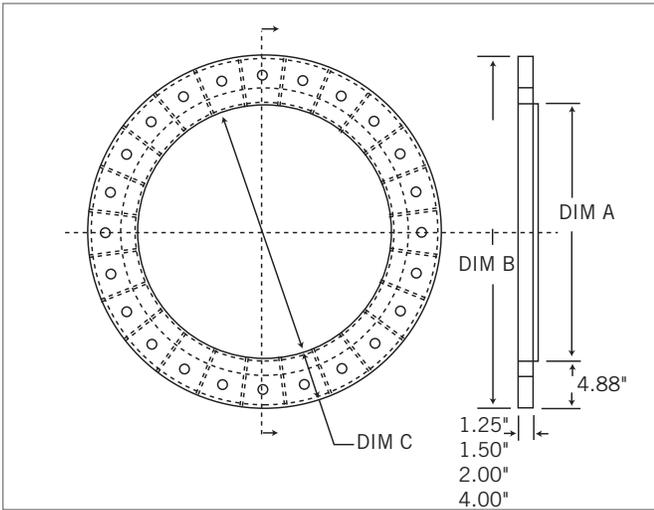
Manhole Opening		DIM A		DIM B		DIM C	
in	mm	in	mm	in	mm	in	mm
24	610	23.75	603.3	33.50	850.9	5.00	127
27	686	26.75	679.5	36.50	927.1	5.00	127
30	762	29.75	755.7	39.50	1003.3	5.00	127
32	813	31.75	806.5	41.50	1054.1	5.00	127
34	864	33.75	857.3	41.50	1054.1	5.00	127

Sloped Manhole Adjusting Ring

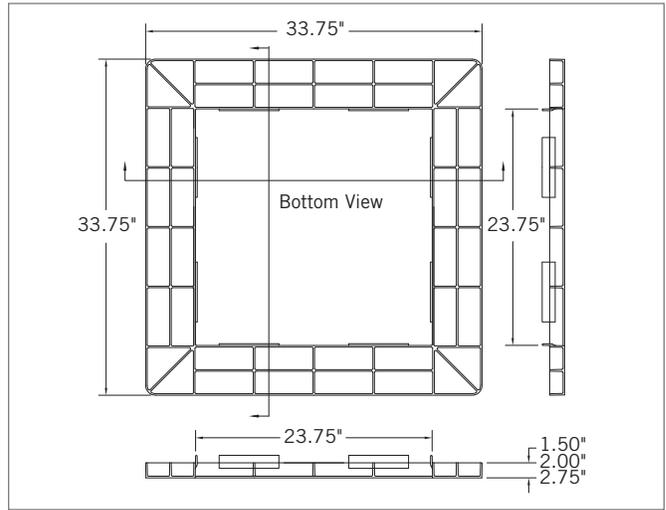
Manhole Opening		DIM D		DIM E	
in	mm	in	mm	in	mm
24	610	1.5	38	0.75	19
27	686	1.5	38	0.75	19
30	762	2.25	57	1.5	38
32	813	2.25	57	1.25	32
34	864	2.25	57	1.25	32

LIFESAVER MANHOLE ADJUSTMENT RINGS

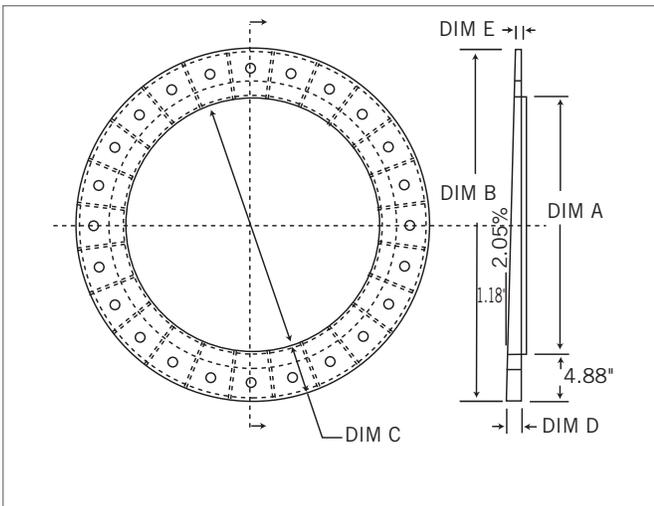
LIFESAVER CATCH BASIN ADJUSTMENT FRAMES



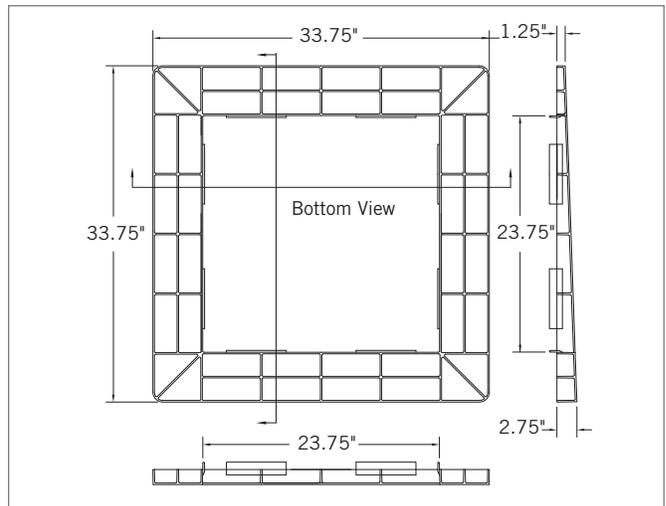
Flat Manhole Adjusting Ring



Flat Rectangular Catch Basin Adjusting Frame



Sloped Manhole Adjusting Ring



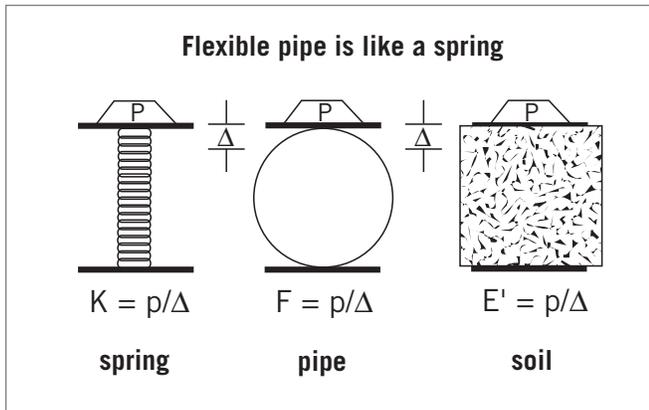
Sloped Rectangular Catch Basin Adjusting Frame

SECTION 2 – DESIGN INFORMATION

Structural Design

PVC pipes are classified as flexible conduits, which means they are designed to transfer loads to the bedding envelope surrounding the pipe by deflecting. A flexible conduit is generally defined as one that can deflect more than 2% of its diameter without damage.

Perhaps the easiest way to visualize pipe-soil interaction is to consider the spring analogy that was used by Dr. A. Moser in his authoritative textbook “Buried Pipe Design”.²



The ability to deflect away from vertical load is what gives PVC pipe its load carrying capability. The arching action of the soil over the pipe tends to reduce the load on the conduit, while the load that is applied is transferred to the surrounding bedding.

High Load Carrying Capabilities Even with Marginal Bedding

The pipe-soil system formed by PVC pipe is surprisingly strong. While PVC pipes are routinely installed with depths of bury exceeding 50 feet (particularly in landfill applications), experimental work has shown that Ultra-Rib pipe is capable of easily withstanding depths of bury up to 100 feet. Concrete pipe installed with identical bedding parameters collapsed. For a complete research report on this research completed at Utah State University, please contact your IPEX representative.

Deflection is Not a Bad Thing

Flexible pipes have a different failure mode than rigid pipes. Rigid pipes crack and eventually collapse under excessive load, whereas flexible pipes simply continue to deflect. PVC sewer pipes can typically deflect up to 30% of their diameter before any leakage occurs at the joints or damage to the pipe. The deflection limit for a PVC pipe is typically set at between 5% and 7.5%, which means that there is a safety factor of between 4 and 6 for deflection.

Rigid pipe manufacturers often point to deflection as a drawback when using PVC pipe, however this simply reflects a lack of understanding of the pipe-soil mechanism. Rigid pipes must also deflect slightly to carry load, but they respond to this slight deflection by cracking. As a result, while the performance limit for flexible pipe is the allowable deflection, the performance limit for concrete pipe is an allowable crack width. While concrete pipe manufacturers claim that their product can “self heal” small cracks, it is advisable to check these installations with a low pressure air test to ensure that the cracked pipe is not leaking.

² Moser, A.P., “Buried Pipe Design, 2nd Edition, pp.22

Calculating Loads on PVC Sewer Pipes

Buried structures are subjected to dead loads from the soil above (and sometimes from structures or buildings) the pipe, and to live loads, which are applied by vehicles or other bodies placed above the pipe temporarily.

The maximum possible soil load on a PVC pipe is known as the prism load, which is the pressure exerted by the full “block” of soil above the pipe. In reality, the actual load is somewhat less than this value, however assuming prism load conditions contributes to a conservative design.

Example

The prism load can be easily calculated if the soil density is known. For example, assume a soil density of 120 lb/ft³ and a depth of bury of 10 feet.

P = soil pressure, (lb/ft²)

w = soil density, (lb/ft³)

H = Depth of bury (ft.)

$$P = wH = (120 \text{ lb/ft}^3)(10 \text{ ft.}) = 1200 \text{ lb/ft}^2 = 8.3 \text{ lb/in}^2$$

Calculating live loads is more complicated and involves using the Boussinesq Solution for stresses in a semi-infinite elastic medium due to a point load applied at the surface^{3,4}. While relatively simple to solve, most designers opt to use standard loads that have been developed over the years.

The dead load and the live load is simply added together to get the total load on the pipe, which is then used to predict the long-term deflection in the pipe installation.

Live Loads Transferred to Buried Pipe							
Depth of Bury (ft.)	Live Load transferred to Pipe (lb/in ²)			Depth of Bury (ft.)	Live Load transferred to Pipe (lb/in ²)		
	Highway - H20	Railway E80	Airport		Highway - H20	Railway E80	Airport
1	12.5	Not Rec.	Not Rec.	14	*	4.17	3.06
2	5.56	26.39	13.14	16	*	3.47	2.29
3	4.17	23.61	12.28	18	*	2.78	1.91
4	2.78	18.4	11.27	20	*	2.08	1.53
5	1.74	16.67	10.09	22	*	1.91	1.14
6	1.39	15.63	8.79	24	*	1.74	1.05
7	1.22	12.15	7.85	26	*	1.39	*
8	0.69	11.11	6.93	28	*	1.04	*
10	*	7.64	6.09	30	*	0.69	*
12	*	5.56	4.76	35	*	*	*

Notes:

1. Table taken from the Uni-Bell Handbook of PVC Pipe - 4th Edition, pp. 210
2. H20 load simulates 20 ton truck traffic + impact (source ASTM A796)
3. E80 load simulates 80,000 lbs/ft railway load + impact (ASTM A796)
4. Aircraft load simulates 180,000 lb. dual tandem gear assembly, 26 inch spacing between tires and 66 inch centre spacing between fore and aft tires under a rigid pavement 12" thick + impact

^{3,4} More information on this calculation can be found in virtually any Soil Mechanics textbook. One of the best is “Soil Engineering” by M.F. Spangler. Information can also be found in Moser’s “Buried Pipe Design” and the Uni-Bell Handbook of PVC Pipe.

The Modulus of Soil Reaction, E'

The modulus of soil reaction is basically a measure of the soil stiffness of the bedding surrounding the pipe. Since flexible pipe transfers load to the surrounding bedding, the E' (known as E prime) value used for calculations has a significant impact on the predicted deflection. Over the years, there have been many studies, done both in the laboratory and the field that have established reasonable design values for E'. Perhaps the most comprehensive work has been completed by Amster Howard of the U.S Bureau of Reclamation:

**TABLE 7.3
AVERAGE VALUES OF MODULUS OF SOIL REACTION, E'
(For Initial Flexible Pipe Deflection)**

Soil type-pipe bedding material (Unified Classification System ^a) (1)	E' for Degree of Compaction of Bedding, in pounds per square inch			
	Dumped (2)	Slight, <85% Proctor, <40% relative density (3)	Moderate, 85%-95% Proctor, 40%-70% relative density (4)	High, >95% Proctor, >70% relative density (5)
Fine-grained Soils (LL > 50) ^b Soils with medium to high plasticity CH, MH, CH-MH	No data available; consult a competent soils engineer; Otherwise use E' = 0			
Fine-grained Soils (LL < 50) Soils with medium to no plasticity, CL, ML, ML-CL, with less than 25% coarse- grained particles	50	200	400	1,000
Fine-grained Soils (LL < 50) Soils with medium to no plasticity, CL, ML, ML-CL, with more than 25% coarse-grained particles Coarse-grained Soils with Fines GM, GC, SM, SC ^c contains more than 12% Fines	100	400	1,000	2,000
Coarse-grained Soils with Little or no Fines GW, GP, SW, SP ^c contains less than 12% Fines	200	1,000	2,000	3,000
Crushed Rock	1,000	3,000	3,000	3,000
Accuracy in Terms of Percentage Deflection ^d	±2	±2	±1	±0.5

^aASTM Designation D 2487, USBR Designation E-3.

^bLL = Liquid limit.

^cOr any borderline soil beginning with one of these symbols (i.e. GM-GC, GC-SC).

^dFor ±1% accuracy and predicted deflection of 3%, actual deflection would be between 2% and 4%.

Note: Values applicable only for fills less than 50 ft (15 m). Table does not include any safety factor. For use in predicting initial deflections only, appropriate Deflection Lag Factor must be applied for long-term deflections. If bedding falls on the borderline between two compaction categories, select lower E' value or average the two values. Percentage Proctor based on laboratory maximum dry density from test standards using about 12,500 ft-lbs/cu ft (598,000 J/m³) (ASTM D 698, AASHTO T-99, USBR Designation E-11). 1 psi = 6.9 kPa.

SOURCE: "Soil Reaction for Buried Flexible Pipe" by Amster K. Howard, U.S. Bureau of Reclamation, Denver, Colorado. Reprinted with permission from American Society of Civil Engineers.

Predicting Long Term Deflection using the Modified Iowa Formula

The Modified Iowa formula is an empirical equation that has been developed based on work originally done in the early 1900's, and is the most commonly used expression to calculate deflection in any flexible conduit.

$$\frac{\% \Delta Y}{D} = \frac{(D_L K P + K W')(100)}{(0.149 \frac{F}{\Delta Y} + 0.061 E')}$$

Where:

ΔL = Deflection Lag Factor (1.0 for Prism loads)

K = Bedding Constant (0.1)

W' = Live load, lbs/in²

F/DY = Pipe Stiffness, lbs/in²

E' = Modulus of soil reaction, lbs/in²

Example: A 24" Ultra-Rib pipe is to be installed 35 feet under a railway track and bedded using highly compacted (>90% Proctor density), well graded granular material. The soil density is 120 lb/ft³.

Calculate the expected ring deflection

1 Calculate the Dead Load:

$$\text{Prism load} = wH = (35\text{ft})(120\text{lb/ft}^3) = 4200\text{lb/ft}^2 = 29 \text{ lb/in}^2$$

2 Calculate the Live Load:

From the Live Load table it can be seen that at 35 feet the effects of an E80 Railway load are negligible.

3 Choose the appropriate E' value

From Amster Howard's work shown in the previous table for compacted crushed rock the E' value is 3000 lb/in²

4 Use the Modified Iowa Formula to Calculate the Deflection

$$\frac{\% \Delta Y}{D} = \frac{(D_L K P + K W')(100)}{(0.149 \frac{F}{\Delta Y} + 0.061 E')} = \frac{(1)(0.1)(29) + (0.1)(0)}{(0.149)(46) + 0.061(3000)} \times 100 = 1.5\%$$

Table 1 – Percent (%) Deflection for SDR35, Ultra-Rib, Ultra-X2 and Perma-loc V Pipes

ASTM EMBEDMENT MATERIAL CLASSIFICATION		DENSITY (PROCTOR) AASHTO T-99	E' psi (kPa)	HEIGHT OF COVER													
				ft. m	1 0.3	2 0.6	3 1	7 2	10 3	13 4	16 5	20 6	23 7	26 8	30 9	33 10	50 15
Manufactured Granular Angular	CLASS I	90%	3,000 (20 700)	0.7	0.5	0.3	0.4	0.4	0.6	0.7	0.9	1.0	1.2	1.3	1.4	2.2	
Clean Sand & Gravel	CLASS II	90%	2,000 (13 800)	1.1	0.7	0.5	0.5	0.6	0.8	1.1	1.3	1.5	1.7	1.9	2.1	3.2	
		80%	1,000 (7 000)	2.0	1.4	1.0	1.0	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0	6.0	
Sand & Gravel with Fines	CLASS III	85%	500 (3 500)	n/r	2.5	1.7	1.8	2.2	2.9	3.7	4.4	5.1	5.9	6.6	7.3	11.0	
Silt & Clay	CLASS IV	85%	400 (2 760)	n/r	3.0	2.1	2.2	2.6	3.5	4.4	5.3	6.1	7.0	7.9	8.8	13.1	

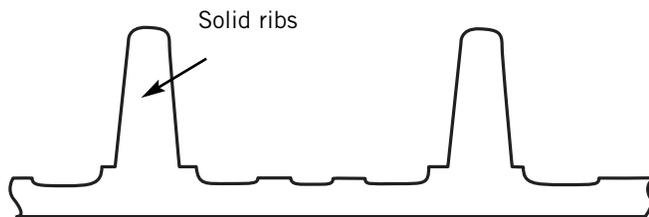
1. Deflection values shown include effect of H2O live load and dead load.
2. External loading based upon a prism load of soil weight of 1 900 kg/m³ (120 lbs. per cubic foot).
3. Bedding classifications correspond to ASTM D2321.
4. The deflection lag factor is 1.0 for a prism load.
5. Recommended maximum deflection of 7.5% provides a generous 4 to 1 factor of safety.
6. n/r = not recommended.

Profile wall vs. Smooth wall Pipe

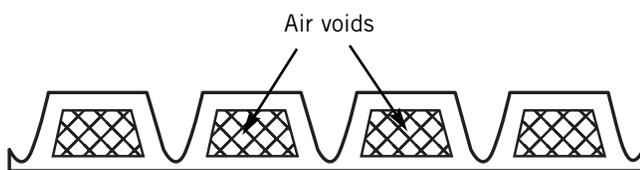
The performance characteristics of SDR35 pipe and Ultra-Rib pipe are identical. They have similar internal diameters, identical ring stiffness of 320 kPa (46 psi), and the same tight joints (50 psi). So, when should one specify Ultra-Rib and when should it be SDR35?

The secret to a successful specification is to specify as many products as possible that meet a certain performance standard. Since SDR35 and Ultra-Rib are identical from a performance perspective, both products can be specified for sanitary and storm sewer applications.

When specifying profile pipe, it is recommended that open profile pipe be specified as it is typically more durable than closed profile pipe. The difference between the two types lies in how they are manufactured. Open profile pipes are extruded as a solid wall pipe, then while it is still hot, mold blocks are used to re-shape the outside wall of the pipe into concentric ribs. This results in a monolithic pipe with no voids in the wall. A closed profile pipe is a thin inside wall with a second corrugated PVC pipe bonded to its outside surface. This encloses air voids within the pipe construction (hence the “closed profile” term).



Ultra-Rib Open Profile



Double Wall Corrugated (DWC) Closed Profile

Longevity and Durability of PVC Pipe Systems

Studies undertaken in Europe and North America confirm that PVC has one of the longest life cycles of any sewer pipe material. These studies include:

Uni-Bell PVC Pipe Association – Examination of 15 Year Old Sewer Pipe

In this study a sewer pipe that had been in service for 15 years in Dallas, Texas was excavated and tested according to ASTM standards. The pipe met all current standards with the exception of the outside diameter, on which it outside the allowable tolerance by 0.002 of an inch.

Wavin International – The Result of 30 Years Research into the Life of Pipe Systems

This study consisted of the examination of over 26,000 metres of sewer pipe installed in some of the most difficult conditions in Europe over the last 30 years. Some of the conclusions of the study were:

- PVC piping systems can be expected to last for several hundred years
- Good results are possible even when the pipes are installed under extremely difficult conditions, such as cohesive clay or peat.
- Even after up to 30 years service, there was no difference in the wall thickness between the “washed” portion of the pipes that carried wastewater and the “unwashed” portion near the crown of the pipes. This indicated abrasion wear was simply not an issue with these pipes.

Reinhard Nowack, Thomas Hulsman – 70 Years of Experience with PVC Pipes

The first PVC pipes for commercial use were produced in Germany in the mid-1930’s. During this study a number of these pipes were excavated and tested. Although these pipes were pressure pipes, many of them were used in chemical transfer applications, and have not had any decrease in service properties. Some of the conclusions of this study were:

- Even some of the earliest commercially produced pipes, which had a rated lifespan of only 50 years, were still performing well 70 years later.
- Better machinery available today and advanced compounding means that pipes produced today will have a longer lifespan than the pipes examined in this study

The fact that PVC is not affected by the aggressive chemicals commonly found in sewage (sulphides, chlorides) means that it has a virtually unlimited lifespan in these applications. A minimum life cycle of 100 years is a conservative value to use when carrying out life-cycle costing calculations.

Chemical and Abrasion Resistance

Sanitary sewers, particularly in industrial areas, can be an extremely aggressive environment for piping materials. Hydrogen sulphide, chlorides from road salt as well as various substances in wastewater can attack concrete and metal components of sewer systems. Furthermore, abrasion caused by grit in wastewater can accelerate the decay process through abrasion and wearing action. Fortunately, PVC and other thermoplastics are virtually immune to attack from these chemicals and are highly resistant to abrasion.

Chemical Attack

Various studies have been undertaken with respect to the chemical resistance of PVC piping systems. Most of these studies have dealt with the issue of permeation by organic chemicals and the most common conclusion is that PVC pipe forms an effective barrier against organic contamination, with an effective permeation time in the order of many centuries even at extremely high levels of organic contamination.

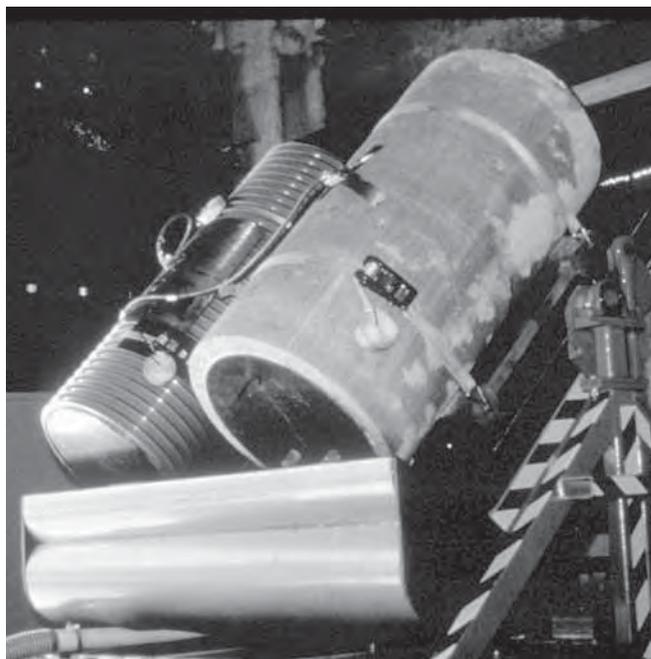
With gravity sewer pipe the concern is typically whether gasoline, oil or other chemical spills could compromise the structural integrity of a PVC culvert or sewer pipe. Testing with various substances has shown conclusively that it is virtually impossible for PVC pipe to be affected by a spill. For example, PVC pipe has been exposed to pure gasoline for years with no effect⁵. While chemicals such as acetone can eventually damage PVC pipe, the effluent running through the pipe would have to be almost pure acetone and would have to run for hours for damage to occur.

Abrasion

Storm sewers and high velocity sanitary sewers can have a significant portion of grit in their flows that can potentially abrade a concrete sewer pipe. Testing carried out at California State University confirms that PVC pipe is considerably more durable than concrete pipe with respect to abrasion.

The results from California State clearly indicate that abrasion should be considered when designing sanitary or storm sewer systems. While it is true that very few concrete sewers have ever failed as a result of abrasion alone, abrasion tends to accelerate the corrosion process of both concrete and reinforcing steel

When considering Ultra-Rib, Ultra-X2 and SDR35 PVC pipes, abrasion can be virtually eliminated as an issue.



Infiltration and Exfiltration

The tight tolerances of Ring-tite, Enviro-Tite, Ultra-X2 and Ultra-Rib allow for extremely tight gasketed joints. The end result is a pipe joint that allows zero infiltration and exfiltration. In order to meet ASTM and CSA standards, all joints must withstand hydrostatic pressure levels of 100kPa (15 psi) as well as a vacuum pressure of -75 kPa (-11 psi).

In fact, the joints of Ring-Tite, Enviro-Tite and Ultra-Rib can withstand pressures in excess of 345 kPa (50 psi). In many jurisdictions a 50 psi capable joint is required when installing a sewer within 8 feet of a water main.

While properly installed IPEX sewer pipes will have zero infiltration, the ASTM standard actually allows a maximum of 2.3 litres per mm diameter per kilometer per day (25 U.S. gal/in. dia/mile/day). This allowance recognizes that PVC sewer systems are often constructed with concrete manholes which generally allow a certain amount of infiltration.

Root Intrusion

Root choked clay and concrete sewers cause millions of dollars worth of damage each year due to sewer backups. IPEX sewer pipe joints are immune to root penetration for two reasons:

- They are tight enough to resist even the thinnest root filaments penetrating
- They do not provide a water source for the roots, so they do not attract root growth.

Each of these points has been proven both through field and laboratory testing.

⁵ Hoogensen Metallurgical Engineering Ltd., "Examination of Submitted PVC Pipe Section", Report to IPEX, December 1998

Gravity Flow Systems: Manning's Equation

The most common procedure for calculating open channel or partially full pipe flow conditions is to use the Manning formula below:

$$V = \left(\frac{1.49}{n} \right) r^{2/3} s^{1/2}$$

Where: V = the average velocity at a cross section ft/sec

R = the hydraulic radius, ft

S = slope, ft/ft

n = the coefficient of roughness

The “n” factor varies both with the degree of roughness of the inside of the pipe, and the flow velocity. Higher flow velocities tend to reduce the “n” factor in sewers as solids deposition and slime build-up on the bottom of the pipe is reduced.

Designing with the PVC sewer pipe, an “n” factor of 0.009 is recommended.⁶ This is supported by a large number of scientific studies, many of which were carried out on “in service” pipes that had been operating for many years. The “n” values in these studies were found to range between 0.007 and 0.011. no published study has ever found an “n” value as high as 0.013 for a PVC system in any sewer operation even at minimum velocities of 2 ft/s (0.6 m/s). Please contact us if you wish to review the results of these studies.

Average Values of the Manning Roughness Factor

Material	Manning n
PVC	.009
Concrete	.013
Cast iron	.015

The relatively low “n” values associated with PVC pipe are a result of various factors:

- Smooth, nonporous inside surface of the pipe
- Longer laying lengths (i.e. fewer joints)
- Lower profile gap at the joints
- Chemical and abrasion resistance of the material

By designing PVC sewer systems with the scientifically appropriate Manning value of 0.009, sewers can be installed at tighter grades, thus reducing excavation costs and disturbance. In some cases, it may even be possible to downsize the pipe while maintaining a particular flow capacity.

⁶ Uni-Bell PVC Pipe Association; “Handbook of PVC Pipe” 4th Edition, August 2001, pp.359

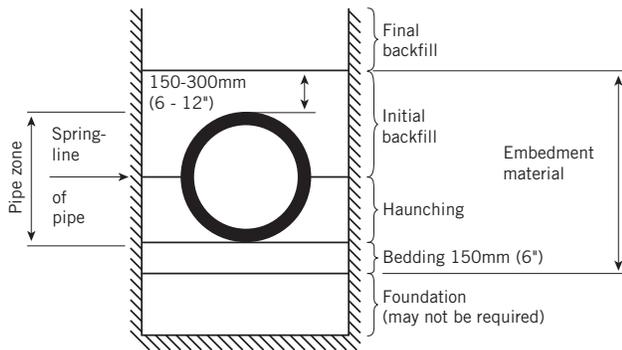
Installation of PVC Sewer Systems

An understanding of flexible conduit terminology is essential for the installer. The soil class and density realized in the bedding, haunching and initial backfill zones are important factors in achieving a satisfactory installation of PVC pipe.

Much of the installation information can also be found in Canadian Standards Association (CSA) Standard B182.11, entitled, "Recommended Practice for the Installation of Thermoplastic Drain, Storm and Sewer Pipe and Fittings" or ASTM Standard D2321, entitled, "Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity Flow Applications."

Trench Zones

The following figure has been prepared to illustrate the various zones used with flexible pipe terminology.



Foundation - A foundation is required when the trench bottom is unstable. Any foundation that will support a rigid pipe without causing loss of grade or structural breakage will be more than adequate for PVC pipes.

Bedding - The bedding directly underneath the pipe is required only to bring the trench bottom up to grade. It should not be so thick or soft that the pipe will settle and lose grade. The sole purpose of the bedding is to provide a firm, stable and uniform support of the pipe. A bedding thickness of 100 mm (4") is most times sufficient. The engineer may wish to increase the bedding to 150 mm (6") for ledge rock foundations.

Haunching - This area is the most important in terms of limiting the vertical deflection of the flexible pipe. Pipe support is obtained in the haunch zone by compacting soil in both directions away from the pipe to the undisturbed trench walls.

Initial Backfill - This zone begins above the springline to a level 150 mm (6") to 300 mm (12") above the top of the pipe. Compaction here will give little additional side support to PVC pipe, but may be required to maintain stability of any above ground surfaces (i.e. roads or sidewalks).

Note: The particle size recommended for the three zones described above should not exceed 38 mm (1.5") for Ring-Tite, Enviro-Tite and Ultra-Rib.

Final Backfill - The remainder of the trench fill above the initial backfill provides no support for a PVC pipe and should be free of stones 150 mm (6") and larger. Compaction may be required for reasons other than support of the PVC pipe since this zone is very significant in supporting the above ground surfaces (i.e. roads or highways).

Embedment Materials

Some general rules about all soils to be used in a buried pipe-line trench include that they must be free of sharp objects, sticks, large clumps, frozen material, organic materials and boulders.

Most of the soils commonly found can be classified into one of the following categories, which are referenced from ASTM D2487.

Class 1

Angular, 6 mm to 38 mm (1/4 - 1 1/2") graded stone, including a number of fill materials such as coral, slag, cinders, crushed stone or crushed shells.

Class 2

Coarse sands and gravels with a maximum particle size of 38 mm (1 1/2"), including various graded sands and gravels containing small percentages of fines, generally granular and non-cohesive.

Class 3

Fine sand and clayey gravels, including fine sands, sand-clay mixtures and gravel-clay mixtures.

Class 4

Silt, silty clays, and clays including inorganic clays and silts of medium to high plasticity and liquid limits.

Class 5

Includes organic soils such as frozen earth, debris and other foreign materials. These materials are not recommended for use in the bedding, haunch or initial backfill zones.

Note: The performance of a flexible conduit does not depend only on the class of embedment materials used, but more importantly, on the density achieved in compaction of the haunching material.

Selection of Embedment Materials

Soil to be used in the pipe zone should be capable of maintaining the specified soil density. For example, if a coarse material such as Class 1 is used for bedding the pipe, it should also be used in the haunch zone to the springline of the pipe. Otherwise, side support may be lost due to migration of the Class 2, 3 or 4 material into the bedding.

When selecting the embedment materials, ensure that native soil migration from the trench walls cannot occur. A well-graded compacted granular material will prevent this condition from occurring. In trenches subject to inundation, the granular material should be compacted to a minimum of 85% Standard Proctor Density.

Preparation of Trench Bottom

Preparation of the trench bottom is the starting point for a satisfactory and safe sewer pipe installation. The trench bottom should be smooth and free from large stones, clumps of dirt, and any frozen material as approved by the engineer. It is economical on most sewer installations to undercut the trench bottom by machine and bring it up to grade by use of granular material.

If the bedding material chosen is a loose granular such as sand, the pipe can be laid directly on it. If the bedding is a hard, compacted material, excavation for the bells (bell holes) should be provided so that the pipe is uniformly supported along the entire length.

Coarse sand, crushed stone or shell often is the most economical granular material because compaction is easily obtained. With all types of soil, voids should be eliminated under and around the lower half of the pipe by working in granular materials by shovel slicing.

Native backfill may be used for the trench bottom providing the soil is free of large stones, hard lumps and debris, and can be properly compacted by tamping. Ensure that the fill does not fit the Class 5 description.

In rocky trenches, place a minimum 100 mm (4") layer of select bedding material to provide a cushion for the pipe. The rock foundation must first be excavated to at least 100 mm (4") below the final grade of the pipe bottom. Any buried pipe, regardless of pipe material, that rests directly on rock may be subject to eventual breakage under the weight of soil and/or live loads.

When an unstable trench bottom is encountered and appears to be unable to support the pipe properly, the engineer may insist that the bottom be excavated and refilled to pipe grade with an approved foundation and bedding material. This layer should be compacted to a minimum 85% Standard Proctor Density.

Curved Sewers

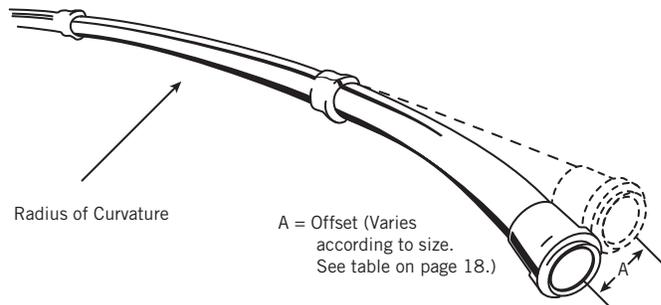
As a cost-saving alternative to manholes, gradual changes in direction for IPEX PVC Sewer Pipe may be achieved using one of the following:

- (a) bending the pipe (IPEX Ring-Tite and Enviro-Tite only)
- (b) deflecting the gasketed joint
- (c) using IPEX PVC fittings

A. Bending the Pipe Barrel

Smaller diameters of IPEX PVC Ring-Tite and Enviro-Tite Pipe up to 300 mm (12") diameter may be subjected to limited bending to follow the outline of a curved trench. *This practice should not be attempted with Ultra-Rib or Ultra-X2 Pipe.* The recommended procedure is as follows:

1. Make a concentric assembly in the usual way. Keep the spigot in straight alignment with the bell.
2. Place compacted backfill around the assembled joint to restrict its movement while the curvature is being made.
3. Place compacted backfill at the inside of the curve, at the mid-point of the pipe length, to form a fulcrum.
4. Using only *manual* effort, move the leading bell of the pipe length to be curved by no more than the offset distance shown in the following table.



Below is a table showing the minimum radius of curvature achieved by bending IPEX Ring-Tite and Enviro-Tite Pipe, and the resultant maximum offset for standard 4 m (13') lengths.

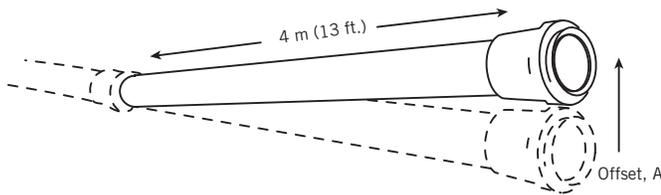
Pipe Size		Min. Radius of Curvature		Max. Offset, A	
mm	in.	m	ft.	mm	in.
100	4	14	46	570	22
125	5	18	59	450	18
150	6	20	66	400	16
200	8	27	89	300	12
250	10	34	112	235	9
300	12	40	132	200	8

Note: Bending is not recommended for Ring-Tite and Enviro-Tite pipe sizes greater than 300 mm (12") or for any size of Ultra-Rib or Ultra-X2 pipe.

B. Deflecting the Joint

The gasketed joints of IPEX PVC Sewer Pipe and Fittings are flexible enough to permit deviation in the assembled joint for directional changes. Below is the recommended procedure for curving a pipeline using joint deflection:

1. Make a concentric assembly, but push the spigot into the bell only to a point about 13 mm (1/2") short of the reference line. This incomplete assembly permits more movement of the end of the pipe at the neck of the bell.
2. Shift the loose bell end of the assembled length by not more than indicated in the following table.
3. This procedure should not be used in conjunction with Method A (bending the pipe barrel).



Below is a table illustrating the maximum allowable angle of deviation at the bell of IPEX PVC Sewer Pipe, as well as the resultant maximum offset for a standard 4 metre (13') length.

Pipe Size		Angle At One Bell	Maximum Offset, A		Radius Of Curvature	
mm	in.	degrees (°)	mm	in.	m	ft.
Ring-Tite and Enviro-Tite						
100 - 300	4 - 12	5	350	14	46	151
375 - 600	15 - 24	3	210	8	76	249
675 - 1050	27 - 42	1.5	105	4	153	502
Ultra-Rib						
200 - 600	8 - 24	5	350	14	46	151
Ultra-X2						
750 - 900	30 - 36	3	210	8	76	249
Big Brute (20 ft. lengths)						
600 - 1200	24 - 48	1.5	160	6.25	233	764

Note: If half lengths of pipe are used, the above offset values must be divided by 2.

C. Using PVC Fittings

IPEX offers standard elbows and short or long radius sweeps in 11¼°, 22½°, 45° or 90°. PVC elbows can also be fabricated to any other angle configuration for all sizes of Ring-Tite, Enviro-Tite, Ultra-X2 or Ultra-Rib pipe. These fittings are assembled in the same manner as the pipe.

Sewer Laterals

In general, service laterals should be taken off at an angle of no greater than 45 degrees from the horizontal. This will minimize the effects of side-soil friction imposing excessive downward loads on the service connection.

When connecting laterals, use a long sweep PVC bend wherever possible to facilitate changes in slope more gradually. Good compaction is imperative beneath the long sweep bends as well as below the branch of the service connection in order to maintain proper soil support. The PVC long sweep bends from IPEX are made to a radius of curvature of six (6) times the nominal diameter of the bend.

Riser Problems Demand Special Attention

When vertical risers cannot be avoided consult the design engineer as more special precautions may be required.

Service lines from the property to the street sewer demand special design considerations when the collection sewer is deeper than 4 m (13') regardless of the piping material used. Service risers from main sewers buried more than 4 m (13') should be taken off at an angle not less than 45° from the vertical. The service should then be moved to the vertical position by an appropriate elbow and vertical section of pipe. In sanitary sewer systems, drop laterals and drop manholes are the most common examples of areas requiring this special attention.

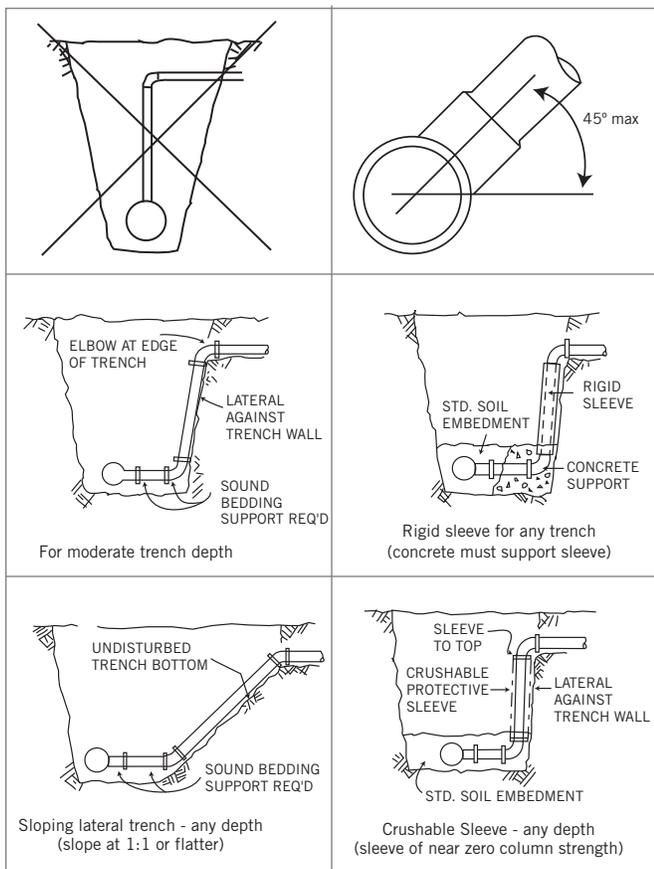
Drop laterals may create undue stresses on the buried pipe and fitting assembly. Horizontal portions of a lateral laid over disturbed uncompacted materials may experience a loss of bedding support if the foundation settles. This can lead to loss of grade and ultimately beam or shear failure in the pipe or fitting. As the soil adjacent to the pipe settles with the foundation, it attempts to drag the pipe with it, magnifying the load on the fittings.

Providing proper support beneath the mainline, service fitting, lateral, elevation fittings and their adjacent fill is critical. Since this is usually difficult, the best approach is to turn the lateral down immediately when entering the trench and keep it against the trench wall thus eliminating any unsupported portion.

Keeping the drop portion (and the upper elbow) immediately adjacent to the trench wall can reduce drag down effects and control beam bending during backfill. Even then, the elbow at the bottom must be both strong enough and bedded on a sound foundation to react to the loads. As depths increase, settlement loads can ultimately fail the system or buckle the riser.

Designs employing sleeves or concrete encasement of the drop portion of the lateral are effective if the designer provides an adequate means of supporting the loads at the bottom.

Sleeving the lateral with a crushable sleeve such as corrugated polyethylene drainage tubing can also solve the problem. As the fill adjacent to the lateral settles, the sleeve folds up and moves down with it. This accordion-like effect displaces the load from the lateral. It should be noted that when this method is used, the annular space between the sleeve and the lateral should not be filled with backfill.



Performance Testing of Sewer Installations

When specifying performance testing for installed sewers it is important to ensure that the complete system is tested. While a video inspection 30 days after installation is usually sufficient to identify any defects in the installation, there are a number of other performance tests that can be carried out.

One of the most useful tests is the low pressure air test, which is used to check the integrity of installed joints both for rigid pipes like reinforced concrete as well as PVC systems. IPEX recommends air testing for all installed sewer pipe, regardless of material, particularly when the pipe is installed in an area with a high water table.

Mandrel testing is generally only required when the video inspection shows significant defects with the installation and the pipe appears to be highly deflected (i.e. more than 7.5%).

Testing of Sewers

Joint Tightness Testing

To ensure the integrity of the assembled gasketed joints of a PVC sewer pipeline, often the designer will require testing after installation is complete. This testing is frequently a requirement for sanitary sewer lines and is a growing trend for storm sewer systems as well.

There are 2 options that may be specified by the designer to test joint tightness – Air Testing or Water Testing. Air testing is preferable where possible because of its accuracy, simplicity and minimal time consumption. Water testing tends to be more expensive than with air, but is advantageous in some situations.

1. Air Testing

Here, the installer must plug both ends of a section of sewer to be tested before subjecting that section of pipe to low pressure air. The air must be maintained at a minimum pressure of 24.0 kPa (3.5 psi) for the specified time period for each diameter shown in the table below. Duration times vary with changes in pipe size and length of test sections. A maximum pressure drop of 3.5 kPa (0.5 psi) is permitted within the specified time duration. If a maximum pressure drop of 7.0 kPa (1.0 psi) is specified, the time values in the table should be doubled.

Should the pressure drop be greater than 3.5 kPa (0.5 psi) within the specified time duration, the installer must locate and repair any deficiencies at his own expense. Re-testing must be performed until a successful test is achieved. Sources of leaks may be dirt in an assembled gasketed joint, incorrectly tightened service saddles or improper plugging or capping of sewer lateral piping. If there is no leakage (i.e. zero pressure drop) after one hour of testing, the section should be passed and presumed free of defects.

If there is groundwater present at a level higher than the pipe invert during the air-test, the test pressure should be increased to a value of 24.0 kPa (3.5 psi) greater than the water head at the bottom of the pipe [to a maximum air test pressure of 34.0 kPa (5.0 psi)].

Pipe Size		Minimum Time	Length for Minimum Time		Time for Longer Meter Length	Time for Longer Feet Length
mm	in.		m	ft.	sec	sec
100	4	1:53	182.0	600	0.623 L	0.190 F
150	6	2:50	121.3	400	1.401 L	0.427 F
200	8	3:47	90.8	300	2.493 L	0.760 F
250	10	4:43	72.8	240	3.894 L	1.187 F
300	12	5:40	60.7	200	5.606 L	1.709 F
375	15	7:05	48.5	160	8.761 L	2.671 F
450	18	8:30	40.5	133	12.615 L	3.846 F
525	21	9:55	34.7	114	17.171 L	5.235 F
600	24	11:20	30.2	100	22.425 L	6.837 F
675	27	12:45	26.8	88	28.382 L	8.653 F
750	30	14:10	24.4	80	35.040 L	10.683 F
900	36	17:00	20.1	66	50.472 L	15.384 F
1050	42	19:54	17.4	57	68.707 L	20.942 F
1200	48	22:47	15.2	50	89.736 L	27.352 F

where L = length of test section in metres
F = length of test section in feet

example - If there is 0.5 metres (1.65 ft.) of water above the invert of a buried PVC sewer line, what must the air-test pressure be?

solution - The static head of the groundwater at the pipe invert will be:

$$0.5 \text{ m} \times (9.73 \text{ kPa} / \text{m}) = 4.87 \text{ kPa}$$

therefore, the total air-test pressure should be:

$$4.87 \text{ kPa} + 24.0 \text{ kPa} = 28.87 \text{ kPa}$$

or

$$1.64 \text{ ft.} \times (.43 \text{ psi} / \text{ft.}) = .71 \text{ psi}$$

therefore, the total air-test pressure should be:

$$.71 \text{ psi} + 3.5 \text{ psi} = 4.21 \text{ psi}$$

Since this value is less than 34.0 kPa (5.0 psi), the installer may proceed with the air test using this start pressure.

Knowing the density of water to be 1000 kg/m³ (62.4 lb/ft³), the maximum head of groundwater permitted above the invert of a PVC sewer pipe for an air test is 1 metre (3.3').

2. Water Testing

Infiltration - The allowable infiltration for any pipe section should be measured by a weir or current meter placed in an appropriate manhole. This is an acceptable method of leakage testing only when the ground-water level is above the top of the pipe throughout the section of line being tested. It is especially useful when the water table is well above the top of the pipe. Usually the designer will give explicit instructions for conducting the test.

Exfiltration - This test is suitable for very dry areas, or where the water table is suitably low that test pressures can easily exceed the static head of the water table. Test pressures should be a minimum of 5.9 kPa (0.9 psi) above the water table head. The test section of pipe shall be filled with water and the leakage rate measured.

For sizes 100 mm - 375 mm (4" -15"), the allowable leakage rate shall be 4.63 liters per mm of pipe diameter per kilometer per 24 hours or 50 USgal./inch/mile/day. For sizes 450 mm (18") and larger, the allowable rate for testing shall be 0.93L/mm/km/day or 10

USgal./inch/mile/day. Should the allowable leakage rate be exceeded for either an infiltration or exfiltration test, the installer must locate and repair any deficiencies at his own expense until a successful test is conducted. Tests are typically conducted from manhole to manhole.

Deflection Testing

Deflection is the way a flexible pipe reacts to vertical soil loads when buried in a trench. It illustrates how the pipe and surrounding soil work together to easily withstand common, and even extreme soil loads.

The maximum deflection of plastic pipe or fittings can be accurately predicted by the designer by knowing the pipe stiffness, soil stiffness and the height of cover. For the majority of underground PVC sewer pipe applications, with proper compaction, the deflection will be well within the recommended maximum allowable of 7.5%. However, if the designer has reason to believe that excessive deflection may be present, a deflection test may be necessary.

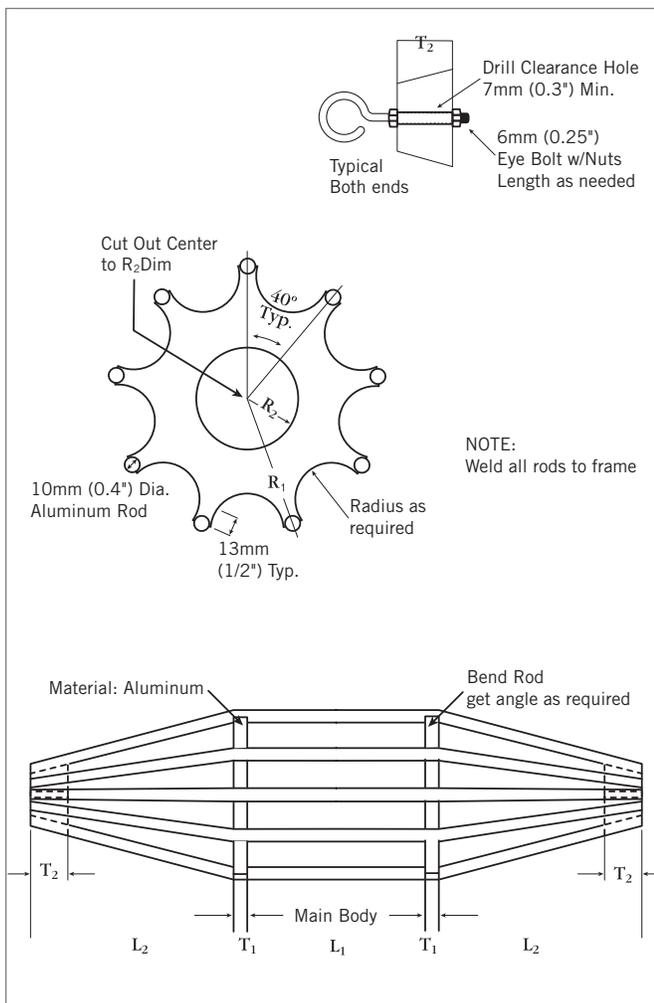
There are two commonly used methods of performing deflection tests on PVC sewer pipe:

1. Go-No-Go Device
2. Physical Measurement

1. Go-No-Go Device

The most popular method of the two is the rigid Go-No-Go mandrel. This gage can accurately determine whether the deflection is within specified limits. The test involves the pulling of a mandrel through an installed sewer line. The mandrel will simply get stuck if the actual deflection is beyond the specified limit (normally 7.5%). The mandrel must be designed to have dimensions which exactly match the clearance inside the pipe, at the deflection limit.

Below is a detailed drawing of a suggested mandrel design for 7.5% deflection, along with tables of appropriate dimensions for Ring-Tite, Enviro-Tite and Ultra-Rib Pipes.



Ring-Tite and Enviro-Tite - Mandrel Dimensions									
Pipe Size	Base I.D.		L1, L2		R2		R1		
	mm	in.	mm	in.	mm	in.	mm	in.	mm
200	8	194.7	7.67	150	6	35	1.4	90.0	3.54
250	10	242.9	9.56	200	8	40	1.6	112.3	4.42
300	12	288.6	11.36	200	8	45	1.8	133.5	5.26
375	15	353.0	13.90	230	10	50	2.0	163.3	6.43
450	18	431.2	16.98	300	12	55	2.2	199.4	7.85
525	21	508.1	20.00	300	12	60	2.4	235.0	9.25
600	24	571.0	22.48	350	14	65	2.6	264.1	10.40
675	27	643.3	25.33	350	14	70	2.8	297.5	11.71

Ultra-Rib - Mandrel Dimensions									
Pipe Size	mm	in.	mm	in.	mm	in.	mm	in.	mm
250	10	245.2	9.7	200	8	40	1.6	114.0	4.5
300	12	291.8	11.5	200	8	45	1.8	135.7	5.3
375	15	357.3	14.1	230	10	50	2.0	166.1	6.5
450	18	438.7	17.3	300	12	55	2.2	204.0	8.0
525	21	515.8	20.3	300	12	60	2.4	239.8	9.4
600	24	584.2	23.0	350	14	65	2.6	271.7	10.7

Notes:

- T1 = 10mm (0.4") and T2 = 25mm (1") for all sizes of mandrels
- For pipes larger than 675mm (27"), physical measurement is recommended.
- Two times dimension R1 is critical passing dimension for deflection mandrels.

2. Physical Measurement

To begin this process, one must measure the vertical inside diameter at a particular point in a PVC sewer pipe before it is installed (D1). Next, measure the inside diameter at that same point after the pipe has been installed and completely backfilled (D2). Now, the deflection at that point can be computed as follows:

$$\text{Deflection} = \frac{D1 - D2}{D1} \times 100\%$$

For accurate results, a micrometer should be used.

Videos

The use of video cameras to inspect the interior of newly installed sewer pipe is very common today. The idea of videotaping the inside of sewer lines was first conceived to fulfill the need to evaluate the decaying condition of older sewers made from traditional pipeline materials such as clay, brick or concrete. The only practical benefit of videos with regard to newly installed PVC sewer pipe is in detecting glaring installation deficiencies such as leaking joints or excessive deflections. Although videos are able to pinpoint the location of a deficiency, they are unable to quantify the magnitude of a problem or whether the deficiency is within allowable limits.

SECTION THREE: APPENDICES

APPENDIX A: REFERENCES

- 1 Hulsman, Nowack; “70 Years of Experience with PVC Pipe”, Conference Paper, Plastic Pipes XII, 2004
- 2 Moser, A.P., “Buried Pipe Design”, 2nd Edition, 2001, pp.22
- 3 Spangler Handy, “Soil Engineering”, 4th Edition, May 1982, pp.352
- 4 Uni-Bell PVC Pipe Association; “Handbook of PVC Pipe” 4th Edition, August 2001, pp.207
- 5 Hoogensen Metallurgical Engineering Ltd., “Examination of Submitted PVC Pipe Section”, Report to IPEX, December 1998
- 6 Uni-Bell PVC Pipe Association; “Handbook of PVC Pipe” 4th Edition, August 2001, pp.359

APPENDIX B: CALCULATION RESULTS

Sewer Pipe Flows - Imperial Measure

Slope (ft/ft)	4" Ring-Tite & Enviro-Tite		6" Ring-Tite & Enviro-Tite		8" Ultra-Rib/ Ring-Tite/Enviro-Tite		10" Ultra-Rib/ Ring-Tite/Enviro-Tite		12" Ultra-Rib/ Ring-Tite/Enviro-Tite		15" Ultra-Rib Ring-Tite/Enviro-Tite	
	Full Velocity, ft/s	Full Flow Capacity, ft ³ /s	Full Velocity, ft/s	Full Flow Capacity, ft ³ /s	Full Velocity, ft/s	Full Flow Capacity, ft ³ /s	Full Velocity, ft/s	Full Flow Capacity, ft ³ /s	Full Velocity, ft/s	Full Flow Capacity, ft ³ /s	Full Velocity, ft/s	Full Flow Capacity, ft ³ /s
0.001	1.0	0.1	1.3	0.2	1.6	0.5	1.8	1.0	2.1	1.6	2.3	2.7
0.002	1.4	0.1	1.8	0.4	2.2	0.8	2.6	1.4	2.9	2.2	3.3	3.7
0.003	1.7	0.1	2.2	0.4	2.7	0.9	3.2	1.7	3.5	2.7	4.1	4.6
0.004	2.0	0.2	2.6	0.5	3.1	1.1	3.6	1.9	4.1	3.1	4.7	5.3
0.005	2.2	0.2	2.9	0.6	3.5	1.2	4.1	2.2	4.6	3.4	5.2	5.9
0.006	2.4	0.2	3.2	0.6	3.8	1.3	4.5	2.4	5.0	3.8	5.7	6.5
0.007	2.6	0.2	3.4	0.7	4.2	1.4	4.8	2.6	5.4	4.1	6.2	7.0
0.008	2.8	0.2	3.7	0.7	4.4	1.5	5.2	2.7	5.8	4.4	6.6	7.5
0.009	3.0	0.3	3.9	0.7	4.7	1.6	5.5	2.9	6.1	4.6	7.0	7.9
0.010	3.1	0.3	4.1	0.8	5.0	1.7	5.8	3.1	6.5	4.9	7.4	8.3
0.020	4.4	0.4	5.8	1.1	7.0	2.4	8.2	4.3	9.2	6.9	10.5	11.8
0.030	5.4	0.5	7.1	1.4	8.6	2.9	10.0	5.3	11.2	8.4	12.8	14.5
0.040	6.3	0.5	8.2	1.6	9.9	3.4	11.5	6.1	12.9	9.7	14.8	16.7
0.050	7.0	0.6	9.2	1.8	11.1	3.8	12.9	6.8	14.5	10.9	16.6	18.7
0.060	7.7	0.7	10.0	1.9	12.2	4.1	14.1	7.5	15.9	11.9	18.1	20.4
0.070	8.3	0.7	10.9	2.1	13.1	4.5	15.2	8.1	17.1	12.9	19.6	22.1
0.080	8.9	0.8	11.6	2.2	14.1	4.8	16.3	8.6	18.3	13.8	21.0	23.6
0.090	9.4	0.8	12.3	2.4	14.9	5.1	17.3	9.2	19.4	14.6	22.2	25.0
0.100	9.9	0.9	13.0	2.5	15.7	5.3	18.2	9.7	20.5	15.4	23.4	26.4

Slope (ft/ft)	18" Ultra-Rib & Ring-Tite		21" Ultra-Rib & Ring-Tite		24" Ultra-Rib & Ring-Tite		27" Ring-Tite		30" Ring-Tite/ Ultra-X2		36" Ring-Tite/ Ultra-X2		42" Ring-Tite	
	Full Velocity, ft/s	Full Flow Capacity, ft ³ /s	Full Velocity, ft/s	Full Flow Capacity, ft ³ /s	Full Velocity, ft/s	Full Flow Capacity, ft ³ /s	Full Velocity, ft/s	Full Flow Capacity, ft ³ /s	Full Velocity, ft/s	Full Flow Capacity, ft ³ /s	Full Velocity, ft/s	Full Flow Capacity, ft ³ /s	Full Velocity, ft/s	Full Flow Capacity, ft ³ /s
0.001	2.7	4.6	3.0	7.0	3.3	9.8	3.5	13.3	3.8	19.1	4.3	30.8	4.8	45.9
0.002	3.8	6.5	4.2	9.9	4.6	13.9	5.0	18.8	5.4	27.0	6.1	43.6	6.8	65.0
0.003	4.7	7.9	5.2	12.2	5.6	17.0	6.1	23.0	6.7	33.0	7.5	53.3	8.3	79.6
0.004	5.4	9.1	6.0	14.1	6.5	19.6	7.0	26.6	7.7	38.1	8.7	61.6	9.6	91.9
0.005	6.0	10.2	6.7	15.7	7.3	21.9	7.9	29.8	8.6	42.6	9.7	68.9	10.7	102.7
0.006	6.6	11.2	7.3	17.2	8.0	24.0	8.6	32.6	9.4	46.7	10.6	75.4	11.7	112.5
0.007	7.1	12.1	7.9	18.6	8.6	25.9	9.3	35.2	10.2	50.5	11.5	81.5	12.7	121.5
0.008	7.6	12.9	8.5	19.9	9.2	27.7	9.9	37.6	10.9	53.9	12.2	87.1	13.5	129.9
0.009	8.1	13.7	9.0	21.1	9.8	29.4	10.5	39.9	11.5	57.2	13.0	92.4	14.4	137.8
0.010	8.5	14.4	9.5	22.2	10.3	31.0	11.1	42.1	12.1	60.3	13.7	97.4	15.1	145.3
0.020	12.0	20.4	13.4	31.4	14.5	43.8	15.7	59.5	17.2	85.3	19.4	137.7	21.4	205.4
0.030	14.7	25.0	16.4	38.5	17.8	53.7	19.2	72.9	21.0	104.5	23.7	168.7	26.2	251.6
0.040	17.0	28.9	18.9	44.5	20.6	62.0	22.2	84.2	24.3	120.6	27.4	194.8	30.3	290.5
0.050	19.0	32.3	21.2	49.7	23.0	69.3	24.8	94.1	27.2	134.9	30.6	217.8	33.8	324.8
0.060	20.8	35.4	23.2	54.4	25.2	75.9	27.2	103.1	29.8	147.7	33.5	238.6	37.1	355.8
0.070	22.5	38.2	25.0	58.8	27.2	82.0	29.4	111.3	32.1	159.6	36.2	257.7	40.0	384.3
0.080	24.0	40.8	26.8	62.9	29.1	87.6	31.4	119.0	34.4	170.6	38.7	275.5	42.8	410.8
0.090	25.5	43.3	28.4	66.7	30.9	92.9	33.3	126.2	36.4	180.9	41.1	292.2	45.4	435.8
0.100	26.9	45.7	29.9	70.3	32.5	98.0	35.1	133.1	38.4	190.7	43.3	308.0	47.9	459.3

Sewer Pipe Flows - Metric Measure

Slope (m/m)	100mm Ring-Tite & Enviro-Tite		150mm Ring-Tite & Enviro-Tite		200mm Ultra-Rib/Ring-Tite/Enviro-Tite		250 mm Ultra-Rib/Ring-Tite/Enviro-Tite		300mm Ultra-Rib/Ring-Tite/Enviro-Tite		375mm Ultra-Rib RingTite/Enviro-Tite	
	Full Velocity, m/s	Full Flow Capacity, L/s	Full Velocity, m/s	Full Flow Capacity, L/s	Full Velocity, m/s	Full Flow Capacity, L/s	Full Velocity, m/s	Full Flow Capacity, L/s	Full Velocity, m/s	Full Flow Capacity, L/s	Full Velocity, m/s	Full Flow Capacity, L/s
0.001	0.3	2	0.4	7	0.5	15	0.6	27	0.6	44	0.7	75
0.002	0.4	3	0.6	10	0.7	21	0.8	39	0.9	62	1.0	106
0.003	0.5	4	0.7	12	0.8	26	1.0	48	1.1	76	1.2	130
0.004	0.6	5	0.8	14	1.0	30	1.1	55	1.2	88	1.4	150
0.005	0.7	5	0.9	16	1.1	33	1.2	61	1.4	98	1.6	168
0.006	0.7	6	1.0	17	1.2	37	1.4	67	1.5	107	1.7	184
0.007	0.8	6	1.0	18	1.3	40	1.5	73	1.6	116	1.9	199
0.008	0.8	7	1.1	20	1.3	42	1.6	78	1.8	124	2.0	212
0.009	0.9	7	1.2	21	1.4	45	1.7	82	1.9	131	2.1	225
0.010	0.9	7	1.2	22	1.5	47	1.8	87	2.0	138	2.3	237
0.020	1.3	11	1.8	31	2.1	67	2.5	123	2.8	196	3.2	336
0.030	1.6	13	2.2	38	2.6	82	3.0	150	3.4	240	3.9	411
0.040	1.9	15	2.5	44	3.0	95	3.5	174	3.9	277	4.5	475
0.050	2.1	17	2.8	49	3.4	106	3.9	194	4.4	310	5.0	531
0.060	2.3	18	3.0	54	3.7	116	4.3	213	4.8	339	5.5	581
0.070	2.5	20	3.3	58	4.0	125	4.6	230	5.2	366	6.0	628
0.080	2.7	21	3.5	62	4.3	134	5.0	246	5.6	392	6.4	671
0.090	2.8	22	3.7	66	4.5	142	5.3	260	5.9	415	6.8	712
0.100	3.0	24	3.9	70	4.8	150	5.5	275	6.2	438	7.1	751

Slope (m/m)	450mm Ultra-Rib & Ring-Tite		525mm Ultra-Rib & Ring-Tite		600mm Ultra-Rib & Ring-Tite		675mm Ring-Tite		750mm Ring-Tite/ Ultra-X2		900mm Ring-Tite/ Ultra-X2		1050mm Ring-Tite	
	Full Velocity, m/s	Full Flow Capacity, L/s	Full Velocity, m/s	Full Flow Capacity, L/s	Full Velocity, m/s	Full Flow Capacity, L/s	Full Velocity, m/s	Full Flow Capacity, L/s	Full Velocity, m/s	Full Flow Capacity, L/s	Full Velocity, m/s	Full Flow Capacity, L/s	Full Velocity, m/s	Full Flow Capacity, L/s
0.001	0.8	129	0.9	199	1.0	273	1.1	375	1.2	538	1.3	869	1.5	1299
0.002	1.2	182	1.3	282	1.4	386	1.5	530	1.7	761	1.9	1229	2.1	1837
0.003	1.4	23	1.6	345	1.7	473	1.8	649	2.0	932	2.3	1506	2.5	2249
0.004	1.6	257	1.8	399	2.0	546	2.1	750	2.3	1076	2.6	1738	2.9	2597
0.005	1.8	288	2.0	446	2.2	611	2.4	838	2.6	1203	2.9	1944	3.3	2904
0.006	2.0	315	2.2	489	2.4	669	2.6	918	2.9	1318	3.2	2129	3.6	3181
0.007	2.2	340	2.4	528	2.6	722	2.8	992	3.1	1423	3.5	2300	3.8	3436
0.008	2.3	364	2.6	564	2.8	772	3.0	1060	3.3	1522	3.7	2459	4.1	3673
0.009	2.4	386	2.7	598	3.0	819	3.2	1125	3.5	1614	3.9	2608	4.4	3896
0.010	2.6	407	2.9	631	3.1	863	3.4	1186	3.7	1701	4.2	2749	4.6	4107
0.020	3.7	576	4.1	892	4.4	1221	4.8	1677	5.2	2406	5.9	3887	6.5	5808
0.030	4.5	705	5.0	1092	5.4	1496	5.8	2054	6.4	2947	7.2	4761	8.0	7113
0.040	5.2	814	5.8	1261	6.2	1727	6.7	2371	7.4	3402	8.3	5497	9.2	8213
0.050	5.8	910	6.4	1410	7.0	1931	7.5	2651	8.3	3804	9.3	6146	10.3	9183
0.060	6.3	997	7.1	1545	7.6	2115	8.3	2904	9.0	4167	10.2	6733	11.3	10059
0.070	6.8	1077	7.6	1669	8.2	2284	8.9	3137	9.8	4501	11.0	7272	12.2	10865
0.080	7.3	1151	8.1	1784	8.8	2442	9.5	3353	10.4	4812	11.8	7774	13.0	11616
0.090	7.7	1221	8.6	1892	9.3	2590	10.1	3557	11.1	5104	12.5	8246	13.8	12320
0.100	8.2	1287	9.1	1994	9.9	2730	10.7	3749	11.7	5380	13.2	8692	14.6	12987

APPENDICES

APPENDIX C: REFERENCE TABLES AND CONVERSION CHARTS

Table C-1	Weights of Water
Table C-2	Decimal & Millimeter Equivalents of Fractions
Table C-3	Volume Conversion
Table C-4	Pressure Conversion
Table C-5	Flow Conversion
Table C-6	Temperature Conversion
Table C-7	Length Conversion

TABLE C-1 WEIGHTS OF WATER

Units of Volume	Weight	
	pounds	kilograms
1 US Gallon	8.350	3.791
1 Imperial Gallon	10.020	4.549
1 litre	2.210	1.003
1 cubic yard	1,685.610	765.267
1 cubic foot	62.430	28.343
1 cubic inch	0.036	0.016
1 cubic cm	0.002	0.001
1 cubic metre	2,210.000	1,000.000

TABLE C-2 DECIMAL & MILLIMETER EQUIVALENTS OF FRACTIONS

Inches		Millimeters	Inches		Millimeters
Fractions	Decimals		Fractions	Decimals	
1/64	0.015625	0.397	33/64	0.515625	13.097
1/32	0.03125	0.794	17/32	0.53125	13.494
3/64	0.046875	1.191	35/64	0.546875	13.891
1/16	0.0625	1.588	9/16	0.5625	14.288
5/64	0.078125	1.984	37/64	0.578125	14.684
3/32	0.09375	2.381	19/32	0.59375	15.081
7/64	0.109375	2.778	39/64	0.609375	15.478
1/8	0.125	3.175	5/8	0.625	15.875
9/64	0.140625	3.572	41/64	0.640625	16.272
5/32	0.15625	3.969	21/32	0.65625	16.669
11/64	0.171875	4.366	43/64	0.671875	17.066
3/16	0.1875	4.763	11/16	0.6875	17.463
13/64	0.203125	5.159	45/64	0.703125	17.859
7/32	0.21875	5.556	23/32	0.71875	18.256
15/64	0.234375	5.953	47/64	0.734375	18.653
1/4	0.250	6.350	3/4	0.750	19.050
17/64	0.265625	6.747	49/64	0.765625	19.447
9/32	0.28125	7.144	25/32	0.78125	19.844
19/64	0.296875	7.541	51/64	0.796875	20.241
5/16	0.3125	7.938	13/16	0.8125	20.638
21/64	0.328125	8.334	53/64	0.828125	21.034
11/32	0.34375	8.731	27/32	0.83475	21.431
23/64	0.359375	9.128	55/64	0.859375	21.828
3/8	0.375	9.525	7/8	0.875	22.225
25/64	0.390625	9.922	57/64	0.890625	22.622
13/32	0.40625	10.319	29/32	0.90625	23.019
27/64	0.421875	10.716	59/64	0.921875	23.416
7/16	0.4375	11.113	15/16	0.9375	23.813
29/64	0.453125	11.509	61/64	0.953125	24.209
15/32	0.46875	11.906	31/32	0.96875	24.606
31/64	0.484375	12.303	63/64	0.984375	25.003
1/2	0.500	12.700	1	1.000	25.400

APPENDICES

TABLE C-3 VOLUME CONVERSION

Units of Volume	Multiply units in left column by proper factor below							
	in. ³	ft. ³	yd. ³	cm. ³	meter ³	liter	U.S. gal.	Imp. gal.
1 inch ³	1	-	-	16.387	-	0.0164	-	-
1 foot ³	1728	1	0.0370	28,317	0.0283	28.32	7.481	6.229
1 yard ³	46,656	27	1	-	0.7646	764.5	202.0	168.2
1 centimeter ³	0.0610	-	-	1	-	0.0010	-	-
1 meter ³	61,023	35.31	1.308	1,000,000	1	999.97	264.2	220.0
1 liter	61.025	0.0353	-	1000.028	0.0010	1	0.2642	0.2200
1 U.S. gallon	231	0.1337	-	3785.4	-	3.785	1	0.8327
1 Imp. gallon	277.4	0.1605	-	4546.1	-	4.546	1.201	1

TABLE C-4 PRESSURE CONVERSION

Units of Pressure	atm	bar	lb/in ²	lb/ft ²	kg/cm ²	kg/m ²	inch H ₂ O	inch Hg	inch air	ft H ₂ O	ft air	mm Hg	mm H ₂ O	kilopascal	N/m ²
atmosphere (atm)	1	0.987	0.068	-	0.968	-	0.002	0.033	-	0.029	-	0.001	-	0.01	-
bar	1.013	1	0.069	-	0.981	-	0.002	0.034	-	0.03	-	0.001	-	0.01	-
pound per square inch (psi)	14.7	14.5	1	0.007	14.22	0.001	0.036	0.491	-	0.434	0.001	0.019	0.001	0.145	-
pound per square foot (psf)	2,116	2,089	144	1	2,048	0.205	5.2	70.73	0.006	62.43	0.076	2.784	0.205	20.89	0.021
kilogram per square centimeter	1.033	1.02	0.07	-	1	0.0001	0.003	0.035	-	0.03	-	0.001	-	0.01	-
kilogram per square meter	10,332	10,197	703	4.88	10,000	1	25.4	345.3	0.031	304.8	0.373	13.6	1	101.97	0.102
inch of water (H ₂ O) (4°C)	406.78	401.46	27.68	0.192	393.7	0.039	1	13.6	0.001	12	0.015	0.535	0.039	4.015	0.004
inch of mercury (Hg) (0°C)	29,921	29,53	2,036	0.014	28,96	0.003	0.074	1	-	0.883	0.001	0.039	0.003	0.295	-
inch of air (15°C)	332,005	327,664	22,592	148.7	321,328	32.13	816.2	11,096	1	9,794	12	436.8	32.13	3,277	3,106
foot of water (4°C)	33.9	33.46	2.307	0.016	32.81	0.003	0.083	1.133	-	1	-	0.045	0.003	0.335	-
foot of air (15°C)	27,677	27,305	1,883	13.07	26,777	2.678	0.006	924.7	0.083	816.2	1	36.4	2.678	273.1	0.273
millimeter of mercury (0°C)	760	750	51.71	0.36	735.6	0.074	1.868	25.4	0.002	22.42	0.027	1	0.074	7.5	0.008
millimeter of water (4°C)	10,332	10,197	703	4.88	10,000	1	25.4	345.3	0.031	304.8	0.373	13.6	1	101.97	0.102
kilopascal (kP)	101.3	100	6.89	0.048	98.07	0.01	0.249	3.386	-	2.99	0.004	0.133	0.01	1	0.001
Newton per square meter	-	-	-	0.021	-	0.102	0.004	-	3.277	-	0.273	0.008	0.102	0.001	1

TABLE C-5 FLOW CONVERSION

Units of Flow Rate	US gps	US gpm	US gph	US gpd	Imp gps	Imp gpm	Imp gph	Imp gpd	liters/sec	liters/min	liters/hr	liters/day
US gal/sec (gps)	1	0.017	-	-	1.2	0.02	-	-	0.264	0.004	-	-
US gal/min (gpm)	60	1	0.017	0.001	72.06	1.2	0.02	0.001	15.85	0.264	0.004	-
US gal/hr (gph)	3,600	60	1	0.042	4,323	72.06	1.2	0.05	951.02	15.85	0.264	0.011
US gal/day (gpd)	86,400	1,440	24	1	103,762	1,729.40	28.82	1.2	22,824	380.41	6.34	0.264
Imperial gal/sec	0.833	0.014	-	-	1	0.017	-	-	0.22	0.004	-	-
Imperial gal/min	49.96	0.833	0.014	0.001	60	1	0.017	0.001	13.2	0.22	0.004	-
Imperial gal/hr	2,997.60	49.96	0.833	0.035	3,600	60	1	0.042	791.89	13.2	0.22	0.009
Imperial gal/day	71,943	1,199	19.98	0.833	86,400	1,440	24	1	19,005	316.76	5.279	0.22
Liters/sec	3.79	0.063	0.002	-	4.55	0.076	0.001	-	1	0.017	-	-
Liters/min	227.12	3.785	0.063	0.003	272.77	4.55	0.076	0.003	60	1	0.017	0.001
Liters/hr	13,627	227.12	3.785	0.158	16,366	272.77	4.55	0.189	3,600	60	1	0.042
Liters/day	327,060	5,451	90.85	3.785	392,782	6,546	109.11	4.55	86,400	1,440	24	1
Cubic ft/sec (cfs)	0.134	0.002	-	-	0.161	0.003	-	-	0.035	0.001	-	-
Cubic ft/min (cfm)	8.02	0.134	0.002	-	9.633	0.161	0.003	-	2.119	0.035	0.001	-
Cubic ft/hr (cfh)	481.25	8.02	0.134	0.006	577.96	9.63	0.161	0.007	127.13	2.119	0.035	0.001
Cubic ft/day (cfd)	11,550	192.5	3.21	0.134	13,871	231.18	3.853	0.161	3,051.20	50.85	0.848	0.001
Acre in/min	0.002	-	-	-	0.003	-	-	-	0.001	-	-	-
Acre in/hr	0.133	0.002	-	-	0.159	0.003	-	-	0.035	-	-	-
Acre in/day	3.182	0.053	0.001	-	3.821	0.064	0.001	-	0.841	0.001	-	-
Cubic m/sec	0.004	-	-	-	0.005	-	-	-	0.001	-	-	-
Cubic m/min	0.227	0.004	-	-	0.273	0.005	-	-	0.06	0.001	-	-
Cubic m/hr	13.628	0.227	0.004	-	16.366	0.273	0.005	-	3.6	0.06	0.001	-
Cubic m/day	327.06	5.451	0.091	0.004	392.78	6.546	0.109	0.005	86.4	1.44	0.024	0.001

Units of Flow Rate	ft ³ /sec	ft ³ /min	ft ³ /hr	ft ³ /day	Acre in/min	Acre in/hr	Acre in/day	m ³ /sec	m ³ /min	m ³ /hr	m ³ /day
US gal/sec (gps)	7.48	0.125	0.002	-	452.6	7.54	0.31	264.2	4.4	0.073	0.003
US gal/min (gpm)	448.8	7.48	0.125	0.005	27,154	452.6	18.86	15,850	264.2	4.403	0.183
US gal/hr (gph)	26,930	448.83	7.481	0.312	1.629E+06	27,154	1,131	951,019	15,850	264.17	11.007
US gal/day (gpd)	646,317	10,772	179.53	7.481	3.910E+07	651,703	27,154	2.282E+07	380,408	6,340	264.17
Imperial gal/sec	6.229	0.104	0.002	-	376.8	6.28	0.26	220	3.67	0.061	0.003
Imperial gal/min	373.73	6.229	0.104	0.004	22,611	376.8	15.7	13,198	220	3.666	0.153
Imperial gal/hr	22,424	373.73	6.229	0.259	1.357E+06	22,611	942.1	791,889	13,198	220	9.165
Imperial gal/day	538,171	8,970	149.49	6.229	3.256E+07	542,656	22,611	1.901E+07	316,756	5,279	220
Liters/sec	28.32	0.472	0.008	-	1,713	28.6	1.19	1,000	16.67	0.278	0.012
Liters/min	1,699	28.32	0.472	0.2	102,790	1,713	71.38	60,000	1,000	16.67	0.694
Liters/hr	101,941	1,669	28.32	1.18	6.167E+06	102,790	4,283	3.600E+06	60,000	1,000	42.67
Liters/day	2,446,575	40,776	679.6	28.32	1.480E+08	2.467E+06	102,790	8.640E+07	1.440E+06	24,000	1,000
Cubic ft/sec (cfs)	1	0.017	-	-	60.5	1.008	0.042	35.31	0.589	0.01	-
Cubic ft/min (cfm)	60	1	0.017	-	3,630	60.5	2.52	2,119	35.31	0.59	0.025
Cubic ft/hr (cfh)	3,600	60	1	0.042	217,800	3,630	151.25	127,133	2,119	35.31	1.471
Cubic ft/day (cfd)	86,400	1,440	24	1	5.227E+06	87,120	3,630	3,051,187	50,853	847.55	35.31
Acre in/min	0.017	-	-	-	1	0.017	0.001	0.584	0.01	-	-
Acre in/hr	0.992	0.001	-	-	60	1	0.042	35.02	0.584	0.01	-
Acre in/day	23.8	0.033	0.006	-	1,440	24	1	840.55	14.001	0.233	0.001
Cubic m/sec	0.028	-	-	-	1.71	0.029	0.001	1	0.017	-	-
Cubic m/min	1.7	0.028	-	-	102.8	1.71	0.071	60	1	0.017	0.001
Cubic m/hr	101.94	1.7	0.028	0.001	6,167	102.8	4.283	3,600	60	1	0.042
Cubic m/day	2446.6	40.78	0.68	0.028	148,018	2,467	102.79	86,400	1,400	24	1

APPENDICES

TABLE C-6 TEMPERATURE CONVERSION

°F	°C	°F	°C	°F	°C	°F	°C	°F	°C
-60	-51	22	-5.6	50	10.0	78	25.6	160	71
-50	-46	23	-5.0	51	10.6	79	26.1	170	77
-40	-40	24	-4.4	52	11.1	80	26.7	180	82
-30	-34	25	-3.9	53	11.7	81	27.2	190	88
-20	-29	26	-3.3	54	12.2	82	27.8	200	92
-10	-23.0	27	-2.8	55	12.8	83	28.3	210	99
0	-17.8	28	-2.2	56	13.3	84	28.9	212	100
1	-17.2	29	-1.7	57	13.9	85	29.4	220	104
2	-16.7	30	-1.1	58	14.4	86	30.0	230	110
3	-16.1	31	-0.6	59	15.0	87	30.6	240	116
4	-15.6	32	0.0	60	15.6	88	31.1	250	121
5	-15.0	33	0.6	61	16.1	89	31.7	260	127
6	-14.4	34	1.1	62	16.7	90	32.2	270	132
7	-13.9	35	1.7	63	17.2	91	32.8	280	138
8	-13.3	36	2.2	64	17.8	92	33.3	290	143
9	-12.8	37	2.8	65	18.3	93	33.9	300	149
10	-12.2	38	3.3	66	18.9	94	34.4	310	154
11	-11.7	39	3.9	67	19.4	95	35.0	320	160
12	-11.1	40	4.4	68	20.0	96	35.6	330	166
13	-10.6	41	5.0	69	20.6	97	36.1	340	171
14	-10.0	42	5.6	70	21.1	98	36.7	350	177
15	-9.4	43	6.1	71	21.7	99	37.2	360	182
16	-8.9	44	6.7	72	22.2	100	37.8	370	188
17	-8.3	45	7.2	73	22.8	110	43	380	193
18	-7.8	46	7.8	74	23.3	120	49	390	199
19	-7.2	47	8.3	75	23.9	130	54	400	204
20	-6.7	48	8.9	76	24.4	140	60		
21	-6.1	49	9.4	77	25.0	150	66		

Degrees Celsius $^{\circ}\text{C} = \frac{5}{9} (^{\circ}\text{F} - 32)$

Degrees Fahrenheit $^{\circ}\text{F} = \frac{9}{5} ^{\circ}\text{C} + 32$

Degrees Kelvin $^{\circ}\text{T} = ^{\circ}\text{C} + 273.2$

Degrees Rankine $^{\circ}\text{R} = ^{\circ}\text{F} + 459.7$

TABLE C-7 LENGTH CONVERSION

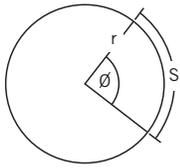
Units of Length	Multiply units in left column by proper factor below							
	in.	ft.	yd.	mile	mm	cm	m	km
1 inch	1	0.0833	0.0278	-	25.4	2.540	0.0254	-
1 foot	12	1	0.3333	-	304.8	30.48	0.3048	-
1 yard	36	3	1	-	914.4	91.44	0.9144	-
1 mile	-	5280	1760	1	-	-	1609.3	1.609
1 millimeter	0.0394	0.0033	-	-	1	0.100	0.001	-
1 centimeter	0.3937	0.0328	0.0109	-	10	1	0.01	-
1 meter	39.37	3.281	1.094	-	1000	100	1	0.001
1 kilometer	-	3281	1094	0.6214	-	-	1000	1

(1 micron = 0.001 millimeter)

APPENDIX D: USEFUL FORMULAS

- Area of a Circle
- Circumference of a Circle
- Length of Circular Arc
- Area of Circle Sector
- Equation of a Circle (cartesian coordinates)
- Equation of a Line (quadratic formula)
- Basic Trigonometric Functions
- Area of an Ellipse
- Circumference of an Ellipse
- Area of a Triangle
- Area of a Trapezoid
- Area of a Parallelogram
- Surface Area of a Sphere
- Volume of a Sphere
- Surface Area of a Cylinder
- Volume of a Cylinder
- Surface Area of an Elliptical Tank
- Volume of an Elliptical Tank
- Surface Area of a Cone
- Volume of a Cone
- Surface Area of a Rectangular Solid
- Volume of a Rectangular Solid

APPENDIX D: USEFUL FORMULAS



Circle

Diameter = $\frac{D}{2}$

Circumference = $\pi D = 2\pi R$

Area = πR^2

Length of Circular Arc

$S = \theta \times \left(\frac{\pi}{180}\right) \times r$ θ in degrees

$S = \theta \times r$ θ in radians

Area of Circle Sector

$A = \theta \times \left(\frac{\theta}{360}\right) \times \pi \times r^2$ θ in degrees

$A = \theta \times \left(\frac{\theta}{2}\right) \times r^2$ θ in radians

Equation of a Circle (cartesian co-ordinates)

- for a circle with center (j, k) and radius (r)

$(x - j)^2 + (y - k)^2 = r^2$

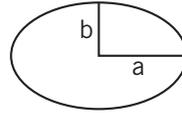
Equation of a line (quadratic formula)

$ax + by + c = 0$

or

$ax^2 + bx + c = 0$

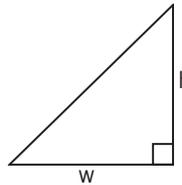
$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$



Ellipse

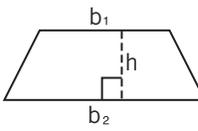
Area = $\pi \times a \times b$

Circumference = $\frac{1 + 4(a-b)^2}{((3a + 5b)(5a + 3b))}$



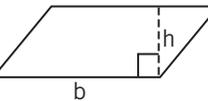
Triangle

Area = $\frac{w \times h}{2}$



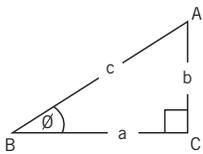
Trapezoid

Area = $\frac{1}{2} (b_1 + b_2) \times h$



Parallelogram

Area = $b \times h$



Trigonometry

$\sin \theta = \frac{b}{c}$

$\cos \theta = \frac{a}{c}$

$\tan \theta = \frac{b}{a}$

Sine Law

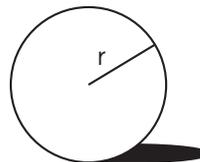
$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C} = 2R$

Cosine Law

$C^2 = a^2 + b^2 - 2ab \cos C$

$b^2 = a^2 + c^2 - 2ac \cos B$

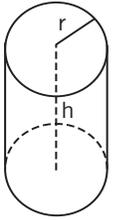
$a^2 = b^2 + c^2 - 2bc \cos A$



Sphere

Surface Area = $4 \pi r^2$

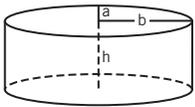
Volume = $\frac{4}{3} \pi r^3$



Cylinder

Surface Area = $(2 \pi r^2) + (2 \pi r h)$

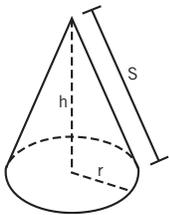
Volume = $\pi r^2 h$



Elliptical Tank

Surface Area = $2 \pi \left(\frac{\sqrt{a^2 + b^2}}{2} \right) h + (2\pi ab)$

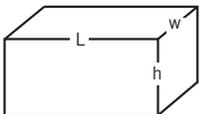
Volume = πabh



Cone

Surface Area = $\pi r S$

Volume = $\pi r^2 \times \frac{h}{3}$



Rectangular Solid

Surface Area = $2 (Lw + Lh + wh)$

Volume = $L \times w \times h$

APPENDIX E: ABBREVIATIONS

AGA	- American Gas Association
ANSI	- American National Standards Institute
API	- American Petroleum Institute
ASME	- American Society of Mechanical Engineers
ASTM	- American Society for Testing and Materials
AWWA	- American Water Works Association
BNQ	- Bureau de Normalization du Quebec
BOCA	- Building Officials and Code Administrators
BS	- British Standards Institution
CPVC	- Chlorinated poly (vinyl chloride) plastic or resin
CS	- Commercial Standard, see Product Standard
CSA	- Canadian Standards Association
DR	- Dimension Ratio
DIN	- German Industrial Norms
FHA	- Federal Housing Administration or Farmers Home Administration
HDB	- Hydrostatic design basis
HDS	- Hydrostatic design stress
IAPD	- International Association of Plastics Distributors
IAPMO	- International Association of Plumbing and Mechanical Officials
IPC	- International Plumbing Code
ISO	- International Standards Organization
JIS	- Japanese Industrial Standards
NSF	- National Sanitation Foundation International
PPI	- Plastics Pipe Institute
PS	- Product Standard when in reference to a specification for plastic pipe and fittings. These specifications are promulgated by the U.S. Department of Commerce and were formerly known as Commercial Standards.
PSI	- Pounds per square inch
PSIG	- Gage pressure in pounds per square inch
PVC	- Poly (vinyl chloride) plastic or resin
RVCM	- Residual Vinyl Chloride Monomer
SCS	- Soil Conservation Service
SDR	- Standard Dimension Ratio
SI	- International System of Units
SPI	- Society of the Plastics Industry, Inc.
UPC	- Uniform Plumbing Code
USASI	- United States of America Standards Institute (formerly American Standards Association)
WOG	- Water, Oil, Gas

SALES AND CUSTOMER SERVICE

Canadian Customers call IPEX Inc.

Toll free: (866) 473-9462

www.ipexinc.com

U.S. Customers call IPEX USA LLC

Toll free: (800) 463-9572

www.ipexamerica.com

About the IPEX Group of Companies

As leading suppliers of thermoplastic piping systems, the IPEX Group of Companies provides our customers with some of the largest and most comprehensive product lines. All IPEX products are backed by more than 50 years of experience. With state-of-the-art manufacturing facilities and distribution centers across North America, we have established a reputation for product innovation, quality, end-user focus and performance.

Markets served by IPEX group products are:

- Electrical systems
- Telecommunications and utility piping systems
- PVC, CPVC, PP, ABS, PEX, FR-PVDF and PE pipe and fittings (1/4" to 48")
- Industrial process piping systems
- Municipal pressure and gravity piping systems
- Plumbing and mechanical piping systems
- PE Electrofusion systems for gas and water
- Industrial, plumbing and electrical cements
- Irrigation systems

Products manufactured by IPEX Inc. and distributed in the United States by IPEX USA LLC.

Ring-Tite®, Enviro-Tite®, Ultra-Rib®, Ultra-X2™, Perma-Loc™, Vortex Flow™ and Lifesaver™ are trademarks of IPEX Branding Inc.

This literature is published in good faith and is believed to be reliable. However it does not represent and/or warrant in any manner the information and suggestions contained in this brochure. Data presented is the result of laboratory tests and field experience.

A policy of ongoing product improvement is maintained. This may result in modifications of features and/or specifications without notice.

