Municipal Water and Sewer Pipe

Technical Manual

Contents

1.0 Introduction

This technical manual is intended to be a collection of information for designers and installers using REHAU PVC municipal piping systems. It is not intended to be a complete treatment of PVC piping systems.

It is the responsibility of the designer to check local specification requirements and to verify that any information provided here is appropriate for the application.

Fig. 1.1:
Installing AQUALOC pressure pipe

Fig. 1.2:
DURALOC sewer pipe lateral installation

Fig. 1.3:
Installing RAURIB sewer pipe

Fig. 1.4:
MUNICIPEX service installation

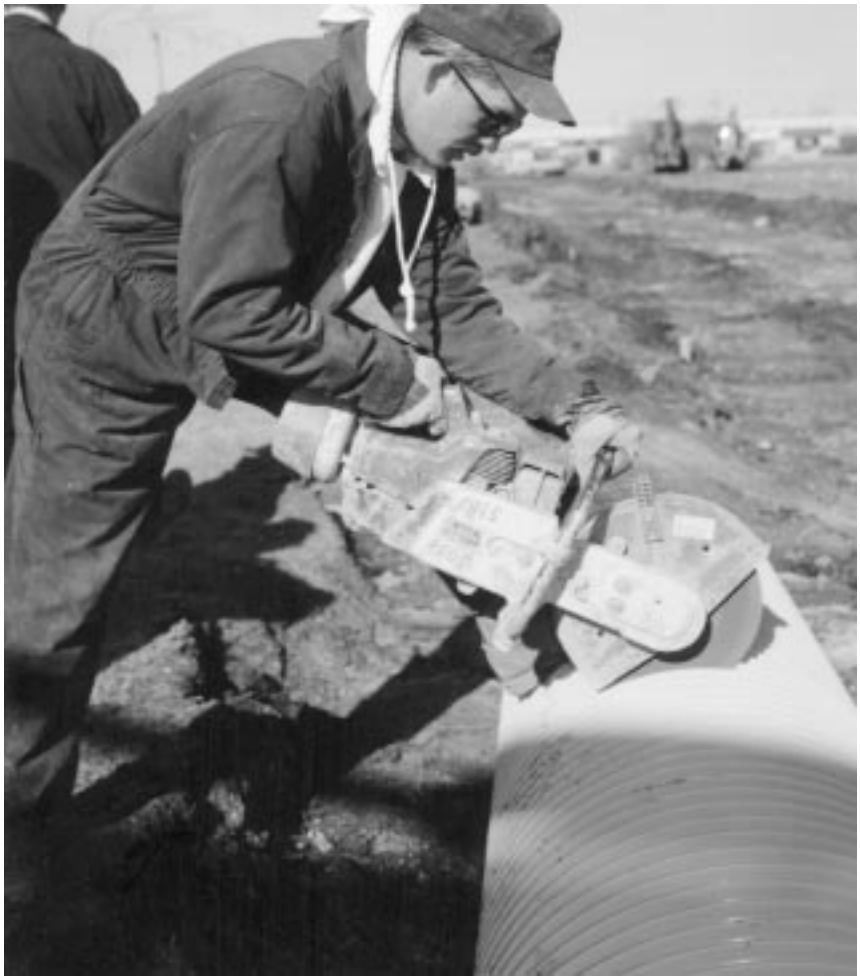

Fig. 1.5:
Installation is made even easier by the ability to cut RAURIB in the field.

Fig 1.6:
Lightweight and durable, DURALOC can be easily stored on the job site.

2.0 AQUALOC PVC Pressure Pipe

2.1 Product Characteristics

REHAU AQUALOC pressure pipe is available in both CIOD and IPS diameters for a complete range of applications in municipal, irrigation and industrial water supply.

2.1.1 Product

AQUALOC PVC pressure pipe is manufactured by REHAU. The AQUALOC product line includes:

Series 200	SDR 21
Series 160	SDR 26
Series 125	SDR 32.5
Series 100	SDR 41
Pressure Class 150	DR 18
Pressure Class 100	DR 25

2.1.2 Joint Options

This design features an integrated (locked-in) system where the seal and mandrel act together as a tool to shape the pipe socket during pipe manufacturing. The seal is firmly locked in the correct position by the cooling and shrinking of the pipe socket.

The seal is used to form its own groove in the socket. The reinforcing element prevents the seal from moving and holds the gasket in its groove to prevent movement during installation thus providing a longer, more dependable service life.

Solvent Cement Joints
This leak-free joint is easily created using solvent cement, which chemically bonds the bell and spigot ends. The solvent dissolves or softens the thermoplastic material and the cement bonds the two pieces into one assembly. The I.D. is tapered to provide a tight fit with the spigot end.

Fig. 2.1:
AQUALOC pressure pipe on the job site

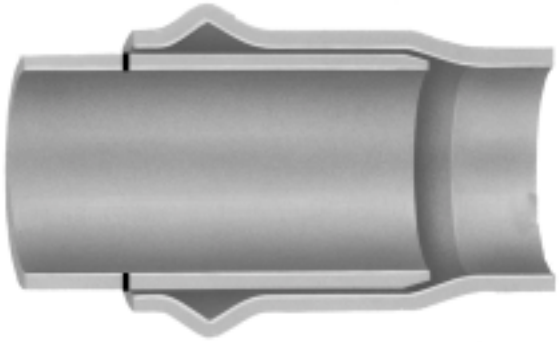

Illustration not to scale.

Fig. 2.2:
AQUALOC joint showing proper insertion point

2.1.3 Standards

All AQUALOC DR 18, DR 25, SDR 21, SDR 26, SDR 32.5, and SDR 41 meets or exceeds:

ASTM D 2241
: Standard Specification for PVC Pressure Pipes SDR Series

ASTM D 3139
: Joints for Plastic Pressure Pipes Using Flexible Elastomeric Seals

BNQ 3660-950
: Innocuits de material plastique et des enduits en contact avec l'eau potable

CSA B 137.3
: Rigid PVC Pipe for Pressure Applications

UNI-B-1
: Recommended Specification for Thermoplastic Pipe Joints, Pressure and Non-Pressure Applications.

BNQ 3624-250
: Tuyaux rigides en PVC pour la conduite et distribution de l'eau sous pression

In addition, AQUALOC DR 18 and DR 25 watermain pipe meets or exceeds:

AWWA C900
: PVC Pressure Pipe and Fabricated Fittings 4"-12" for Water Distribution

AWWA C905
: PVC Pressure Pipe and Fabricated Fittings 14"-48" for Water Transmission and Distribution

NSF Standard 61
: Plastic Pipe Components and Related Materials

FM Approval Standard Class No. 1610
: Underground Fire Protection

Underwriters Laboratories of Canada
: ULC Listed

AQUALOC Recommended Installation Standards and References:

ASTM D 2774
: Underground Installation of Thermoplastic Pressure Piping

AWWA C605
: Underground Installation of PVC Pressure Pipe for Water

UNI-B-3
: Recommended Practice for the Installation of PVC Pressure Pipe

UNI-B-8
: Recommended Practice for the Direct Tapping PVC Pressure Water Pipe

UNI-B-13
: Recommended Standard Performance Specification for Joint Restraint Devices for Use with PVC Pipe

REHAU Municipal PVC Pipe Installation Guide

AQUALOC Tapping Guide

2.1.4 Short Form Specifications and Dimensional Data

Short Form Specifications for Series Pipes 21, 26, 32.5 and 41

AQUALOC Series 200, 160, 125 or 100 pipes shall conform to ASTM Standard D 2241 for series PVC pressure pipe and be certified to meet or exceed CSA Standards B 137.3 and B 137.0, and shall be NSF 61 Certified. All pipe shall be made from virgin resin conforming to ASTM D 1784.

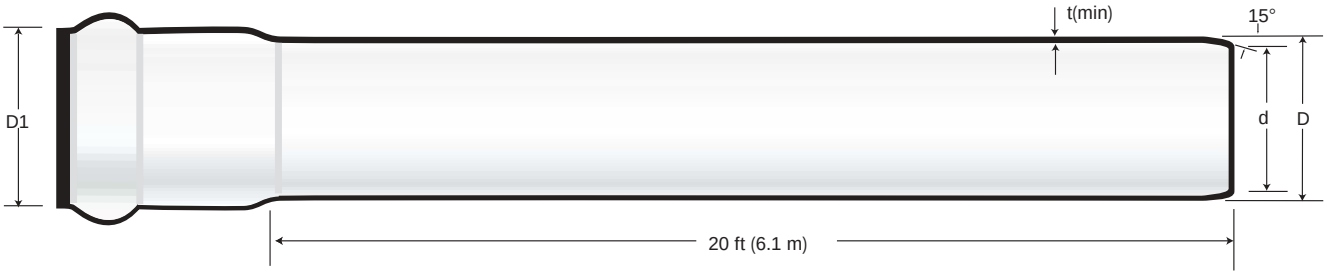

Fig. 2.3:
AQUALOC Series gasketed bell pipe dimensions

Size		D		d		D1		t(min)	
in	mm	in	mm	in	mm	in	mm	in	mm
1 1/2	40	1.90	48.30	1.71	43.42	2.25	57.15	0.090	2.28
2	50	2.38	60.40	2.14	54.29	3.00	76.20	0.113	2.86
2 1/2	65	2.87	73.00	2.58	65.62	3.50	88.90	0.137	3.48
3	75	3.50	88.90	3.15	79.91	4.50	114.30	0.167	4.24
4	100	4.50	114.30	4.05	102.77	5.50	139.70	0.214	5.44
6	150	6.63	168.30	5.96	151.30	8.00	203.20	0.316	8.02
8	200	8.62	219.10	7.76	197.00	10.25	260.35	0.409	10.40
10	250	10.75	273.10	9.67	245.49	13.25	336.55	0.512	13.00
12	300	12.75	323.90	11.47	291.25	15.50	393.70	0.606	15.40

Table 2.1:
Series 200 (SDR 21) - White

Size		D		d		D1		t(min)	
in	mm	in	mm	in	mm	in	mm	in	mm
1 1/2	40	1.90	48.30	1.73	43.97	2.25	57.15	0.080	2.02
2	50	2.38	60.40	2.18	55.47	3.00	76.20	0.091	2.30
2 1/2	65	2.87	73.00	2.64	67.11	3.50	88.90	0.109	2.78
3	75	3.50	88.90	3.22	81.65	4.50	114.30	0.135	3.42
4	100	4.50	114.30	4.13	105.01	5.50	139.70	0.172	4.38
6	150	6.63	168.30	6.09	154.56	8.00	203.20	0.255	6.48
8	200	8.62	219.10	7.92	201.20	10.25	260.35	0.331	8.42
10	250	10.75	273.10	9.87	250.79	13.00	330.20	0.413	10.50
12	300	12.75	323.90	11.72	297.61	15.25	387.35	0.488	12.40

Table 2.2:
Series 160 (SDR 26) - White

Size		D		d		D1		t(min)	
in	mm	in	mm	in	mm	in	mm	in	mm
3	75	3.50	88.90	3.27	83.09	4.25	107.95	0.108	2.74
4	100	4.50	114.30	4.21	106.88	5.00	139.70	0.138	3.50
6	150	6.63	168.30	6.19	157.32	8.00	203.20	0.204	5.18
8	200	8.62	219.10	8.06	204.80	10.00	254.00	0.265	6.72
10	250	10.75	273.10	10.05	255.24	12.75	232.85	0.331	8.40
12	300	12.75	323.90	11.92	302.78	15.00	381.00	0.392	9.96

Table 2.3:
Series 125 (SDR 32.5) - White

Size		D		d		D1		t(min)	
in	mm	in	mm	in	mm	in	mm	in	mm
4	100	4.50	114.30	4.28	108.41	4.75	120.65	0.109	2.78
6	150	6.63	168.30	6.28	159.57	7.75	196.85	0.162	4.12
8	200	8.62	219.10	8.18	207.77	10.00	254.00	0.209	5.32
10	250	10.75	273.10	10.19	258.93	12.50	317.50	0.262	6.66
12	300	12.75	323.90	12.09	307.15	14.75	374.65	0.311	7.90

Table 2.4:
Series 100 (SDR 41) - White

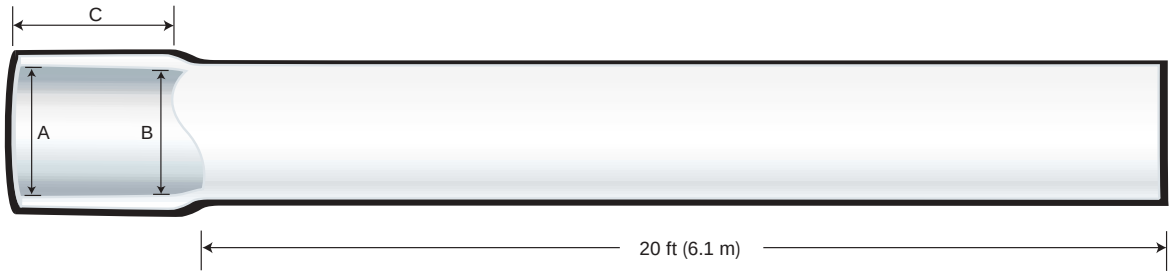

Illustration not to scale.

Fig. 2.4:
AQUALOC Series solvent bell pipe dimensions

Size		A		B		C	
in	**mm**	**in**	**mm**	**in**	**mm**	**in**	**mm**
1 1/2	40	1.91	48.56	1.89	48.11	2.00	50.80
2	50	2.39	60.63	2.36	60.02	2.25	57.15
2 1/2	65	2.89	73.38	2.86	72.67	2.50	63.50
3	75	3.52	89.31	3.48	88.49	3.25	82.55

Table 2.5:
Series 200 (SDR 21) and Series 160 (SDR 26) - White

Short Form Specifications for DR 18 or DR 25

AQUALOC Class 150 and Class 100 pipes shall conform to the AWWA C900 and C905 Standard for PVC pressure pipe and be certified to meet or exceed CSA Standards B 137.3 and B 137.0, BNQ Standards 3624-250 and 3660-950 and shall be NSF 61 Certified and ULC Listed. All pipe shall be made from virgin resin conforming to standard ASTM D 1784.

The standard dimensional ratio (SDR) for both barrel and bell dimensions is 21 for Series 200 pipe, 26 for Series 160 pipe, 32.5 for Series 125 pipe, and 41 for Series 100 pipe. The dimensional ratio (DR) is 18 for Class 150 pipe and 25 for Class 100 pipe.

Fittings used with REHAU pipe must have at least the same pressure rating as the PVC pipe. They may be of mechanical joint design (AWWA C111 and AWWA C110) or push-on design (AWWA C111) sized for PVC pipe. Wall thickness must be to AWWA C110 or C153 requirements.

Transition gaskets are required for connections between series pipe and cast or ductile iron mechanical joint (MJ) fittings.

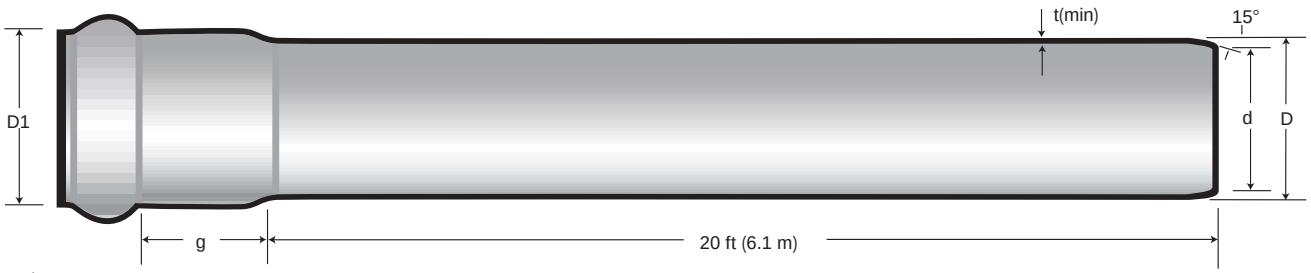

Fig. 2.5:
AQUALOC pipe dimensions

Illustration not to scale.

Size in	D		d		d1		t(min)		g		weight*	
	mm	in	mm	in	mm	in	mm	in	mm	in	kg/m	lb/ft
4	121.9	4.80	108.4	4.27	151.6	5.97	6.78	0.267	70.1	2.76	3.8	2.53
6	175.3	6.90	155.8	6.13	217.7	8.57	9.73	0.383	78.9	3.11	7.6	5.12
8	229.9	9.05	204.3	8.04	280.9	11.06	12.78	0.503	87.9	3.46	13.1	8.80
10	281.9	11.10	250.6	9.87	341.9	13.46	15.67	0.617	95.0	3.74	19.8	13.27
12	335.3	13.20	298.0	11.73	400.6	15.77	18.62	0.733	100.1	3.94	27.9	18.76
14	388.6	15.30	344.9	13.58	476.3	18.75	21.59	0.850	124.9	4.92	39.6	26.64

Table 2.6:
DR 18 - Class 150 C. I. Outside Diameter - Blue

Size in	D		d		d1		t(min)		g		weight*	
	mm	in	mm	in	mm	in	mm	in	mm	in	kg/m	lb/ft
4	121.9	4.80	112.2	4.42	151.6	5.97	4.88	0.192	70.1	2.76	2.8	1.86
6	175.3	6.90	161.2	6.35	217.7	8.57	7.01	0.276	79.0	3.11	5.6	3.74
8	229.9	9.05	211.5	8.33	280.9	11.06	9.19	0.362	87.9	3.46	9.6	6.47
10	281.9	11.10	259.3	10.21	341.9	13.46	11.30	0.445	95.0	3.74	14.5	9.72
12	335.3	13.20	308.5	12.14	400.6	15.77	13.41	0.528	100.1	3.94	20.4	13.93
14	388.6	15.30	357.1	14.06	463.6	18.25	15.60	0.614	125.0	4.92	29.0	19.50
16	441.9	17.40	404.6	15.93	527.1	20.75	17.70	0.697	150.1	5.91	35.6	23.28

Table 2.7:
DR 25 - Class 100 C. I. Outside Diameter - Blue

*Weights are approximate.

2.1.5 Handling, Storage and Installation

Store PVC pipe in delivery modules and keep clean until ready for use. Avoid excessive heat, cold and impact. For ordering information, refer to the most recent version of the REHAU PVC Pipe Module Loading Chart. For installation procedures, refer to the *REHAU Municipal PVC Pipe Installation Guide.*

PVC pipe must be handled, stored and installed in accordance with the current edition of the *REHAU Municipal PVC Pipe Installation Guide.*

Foundation, bedding and trench width must be such that the pipe can be installed and maintained under the load of backfill to the specified line and grade.

Fig. 2.6:
Storage of PVC pipe

The general rule is that the maximum trench width, from the bottom of the trench to 8 inches (200 mm) above the pipe, should not exceed the outside diameter of the pipe plus 2 feet. Sufficient room must be available to properly bed and haunch the pipe for support.

Trench bottoms must be dry, free of frost, large stones, or other hard objects and be graded to provide continuous support for the pipe. In areas where trench bottoms are unsuitable for direct support of pipe (due to large stones, rock, wet or stony soil), excavate trenches 4 to 6 inches (100 mm to 150 mm) below pipe. Place and compact a 4- to 6-inch (100 mm to 150 mm) bedding layer under the pipe. Grade to provide full support of the barrel and bell ends.

Dewater trenches to keep free of mud.

Lay pipe on a smooth, even bed providing full support for the barrel. Excavate and fill as required to equally support bell ends. Laying pipe on unstable soil, steep inclines, or in other adverse conditions should be under the direction of the engineer.

Clean bell and gasket and apply lubricant to spigot end before joining pipes. All joints must be inserted to the proper “stop” mark on the pipe. Protect pipe from damage if levers or equipment are used for joining the pipes.

Pipes must be in proper, straight alignment before joints are forced home. It is not recommended to deflect AQUALOC joints for the purpose of installation.

Keep interior of pipes and fittings clean at all times.

Bevel and remove burrs on ends of cut lengths. Make proper insertion stop mark before making joints.

Complete procedures for forming solvent cement joints can be found in the *REHAU Industrial Technical Manual.*

Provide thrust blocks at bends exceeding 10°, and at intersections, pipe size changes, and at all fittings. AQUALOC will accommodate the maximum expansion and contraction that can occur, with a considerable safety margin. Offset expansion joints in the lines are not required.

Make joints connecting cast iron fittings with series pipe by using transition gaskets. Valves, hydrants and other heavy fittings must be adequately supported to prevent differential settlement causing stress on pipe lines.

Backfill around and above pipe to provide compacted cover of at least 8 inches (200 mm). Take care not to displace the installed lines during placement and compaction.

Do not backfill with frozen fill, ice or debris. Do not use mechanical tampers until compacted fill is 2 feet (0.6 m) above pipe. Place balance of fill by conventional methods.

For selection of materials for use in bedding, haunching, initial and final backfilling, refer to the *REHAU Municipal PVC Pipe Installation Guide,* as well as other installation references included in Section 2.1.3.

For information on tapping for service fittings please refer to the *REHAU AQUALOC Pressure Pipe Tapping Guide*.

Fig. 2.8:
Installation of AQUALOC pressure pipe

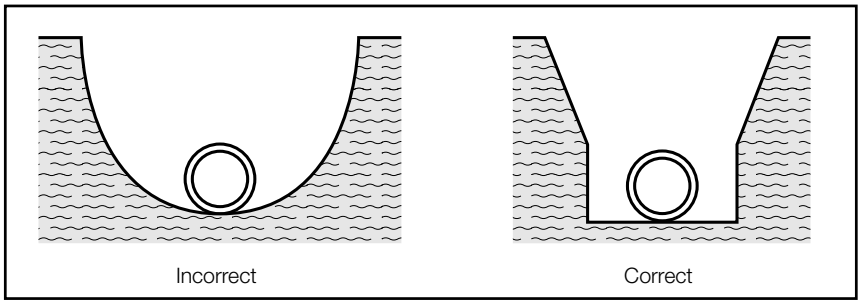

Fig. 2.7:
Proper excavation

2.1.6 Testing

Conduct hydrostatic and leakage tests on installed lines in accordance with AWWA C605. Safety during pressure testing is paramount. Please refer to the section on pressure testing AQUALOC in the *REHAU Municipal PVC Pipe Installation Guide*.

Leave joints exposed until satisfactory testing has been completed. Brace the line as required to prevent movement.

Make sure that air is vented from the line before commencing with tests.

Hydrostatic Test
Test the installed line for one hour at a hydrostatic pressure of 50% above normal operating pressure, measured at the low point in the test section. The hydrostatic pressure test must not exceed the maximum rating for the pipe. If hydrostatic testing or testing at higher pressure is required, please contact your REHAU regional sales office before testing.

Leakage Test
Conduct a leakage test for two hours at the maximum operating hydrostatic pressure, in accordance with AWWA C605, measured at the low point in the test.

Leakage must not exceed values in Table 2.8.

L = allowable leakage (gal/hr)
N = number of joints in the tested line (pipe and fittings)
D = nominal diameter (in)
P = average test pressure (psi)

$$L = \frac{ND\sqrt{P}}{7400}$$

Gasketed joint pipe in 6.1 meter lengths.

Nominal Pipe Size		Average Test Pressure, psi (kPa)		
in	mm	100 (690)	150 (1034)	200 (1380)
4	100	0.27	0.33	0.38
6	150	0.41	0.50	0.57
8	200	0.54	0.66	0.76
10	250	0.68	0.83	0.96
12	300	0.81	0.99	1.15
14	350	0.95	1.06	1.34
16	400	1.08	1.21	1.53

Note: To obtain leakage in litres per hour, multiply the values in the table by 3.72

Table 2.8:
Allowable leakage rates (AWWA C605) imperial gallons/hour/50 joints

2.2 Buried Pipe Lines

2.2.1 Pipe Stiffness

Pipe stiffness may be measured by testing according to ASTM D 2412.

It may also be calculated by:

$$PS = 4.47 \frac{E}{(DR - 1)^3}$$

E= modulus of elasticity of PVC material (See Table 2.13)

Pressure Pipe	psi	kPa
DR 18	378	2606
DR 25	134	925
SDR 26	119	821

Table 2.9:
Typical values of pipe stiffness for pressure pipe

2.2.2 Loading Design

REHAU PVC pressure pipe is a flexible pipe with considerable inherent strength. It has the added benefit that it can deflect without breaking, thereby taking full advantage of the surrounding soil compacted during installation.

The load carrying capabilities of a flexible pipe can only be fully realized if the surrounding soil is considered as an integral part of the product. In order to do this the equation developed by M.G. Spangler along with that of Professor Anson Marston must be used. A flexible pipe will not break, but will deflect. The vertical dimension will decrease and the horizontal dimension increase, further compacting the soil at the side of the pipe until complete stability around the pipe is achieved.

Once stable, flexible pipe is capable of withstanding approximately three times the load of a similar rigid pipe. Any excess load is transmitted to the surrounding soil.

Soil Type/Pipe Zone Material (Unified Classification System†) (1)	E[1] for Degree of Compaction of Pipe Zone Backfill psi			
	Loose (2)	Slight < 85% Proctor < 40% rel. density (3)	Moderate 85-95% Proctor 40-70% rel. density (4)	High > 95% Proctor > 70% rel. density (5)
Fine-grained soils (LL>50)‡ Soils with medium to high plasticity; CH, MH, CH-MH	No data available: consult a competent soils engineer; otherwise use E[1] = 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	1000
Fine-grained soils (LL<50) Soils with medium to no plasticity: CL, ML, ML-CL, with more than 25% coarse-grained particles	100	400	1000	2000
Coarse-grained soils with fine; GM, GC, SM, SC,§ contains more than 12% fines	100	400	1000	2000
Coarse-grained soils with little or no fines; GW, GP, SW, SP, § contains less than 12% fines	200	1000	2000	3000
Crushed rock	1000	3000	3000	3000
Accuracy in terms of percentage deflection	±2	±2	±1	±0.5

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-lb/ft^3 (598,000 J/m^3) (ASTM D 698, AASHTO T-99, USBR Designation E-11). 1 psi = 6.9 kN/m^2.

**The pipe zone embedment conditions included in this table are not intended as installation recommendations and are provided for information only. For installation recommendations, see AWWA Manual M23 (1980).*
†ASTM Designation D 2487. USBR Designation E-3.
‡LL = Liquid Limit.

Based on Table 1, page 34, *Journal Geotechnical Engineering, ASCE.*

Table 2.10:
*Typical values of modulus of soil reaction E[1] for average initial flexible pipe deflection**

In order to achieve maximum benefit from flexible pipe, good bedding (class B) and good consolidation at the sides of the pipe are required. An 8 inch (200 mm) cover of selected material above the pipe will provide the same protection as for other pipes. The following tables will indicate the deflection that may be experienced under conditions of earth and/or wheel loads. For design purposes, 7 1/2% deflection is allowable and accepted. This uses a safety factor of four, since buckling failure will not take place until at least 30% deflection.

E[1] Value	Height of Cover, ft (m)							
	2 (0.6)	4 (1.2)	6 (1.8)	8 (2.4)	10 (3.0)	12 (3.7)	16 (4.9)	20 (6.1)
SDR 21 (Series 200)								
200	0.37	0.73	1.10	1.46	1.83	2.20	2.93	3.66
400	0.29	0.58	0.87	1.15	1.44	1.73	2.31	2.89
700	0.22	0.44	0.66	0.88	1.10	1.32	1.75	2.19
1000	0.18	0.35	0.53	0.71	0.88	1.06	1.41	1.77
SDR 26 (Series 160)								
200	0.57	1.14	1.71	2.28	2.85	3.42	4.56	5.69
400	0.40	0.80	1.21	1.61	2.01	2.41	3.22	4.02
700	0.28	0.56	0.84	1.12	1.39	1.67	2.23	2.79
1000	0.21	0.43	0.64	0.85	1.07	1.28	1.71	2.13
SDR 32.5 (Series 125)								
200	0.80	1.61	2.41	3.22	4.02	4.82	6.43	8.04
400	0.51	1.01	1.52	2.02	2.53	3.04	4.05	5.06
700	0.33	0.65	0.98	1.30	1.63	1.95	2.60	3.25
1000	0.24	0.48	0.72	0.96	1.20	1.44	1.92	2.40
SDR 41 (Series 100)								
200	1.02	2.04	3.05	4.07	5.09	6.11	8.15	10.18
400	0.58	1.17	1.75	2.33	2.92	3.50	4.67	5.83
700	0.36	0.71	1.07	1.42	1.78	2.13	2.84	3.56
1000	0.26	0.51	0.77	1.02	1.28	1.53	2.05	2.56
DR 18 (Class 150)								
200	0.25	0.50	0.75	1.00	1.25	1.50	2.01	2.51
400	0.21	0.42	0.64	0.85	1.06	1.27	1.69	2.12
700	0.17	0.34	0.52	0.69	0.86	1.03	1.37	1.72
1000	0.14	0.29	0.43	0.58	0.72	0.87	1.16	1.45
DR 25 (Class 100)								
200	0.53	1.06	1.59	2.12	2.65	3.18	4.23	5.29
400	0.38	0.76	1.14	1.53	1.91	2.29	3.05	3.81
700	0.27	0.54	0.81	1.08	1.34	1.61	2.15	2.69
1000	0.21	0.42	0.62	0.83	1.04	1.25	1.66	2.08

Table 2.11:
Dead load deflection only for AQUALOC (%)

E^1 Value	Height of Cover, ft (m)							
	2 (0.6)	4 (1.2)	6 (1.8)	8 (2.4)	10 (3.0)	12 (3.7)	16 (4.9)	20 (6.1)
SDR 21 (Series 200)								
200	1.59	1.34	1.40	1.62	1.83	2.20	2.93	3.66
400	1.25	1.06	1.11	1.27	1.44	1.73	2.31	2.89
700	0.95	0.80	0.84	0.97	1.10	1.32	1.75	2.19
1000	0.77	0.65	0.68	0.78	0.88	1.06	1.41	1.77
SDR 26 (Series 160)								
200	2.47	2.09	2.18	2.51	2.85	3.42	4.56	5.69
400	1.74	1.47	1.54	1.77	2.01	2.41	3.22	4.02
700	1.21	1.02	1.07	1.23	1.39	1.67	2.23	2.79
1000	0.93	0.78	0.82	0.94	1.07	1.28	1.71	2.13
SDR 32.5 (Series 125)								
200	3.49	2.95	3.08	3.55	4.02	4.82	6.43	8.04
400	2.19	1.86	1.94	2.23	2.53	3.04	4.05	5.06
700	1.41	1.19	1.25	1.44	1.63	1.95	2.60	3.25
1000	1.04	0.88	0.92	1.06	1.20	1.44	1.92	2.40
SDR 41 (Series 100)								
200	4.42	3.74	3.90	4.49	5.09	6.11	8.15	10.18
400	2.53	2.14	2.24	2.58	2.92	3.50	4.67	5.83
700	1.54	1.30	1.36	1.57	1.78	2.13	2.84	3.56
1000	1.11	0.94	0.98	1.13	1.28	1.53	2.05	2.56
DR 18 (Class 150)								
200	1.09	0.92	0.96	1.11	1.25	1.50	2.01	2.51
400	0.92	0.78	0.81	0.94	1.06	1.27	1.69	2.12
700	0.75	0.63	0.66	0.76	0.86	1.03	1.37	1.72
1000	0.63	0.53	0.55	0.64	0.72	0.87	1.16	1.45
DR 25 (Class 100)								
200	2.29	1.94	2.03	2.34	2.65	3.18	4.23	5.29
400	1.65	1.40	1.46	1.68	1.91	2.29	3.05	3.81
700	1.17	0.99	1.03	1.19	1.34	1.61	2.15	2.69
1000	0.90	0.76	0.80	0.92	1.04	1.25	1.66	2.08

Table 2.12:
Dead load deflection plus H20 live load for AQUALOC (%)

2.3 Typical Mechanical Properties

The following table indicates typical mechanical properties of PVC materials used in AQUALOC pipe. All tests and measurements are taken at 73°F (23°C).

Specific gravity (no units)	1.41	1.41
Tensile strength	7,200 psi	46.6 MPa
Comprehensive strength	9,600 psi	66 MPa
Modulus of elasticity in tension	415,000 psi	2861 MPa
Flexural strength	14,500 psi	100 MPa
Izod impact notched, ft lb/in unnotched, ft lb/in	 0.8 psi 45 psi	 3.58N 202N
Hardness (Shore “D”)	78/82	
Cell classification	12454B	

Table 2.13:
Typical mechanical properties

2.3.1 Physical and Chemical Requirements

All physical and chemical tests are conducted at 73°F (23°C).

Test	Method	Measures	Minimum Requirements
Compound	ASTM D 1784	Cell Classification	
Sustained Pressure Test	ASTM D 1598	Long term pressure capacity	1000 hours: SDR 26/340 psi SDR 32.5 DR 25/350 psi DR 18/500 psi
Quick Burst Test	ASTM D 1599	Strength to resist water hammer	60-90 seconds SDR 26/500 psi DR 25/535 psi DR 18/755 psi
Acetone Immersion Test	ASTM D 2152	Extrusion quality	20 min. immersion with no flaking or disintegration
Flattening Test	CSA B 137.3	Ductility under load	95% flattening in 2-5 minutes with no splitting, cracking or breaking
Impact Test	CSA B 137.3	Strength and resistance to impact. Rigorous test conducted at low temperature	0% C 4"/135 joules 6"/160 joules 8"/175 joules 10"/190 joules 12"/205 joules
Joint Tightness	ASTM D 3139	Joint Tightness under installed conditions	15 psi hydrostatic 22 in Hg vacuum each for 10 minutes
Health Effects	NSF Standard 61	Toxicity levels of compounds	Concentration of all constituent chemical compounds are well below minimum levels for toxicity in humans.

Table 2.14:
Physical and chemical requirements

2.3.2 Water Flow/Friction Loss Through Rigid Plastic Pipe

AQUALOC PVC pressure pipe has a smooth bore (C=150) reducing friction head loss and resulting in lower pumping costs.

The following chart and example illustrates how flow can be determined through PVC pressure pipe. Please note that fittings will reduce flow and are not considered here.

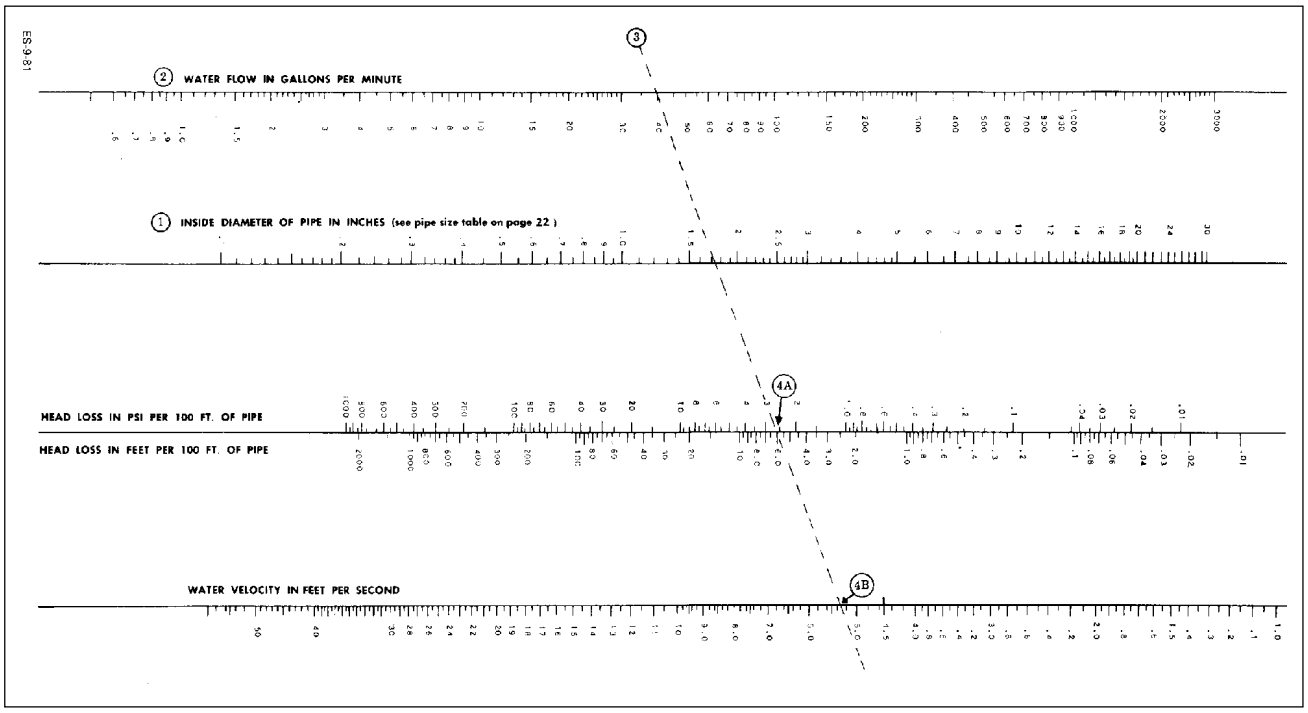

Fig. 2.9:
Water flow/friction loss through rigid plastic pipe

How to use this graph:
1) Select the desired pipe size.
2) Determine the amount of water to flow through the pipe.
3) Place a straightedge on these two points.
4) The points at which the straightedge intersects the head loss line and the velocity line determine these two values under the given conditions.

This graph should be used for approximate values only.

Example:

1 1/2" SDR 26 pipe (I.D. = 1.740")
40 gallon per minute service
Line up these two points with a straightedge
Read 2.6 psi (or 6 ft) from the head loss line
Read 5.38 ft per second from the velocity line

The values on this graph are based on the Hazen-Williams formula:

$$f = .2083 \left(\frac{100}{C}\right)^{1.85} \times \frac{Q^{1.85}}{d_i^{4.8655}}$$

Where:
f = Friction head loss in feet of water per 100 feet of pipe
d_i = Inside diameter of pipe in inches
Q = Flow in gallons per minute
C = Constant for inside roughness of pipe (150 for PVC)

Metric conversion factors:
1 in = 25.4 mm
1 ft = 304.8 mm
1 psi = 6.895 kPa
1 fps = 0.3048 m/s
1 imp gal/min = 0.0758 l/s
1 US gal/min = 0.0631 l/s

2.3.3 Thermal Expansion and Contraction

PVC has one of the lowest coefficients of thermal expansion of any polymer material used in potable water piping systems.

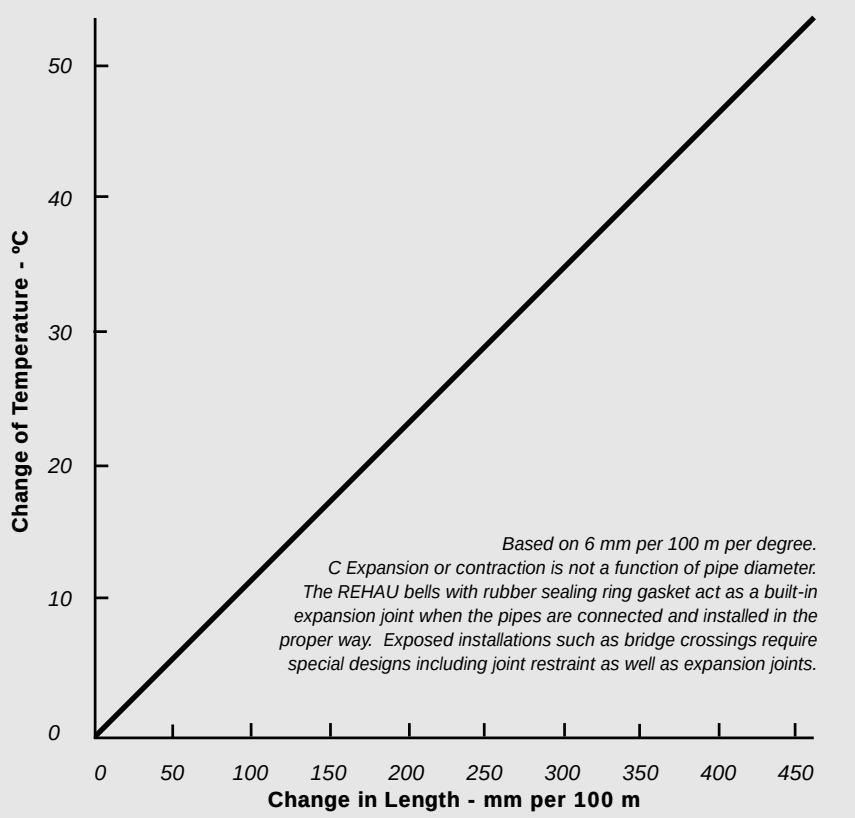

Fig. 2.10:
Thermal expansion and contraction

2.3.4 Reduction in Working Pressure with Increase in Temperature

Municipal systems normally operate at stable temperatures. Designers should be aware that at elevated temperatures the performance of PVC will be affected. It is generally not recommended that PVC pipe be used in pressure applications where temperatures will exceed 60°C (140°F).

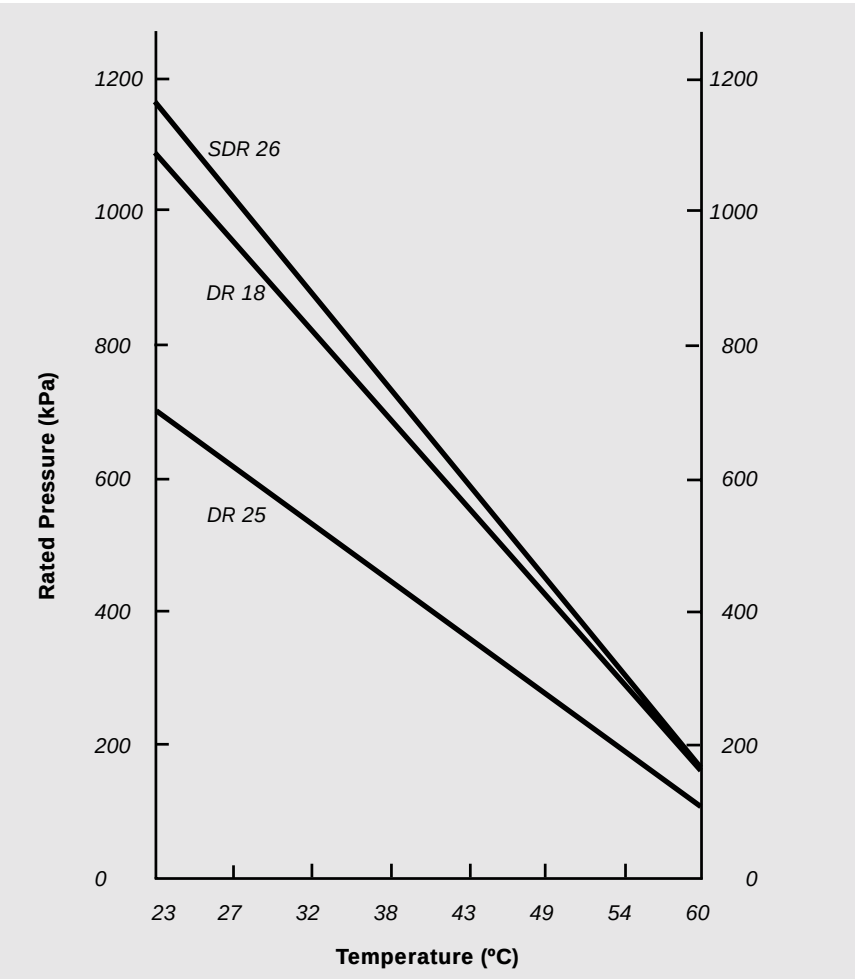

Fig. 2.11:
Reduction in working pressure with increase in temperature

2.3.5 Water Hammer in PVC Pressure Pipe

AQUALOC 4"-12" DR 18 and DR 25 are designed to accommodate surge pressures from shock waves that can accompany rapid opening and closing of valves within the piping system. These pipes have safety factors of 2.5:1 associated with their working pressures.

16" DR 18 and DR 25, and all sizes of SDR 21, 26, 32.5 and 41 Series pipes have a safety factor of 2:1. No allowance for surge or water hammer is made.

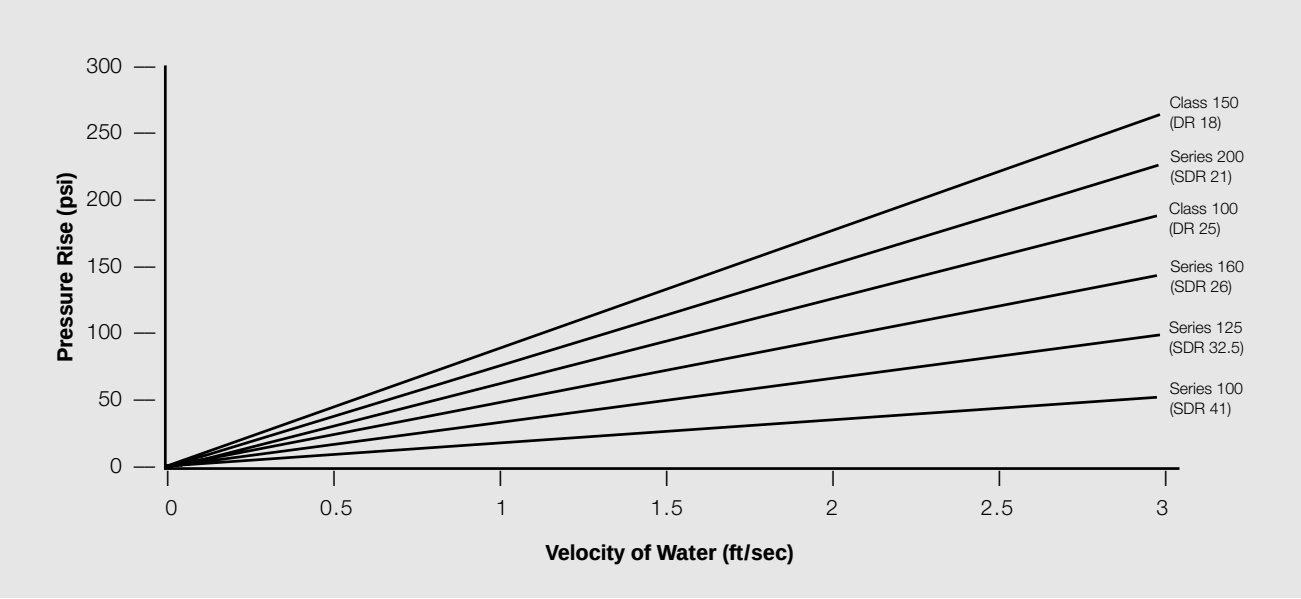

Fig. 2.12:
Water hammer in PVC pressure pipe due to instantaneous closure

3.0 DURALOC and RAURIB Sewer Pipe

3.1 Product Characteristics

REHAU's PVC sewer pipe offers the best of everything: outstanding, economical performance and durability. REHAU produces DURALOC solid wall DR 28 and DR 35 as well as RAURIB, open-profile PVC pipe for both storm and sewer applications.

3.1.1 Products

REHAU DURALOC solid wall DR 28 and DR 35 and RAURIB ribbed sewer pipes are offered by REHAU complete with standard fittings as required. DR 35 and RAURIB are of equal pipe stiffness, i.e., 320 kPa and 46 psi and designed for both storm and sanitary sewer applications.

3.1.2 Joint Options

This design features an integrated (locked-in) system where the seal and mandrel act together as a tool to shape the pipe socket during pipe manufacturing. The seal is firmly locked in the correct position by the cooling and shrinking of the pipe socket.

The seal is the forming tool to shape its own groove in the socket. The reinforcing element prevents the seal from moving and holds the gasket in its groove to prevent movement during installation and to give long, dependable service life.

Solvent Cement Joints

This leak-free joint is easily created using solvent cement, which chemically bonds the bell and spigot ends. The solvent dissolves or softens the thermoplastic material and the cement bonds the two pieces into one assembly. The I.D. is tapered to provide a tight fit with the spigot end.

Fig. 3.1:
Tamping of backfill during installation of DURALOC sewer pipe

Fig. 3.2:
RAURIB being installed in a sanitary sewermain

Illustration not to scale.

Fig. 3.3:
DURALOC Joint

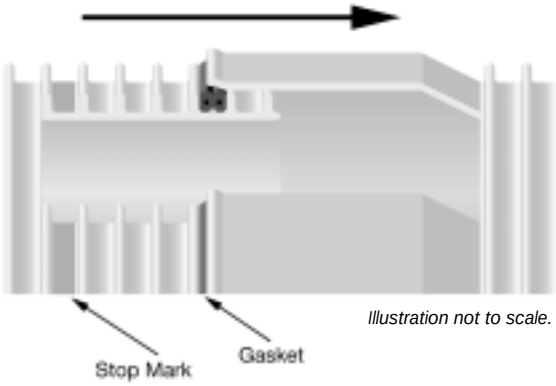

Illustration not to scale.

Fig. 3.4:
Typical joining of RAURIB bell showing gasket and location of stop mark

3.1.3 Standards

All DURALOC pipe meets or exceeds the following standards:

CSA B 182.1
: Plastic Drain and Sewer Pipe and Pipe Fittings

CSA B 182.2
: PVC Sewer Pipe and Fittings PSM Type

BNQ 3624-130
: Tuyaux et Raccords en Plastique PVC de Diameter Egal ou Inferior 150mm Pour E' oui Sous Terrain

BNQ 3624-135
: Tuyaux et Raccords en Plastique PVC non Plastitied de Diameter Egal ou Superior 200mm pour Egout Sous Terrain et Drainage de Sol

UNI-B-9
: Recommended Standard Specification for Polyvinyl Chloride (PVC) Plastic Gravity Sewer Pipe and Fittings

ASTM D 3034
: Standard Specification for Type PSM Polyvinyl Chloride (PVC) Sewer Pipe and Fittings

DURALOC Recommended Installation Standards and References:

UNI-PUB-6
: Recommended Practice for the Installation of Polyvinyl Chloride (PVC) Sewer Pipe

ASTM D 2321
: Standard Recommended Practice for Underground Installation of Flexible Thermoplastic Sewer Pipe

CSA B 182.11
: Recommended Practice for the Installation of Thermoplastic Drain Storm and Sewer Pipe and Fittings. Second Edition.

All RAURIB sewer pipe meets or exceeds the following standards:

ASTM F 794
: Standard Specification for Polyvinyl Chloride (PVC) Large Diameter Ribbed Gravity Sewer Pipe and Fittings Based on Controlled Inside Diameter

CSA B 182.4
: Profile (ribbed) PVC Sewer Pipe and Fittings

BNQ 3624-135
: Piping PVC Rigid Plastic Pipe and Fittings, 200 mm in Diameter or Greater, for Underground Sewage Application. This standard is applicable to pipe and fittings with a smooth or ribbed surface.

RAURIB Recommended Installation Reference:

REHAU Municipal PVC Pipe Installation Guide

3.1.4 Specifications

Short Form Specification DURALOC

DURALOC DR 28 and DR 35 are manufactured from PVC compound having cell classification 12364-C or 12454-B as defined by ASTM D 1784. Pipes and gaskets must be certified as follows: CSA B 182.1 and CSA B 182.2; Bureau de normalisation du Quebec BNQ 3624-130 and 3624-135; and ASTM D 3034.

The minimum pipe stiffness must be 625 kPa (90psi) for DR 28 and 320 kPa (46 psi) for DR 35. Gasketed joints are locked into the gasket grooves during the manufacturing process. Use of REHAU lubricant during installation is recommended. This lubricant is formulated for use with potable water to eliminate any eventuality of cross-contamination of potable water systems. Pipe shall be available in 13 feet (4 m) lay lengths

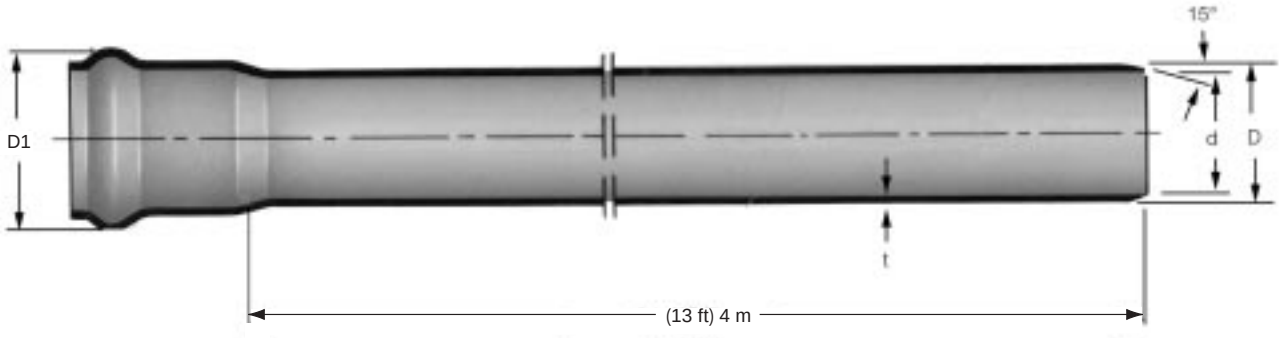

Fig. 3.5:
DURALOC pipe dimensions

Size	D		d		D1		t(min)		Weight*	
in	mm	in	mm	in	mm	in	mm	in	lb/ft	kg/m
4	107.05	4.21	99.31	3.91	130.34	5.13	3.81	.150	1.24	1.85
5	143.25	5.64	133.10	5.24	168.91	6.65	5.10	.201	2.21	3.29
6	159.37	6.27	147.83	5.82	188.10	7.41	5.69	.224	2.73	4.06

*Weights are approximate.

Table 3.1:
DR 28 Lateral Sewer Pipe available in white, green, and black - 13 ft (4 m)

Size	D		d		D1		t(min)		Weight*	
in	mm	in	mm	in	mm	in	mm	in	lb/ft	kg/m
4	107.05	4.21	100.93	3.97	128.84	5.07	3.06	.120	1.06	1.58
6	159.37	6.27	150.27	5.92	185.82	7.32	4.55	.180	2.25	3.35
8	213.35	8.40	201.15	7.92	244.79	9.64	6.10	.240	3.95	5.89
10	266.70	10.50	251.46	9.90	304.75	12.00	7.62	.300	6.18	9.19
12	317.50	12.50	299.36	11.79	360.27	14.18	9.07	.357	8.80	13.10
15	388.63	15.30	366.43	14.43	439.21	17.29	11.10	.437	12.47	18.56

*Weights are approximate.

Table 3.2:
DR 35 Gravity Sewer Pipe available in green and white - 13 ft (4 m)

Short Form Specification RAURIB

The storm or sanitary sewer pipe shall be RAURIB seamless, profile wall PVC pipe manufactured in accordance with and certified to CSA B 182.4 and BNQ 3624-135 standards. Extrusion quality and impact resistance testing shall be carried out to ASTM standards D 2152 and F 794. Pipe stiffness shall be 320 kPa (46 psi) at 5% vertical deflection when measured according to the ASTM D 2412 standard. Joint performance shall be tested on regular production under deflection and in accordance with CSA B 182.4 at 25 feet (7.5 m) of head or at 22 inches Hg vacuum. Additionally, the pipe joint must withstand 345 kPa (50 psi) of hydrostatic pressure when tested in accordance with ASTM D 3212 methods at 5% deflection, for one hour.

Pipe shall be extruded and formed simultaneously with a smooth interior and with reinforcing ribs on the exterior at right angles to the pipe barrel. Pipe bells shall be produced stress-free by an in-line forming process. Exterior ribs shall allow placement of the joint sealing gasket for a tight seal without any additional cutting or machining of the pipe.

Pipe diameters available: 8" (200 mm) through 24" (600 mm).

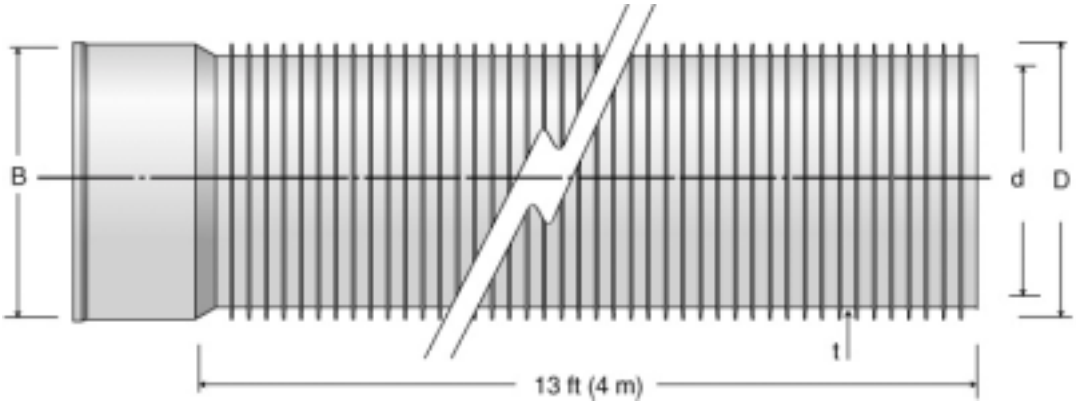

Illustration not to scale.

Fig. 3.6:
RAURIB pipe dimensions

Size	D		d		B (Bell I.D.)		t(Min)		Weight*	
in	mm	in	mm	in	mm	in	mm	in	lb/ft	kg/m
8	223.50	8.80	200.70	7.89	224.30	8.94	2.40	0.069	2.24	3.34
10	279.40	11.00	250.60	9.86	280.40	11.16	2.40	0.081	3.43	5.11
12	332.70	13.10	298.10	11.74	333.90	13.29	3.00	0.097	4.80	7.15
15	406.55	16.01	365.10	14.37	412.19	16.23	3.40	0.134	6.19	9.21
18	498.50	18.63	448.30	17.65	504.10	19.85	3.80	0.150	9.73	14.48
24	650.50	25.61	596.70	23.50	669.25	25.96	4.60	0.181	17.96	26.73

*Weights are approximate.

Table 3.3:
RAURIB dimensional data

3.1.5 Handling, Storage and Installation

Store PVC pipe in delivery modules and keep clean until ready for use. Avoid excessive heat, cold and impact. For ordering refer to the most recent version of *REHAU's Municipal Pipe Loading Chart.* For procedures, refer to the *REHAU Municipal PVC Pipe Installation Guide.*

PVC pipe must be handled, stored and installed in accordance with the current edition of the *REHAU Municipal PVC Pipe Installation Guide*.

Fig. 3.7:
Unloading DURALOC sewer pipe on a jobsite

Fig. 3.8:
Arrival of RAURIB sewer pipe to jobsite

Foundation, bedding and trench width must be such that pipe can be installed and maintained under the load of backfill to the specified line and grade. The general rule is that the maximum trench width to a height of 8 inches (200 mm) above the pipe, should not exceed the outside diameter of the pipe plus 2 feet. Sufficient room must be available to properly bed and haunch the pipe for support.

Trench bottoms must be dry, free of frost, large stones, or other hard objects and be graded to provide continuous support for the pipe. In areas where trench bottoms are unsuitable for direct support of pipe (due to large stones, rock, wet or stony soil), excavate trenches 4- to 6-inch (100- to 150-mm) below pipe. Place and compact a 4- to 6-inch (100- to 150-mm) bedding layer under the pipe. Grade to provide full support of the barrel and bell ends.

Dewater trenches to keep free of mud.

Lay pipe on smooth even bed providing full support for the barrel. Excavate and fill as required to equally support bell ends. Laying pipe on unstable soil, steep inclines, or in other adverse conditions should be under the direction of the engineer.

Clean bell and gasket and apply lubricant to spigot end before joining pipes. All joints must be inserted to the proper "stop" mark on the pipe. Protect pipe from damage if levers or equipment are used for joining the pipes.

DURALOC pipe joints may be deflected for curvature during installation. For procedures, refer to the *REHAU Municipal PVC Pipe Installation Guide.*

Complete procedures for forming solvent cement joints can be found in the *REHAU Industrial Technical Manual.*

Backfill around and above pipe to provide compacted cover of at least 8 inches (200 mm). Take care not to displace the installed lines during placement and compaction.

Fig. 3.9:
Backfilling DURALOC sewer pipe

Do not backfill with frozen fill, ice or debris. Do not use mechanical tampers until compacted fill is 2 feet (0.6 m) above pipe. Place balance of fill by conventional methods.

3.1.6 Testing

Deflection testing and leakage testing may be required. See *REHAU Municipal PVC Pipe Installation Guide for instructions.*

3.2 Buried Pipe Lines

3.2.1 Pipe Stiffness

$$\text{(PS) Pipe Stiffness } \frac{F}{\Delta Y}$$

Pipe stiffness may be developed by actual testing according to ASTM D 2412. It can also be calculated as follows:

$$PS = 4.47 \frac{E}{(DR - 1)^3}$$

For material with E modulus = 420,000 psi, DURALOC DR 35 and RAURIB will meet or exceed PS of 320 kPa (46 psi). DURALOC DR 28 meets or exceeds PS 625 kPa (90 psi).

3.2.2 Loading

REHAU DURALOC and RAURIB sewer pipe are flexible pipe with considerable inherent strength. They have the added advantage that they can deflect without breaking, thereby taking full advantage of the surrounding soil compacted during installation.

The load carrying capabilities of flexible pipe can only be fully realized if the surrounding soil is considered as an integral part of the product. In order to do this, the equations developed by M.G. Spangler and Professor Anson Marston must be used. Flexible pipe will not break, but will deflect. The vertical dimension will decrease and the horizontal dimension increase, further compacting the soil at the side of the pipe until complete stability around the pipe is achieved.

Once stable, flexible pipe is capable of withstanding approximately three times the load of a similar rigid pipe. Any excess load is transmitted to the surrounding soil.

In order to achieve maximum benefit from flexible pipe, good bedding (class B) and good consolidation at the sides of the pipe are required. An 8 inch (200 mm) cover of selected material above the pipe will provide the same protection as for other pipes.

E[1] Value	Height of Cover, ft (m)							
	2 (0.6)	4 (1.2)	6 (1.8)	8 (2.4)	10 (3.0)	12 (3.7)	16 (4.9)	20 (6.1)
DURALOC SDR 28 (625 kPa Stiffness)								
200	0.65	1.29	1.94	2.59	3.23	3.88	5.17	6.46
400	0.44	0.88	1.32	1.76	2.19	2.63	3.51	4.39
700	0.30	0.59	0.89	1.18	1.48	1.78	2.37	2.96
1000	0.22	0.45	0.67	0.89	1.12	1.34	1.79	2.23
DURALOC SDR 35 and RAURIB (320 kPa Stiffness)								
200	0.88	1.75	2.63	3.51	4.38	5.26	7.02	8.77
400	0.54	1.07	1.60	2.14	2.67	3.21	4.27	5.34
700	0.34	0.67	1.01	1.35	1.68	2.02	2.69	3.37
1000	0.25	0.49	0.74	0.98	1.23	1.47	1.97	2.46

Table 3.4:
Dead load deflection only - DURALOC and RAURIB (%)

E[1] Value	Height of Cover, ft (m)							
	2 (0.6)	4 (1.2)	6 (1.8)	8 (2.4)	10 (3.0)	12 (3.7)	16 (4.9)	20 (6.1)
DURALOC SDR 28 (625 kPa Stiffness)								
200	2.80	2.37	2.48	2.85				
400	1.90	1.61	1.68	1.94		See Above		
700	1.28	1.09	1.13	1.31				
1000	0.97	0.82	0.86	0.99				
DURALOC SDR 35 and RAURIB (320 kPa Stiffness)								
200	3.81	3.22	3.36	3.87				
400	2.32	1.96	2.05	2.36		See Above		
700	1.46	1.23	1.29	1.49				
1000	1.07	0.90	0.94	1.09				

For E[1]Values, see Section 2.2.2.
Note: Live loading will generally have little effect after 8' of bury.

Table 3.5:
Dead load deflection plus H20 live load deflection (%)

3.2.3 Designing Sewer Pipelines/Long Term Deflection

The following tables will indicate the deflection that may be experienced under conditions of dead loads and/or live loads. For design purposes, 7 1/2% deflection is allowable and accepted. This uses a safety factor of four since buckling failure will not take place until at least 30% deflection.

3.2.4 Calculated Long Term Deflection of Buried PVC Pipe (%)

The following table is used to predict long-term deflection when designing sewer pipelines within 320 kPa stiffness. H20 live loading is included.

ASTM embedment material classification		Density Proctor AASHTO T-99	Height of Cover (ft)													
			3	5	8	10	12	14	16	18	20	22	24	26	28	30
Manufactured granular angular	CLASS I		0.2	0.3	0.4	0.5	0.6	0.7	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6
Clean sand and gravel	CLASS II	90%	0.2	0.3	0.5	0.7	0.8	0.9	1.1	1.2	1.3	1.4	1.6	1.7	1.8	2.0
		80%	0.9	1.4	2.3	3.2	3.6	4.1	5.0	5.5	6.0	6.4	7.3	7.7	8.2	9.1
Sand and gravel with fines	CLASS III	90%	0.2	0.4	0.6	0.8	0.9	1.1	1.2	1.4	1.6	1.7	1.9	2.1	2.2	2.3
		85%	0.7	0.9	1.7	2.2	2.6	3.0	3.5	3.9	4.3	4.8	5.2	5.6	6.0	6.5
		75%	1.1	1.8	2.9	3.8	4.5	5.5	6.8	8.5	9.9	11.3	12.7	14.1	15.5	16.8
		65%	1.3	2.4	3.6	4.7	5.5	6.8	8.5	9.6	11.4	13.0	14.5	16.0	17.3	18.0
Silt and clay	CLASS IV	85%	0.65	0.9	1.7	2.2	2.6	3.0	3.5	3.9	4.3	4.8	5.2	5.6	6.0	6.5
		75%	1.3	2.3	3.3	4.3	5.0	6.5	7.8	9.5	10.6	12.2	13.5	15.0	16.3	17.0
		65%	1.3	2.4	3.6	4.7	5.5	8.0	10.5	12.5	15.0	17.6	20.0	22.0	24.0	26.0

☐ These zones not recommended

1. No length of pipe installed under conditions specified will deflect more than is indicated; the pipe will deflect less than the amount indicated if specified density is obtained.
2. Embedment material classifications are as per ASTM D 2321 "Underground Installation of Flexible Thermoplastic Sewer Pipe."
3. Deflections listed in table are maximum long-term values. Recommended maximum deflection is 7 1/2%.
4. Listed deflections are those caused by soil loading only and do not include initial out-of-roundness, etc. Source: Utah State University

Table 3.6:
Maximum long-term deflection for DURALOC DR 35 and RAURIB sewer pipe

3.2.5 Flow in Gravity Sewer Pipes

The following table is derived from calculations using Manning's formula. Manning's coefficient of flow represented by n, is critical to these calculations. For PVC, n = .009, while concrete and corrugated metal pipe with lower rates of flow have n = .013 and n = .024 respectively.

There is a tendency in pipeline design to use an oversimplified approach, which does not sufficiently account for the pipe material used and the actual velocity of flow at which the sewer system will operate. Since flow friction increases as flow decreases only n values for low flow conditions should be used in design, i.e., < 2.5 ft/sec.

Nominal	S=0.1				S=0.3				S=0.5			
Pipe Size	V(M/s)	V(f/s)	Q(kL/d)	Q(kG/d)	V(M/s)	V(f/s)	Q(kL/d)	Q(kG/d)	V(M/s)	V(f/s)	Q(kL/d)	Q(kG/d)
150 (6")	0.39	1.279	600.0	141.9	0.68	2.23094	1039	245.8	0.88	2.887	1341.6	317.4
200 (8")	0.48	1.575	1306.5	309.1	0.83	2.72306	2262	535.2	1.07	3.510	2921.5	691.2
250 (10")	0.55	1.804	2362.0	558.8	0.96	3.14957	4091	967.9	1.24	4.068	5281.5	1249.5
300 (12")	0.62	2.034	3752.2	887.7	1.08	3.54326	6499	1537.6	1.39	4.560	8390.2	1985.0
375 (15")	0.71	2.329	6410.1	1516.5	1.23	4.03538	11102	2626.6	1.59	5.216	14333.4	3391.1
450 (18")	0.78	2.559	11545.0	2731.4	1.41	4.62593	19323	4571.5	1.83	6.004	24950.0	5902.8
525 (21")	0.91	2.986	17170.0	4062.2	1.58	5.18366	29740	7036.1	2.03	6.660	38390.0	9082.5
600 (24")	0.99	3.248	23950.0	5666.2	1.71	5.61017	41475	9812.4	2.21	7.251	53540.0	12667.0
675 (27")	1.07	3.511	32974.0	7801.2	1.86	6.10229	57100	13509.0	2.39	7.841	73730.0	17443.0

S = pipeline slope in % V = effluent velocity Q = flow rate

Table 3.7:
Available flow for PVC pipe; n = .009 where S = 0.1, 0.3 & 0.5%

Nominal	S=0.7				S=1.0			
Pipe Size	V(M/s)	V(f/s)	Q(kL/d)	Q(kG/d)	V(M/s)	V(f/s)	Q(kL/d)	Q(kG/d)
150 (6")	1.04	3.412	1587.4	375.5	1.24	4.068	1897.3	448.9
200 (8")	1.26	4.134	2456.0	581.1	1.51	4.954	4131.7	977.5
250 (10")	1.47	4.823	6249.0	1478.4	1.75	5.74	7469.1	1767.1
300 (12")	1.65	5.413	9927.0	2348.6	1.97	6.463	11865.5	2807.2
375 (15")	1.88	6.168	16959.0	4012.3	2.26	7.415	20270.5	4795.7
450 (18")	2.16	7.087	29515.0	6982.8	2.58	8.464	35275.0	8345.6
525 (21")	2.41	7.907	45430.0	10748.1	2.88	9.45	54300.0	12846.6
600 (24")	2.62	8.595	63350.0	14987.7	3.13	10.27	75720.0	17914.3
675 (27")	2.83	9.285	87240.0	20639.7	3.39	11.12	104270.0	24668.8

S = pipeline slope in % V = effluent velocity Q = flow rate

Table 3.8:
Available flow for PVC pipe; n = .009 where S = 0.7 & 1.0%

4.0 MUNICIPEX

4.1 Product Characteristics

MUNICIPEX pipe is an engineered water service line pipe. MUNICIPEX cannot corrode therefore it delivers greater service life while retaining maximum flow. Made specifically for potable water in SDR9 copper tube size (CTS) dimensions, MUNICIPEX replaces traditional type 'K' copper service lines, and has higher flexibility and impact strength. MUNICIPEX meets all necessary certifications and is field-proven for use in municipal service lines.

4.1.1 Product

MUNICIPEX pipe is cross-linked polyethylene, manufactured using the high-pressure peroxide method of cross-linking (Engel method), denoted by the designation PEXa. A thermoset polymer, MUNICIPEX is used with brass compression joint or compression sleeve fittings. It is produced in SDR9 copper tube sizes according to ASTM F 876, F 877 and CSA B 137.5.

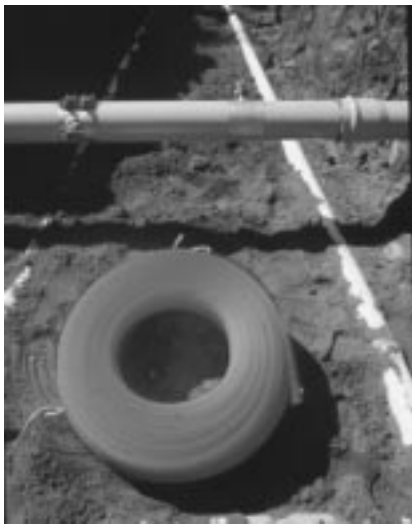

Fig. 4.1:
MUNICIPEX on job site ready for installation

REHAU's manufacturing process co-extrudes a thin, durable, UV-resistant (ultraviolet), polyethylene sheath or "shield" over MUNICIPEX pipes, while still meeting all dimensional requirements.

In addition to its distinctive blue color, the co-extruded sheath has the added benefit of a UV shield, protecting the pipe against degradation caused by UV exposure (sunlight) for up to one year.

4.1.2 Standards

MUNICIPEX pipe meets or exceeds the following standards:

ASTM F 876
Standard Specification for Cross-linked Polyethylene (PEX) Tubing
ASTM F 877
Cross-linked Polyethylene (PEX) Plastic Hot and Cold Water Distribution Systems
CSA B 137.5
Cross-linked Polyethylene (PEX) Tubing Systems for Pressure Applications
NSF Standard 14
Plastic Piping System Components and Related Materials
NSF Standard 61
Drinking Water System Components - Health Effects
PPI TR-4
HDB Listed Materials

MUNICIPEX has also been independently reviewed and approved by:
ICBO (ES ER-5200)
IAPMO Research & Testing Inc.

4.1.3 Short Form Specification for MUNICIPEX

Service line pipe to be cross-linked polyethylene (PEXa) pipe manufactured using the high-pressure peroxide (Engel) method of cross-linking, with an approved cell classification of 354400 in accordance with ASTM D 3350, and a minimum degree of cross-linking of 80% in accordance with ASTM D 2765, Method B.

Pipe to have a co-extruded UV shield made from UV-resistant, high-density polyethylene, color blue. UV Shield to allow exposure to natural sunlight for up to one year.

Pipe to be certified to standards CSA B 137.5, ASTM F 876, ASTM F 877, PPI TR-4, NSF 14 and NSF 61, by an approved testing agency.

Pipe to be manufactured in an ISO 9001 Certified production facility.

Approved temperature and pressure ratings based on PPI Hydrostatic Design Basis as certified by CSA and NSF or equivalent testing agency.

Minimum Burst Pressure Requirements
475 psi @ 73.4°F (3310 kPa @ 23°C)
210 psi @ 180°F (1450 kPa @ 82.2°C)
180 psi @ 200°F (1240 kPa @ 93.3°C)

Hydrostatic Pressure Ratings (Continuous Operation)
160 psi @ 73.4°F (1105 kPa @ 23°C)
100 psi @ 180°F (690 kPa @ 82.2°C)
80 psi @ 200°F (550 kPa @ 93.3°C)

Pipe to carry the following markings: Manufacturer's name or trademark, nominal size, ASTM F 876, F 877, CSA B 137.5, NSF-pw, PEXa (material designation), SDR9 (standard dimension ratio), 160 psi @ 73.4°F, 100 psi @ 180°F, potable tubing, manufacturing date and machine number, and footage mark.

Nominal Size (in)	O.D.*	Wall Thickness**	I.D. lb/ft	Weight gal/ft	Capacity	Pressure Ratings
3/4"	0.875	0.097	0.675	0.11	0.0189	160 psi @ 73.4°F (1105 kPa @ 23°C)
1"	1.125	0.125	0.870	0.18	0.0316	100 psi @ 180°F (690 kPa @ 82.2°C)

* Average dimensions from ASTM F 876
**Minimum wall thickness from ASTM F 876

Table 4.1:
MUNICIPEX sizes and dimensions

4.1.4 Handling, Storage and Installation

MUNICIPEX is shipped as coils, boxed in lengths of 100, 300 and 500 feet (31, 91 and 152 m). Pipe should be kept in boxes until installation begins.

Piping must be completely buried or protected by opaque conduit unless installed indoors, out of sunlight. Maximum exposure time to sunlight is one year.

MUNICIPEX must be cut squarely using an approved cutting tool, do not use a hacksaw or knife.

Fig. 4.1:
Cut MUNICIPEX with approved tool

REHAU's EVERLOC® compression sleeve fitting may be used for connections to valves, taps or meter housings (check local codes and approvals). Buried EVERLOC fittings must be protected by wrapping the fitting in two layers of black electrical tape (do not use duct tape), or sealing with a low-temperature heat shrink (without adhesive) of a type that is approved by REHAU or supplied by REHAU.

Fig. 4.2:
EVERLOC Fittings are used for connections

Fig. 4.3:
MUNICIPEX installed with regular corporation brass

MUNICIPEX can be used with AWWA C800 compression joint brass valves and fittings for all underground connections. These connections must use an approved support liner (typically stainless steel) inside the pipe to allow proper compression at the joint.

By using these liners, MUNICIPEX attaches to compression joint connections in the same manner as type 'K' copper or CTS polyethylene tubing.

At the connection between MUNICIPEX pipe and the water main, MUNICIPEX should leave the main at a 10 to 20 degree angle above the horizontal. This will result in a 'gooseneck' in the pipe that should be at least 4 feet (1.2 m) long. It is not required to use the 45° gooseneck common with copper service line.

Ensure that there is no angle or misalignment where MUNICIPEX connects with joints. MUNICIPEX pipe should connect straight into each joint, and there should be no stress on the connection.

MUNICIPEX should be laid with sufficient slack to accommodate contraction due to cooling of the pipe, or expansion if the pipe was cold when installed. This is accomplished by snaking MUNICIPEX in the trench, with side-to-side offset of approximately 1% of the length of the pipe between connections for every 18°F (10°C) of expected temperature change. See Table 4.2 for recommended offsets.

Snaking will also allow the pipe to expand gradually over a wider area if it expands, rather than at one specific point.

Temperature ºF	9	18	27	36	45	54	63	72
Change ºC	5	10	15	20	25	30	35	40
Length			**Offset in (mm)**					
20 ft (6 m)	2.25 (55)	3.00 (75)	3.75 (95)	4.50 (115)	5.25 (130)	6.00 (150)	6.75 (170)	7.50 (190)
50 ft (15 m)	5.5 (140)	7.5 (180)	9.0 (225)	10.5 (265)	12.5 (310)	14.0 (350)	16.0 (400)	18.0 (450)
100 ft (30 m)	12 (300)	15 (375)	18 (450)	22 (550)	25 (625)	29 (725)	32 (800)	36 (900)

See MUNICIPEX Installation Guide for more information.

Table 4.2:
Recommended offsets for snaking MUNICIPEX

4.1.5 Testing

Conduct hydrostatic and leakage tests in accordance with AWWA C605. Safety during testing is paramount. Please refer to engineer's instructions for specific test pressure and duration.

4.2 Typical Mechanical Properties

In addition to the dimensions, weights and pressure ratings shown Table 4.1, the following information is also required for certain designs and applications.

4.2.1 Chemical Resistance

MUNICIPEX is resistant to a great number of chemical compounds. For a complete chemical resistance chart, please refer to the *REHAU Chemical Resistance Chart.*

4.2.2 Flow

MUNICIPEX has a smooth, inner wall that minimizes pressure loss through the pipe. It is resistant to mineral build-up, and deposits inside the pipe, allowing it to retain maximum flow rate throughout the life of the pipe. See Table 4.4 for MUNICIPEX pressure loss.

4.2.3 Thermal Properties

MUNICIPEX is a thermoset polymer meaning that it has high temperature capabilities. It is rated for continuous operation of 80 psi at 200°F. Also, because it is cross-linked, it is more flexible than non-cross-linked materials at all temperatures, and especially when cold. MUNICIPEX is still flexible down to -184°F (-120°C).

4.2.4 Impact Resistance

MUNICIPEX has a high impact-resistance that results in "no break" during standard testing. This performance applies at temperatures well below freezing.

4.2.5 Pressure Capability

MUNICIPEX carries the following temperature and pressure ratings for continuous operation:
80 psi @ 200°F (550 kPa @ 93°C)
100 psi @ 180°F (690 kPa @ 82°C)
160 psi @ 73.4°F (1105 kPa @ 23°C)

MUNICIPEX exceeds the following minimum burst pressure requirements:
180 psi @ 200°F (1240 kPa @ 93°C)
210 psi @ 180°F (1450 kPa @ 82°C)
475 psi @ 73.4°F (3310 kPa @ 23°C)

4.2.6 UV Resistance

With its co-extruded blue UV Shield, MUNICIPEX is resistant to degradation caused by UV exposure (sunlight) for up to one year.

Properties	Standard	Value
Density	ASTM D 1505	58 lb ft^3 (930 kg/m^3)
Degree of Cross-Linking	ASTM D 2765	85-87%
Thermal Conductivity	DIN 52612	0.24 BTU/(hr-ft- °F) (0.41 w/[m °K])
Linear Expansion	DIN 42328	9.33 x 10-4 in/(ft °F) (0.14 mm/[m °K])
Pressure Rating	CSA B 137.5 ASTM F 876/877 NSF 14	73.4ºF (23ºC): 160 psi* 180ºF (82ºC): 100 psi* 200ºF (93ºC): 80 psi*
Modulus of Elasticity	DIN 53457	87,000 psi (600 N/mm^2)
Temperature Working Range	N/A	-184ºF to 248ºF (-120ºC to 120ºC)
Maximum Short-term Exposure	N/A	392ºF (200ºC)
Melt Temperature	N/A	752ºF (400ºC)

*MUNICIPEX exceeds these minimums.

Table 4.3:
MUNICIPEX physical properties

	3/4" MUNICIPEX Flows*			1" MUNICIPEX Flows*		
Flow USGPM	Velocity (fps)	Head Loss psi/100 ft	Head Loss ft/100 ft	Velocity (fps)	Head Loss psi/100 ft	Head Loss ft/100 ft
1.0	0.9	0.3	0.7	0.5	0.1	0.2
2.0	1.8	1.1	2.5	1.1	0.3	0.7
3.0	2.7	2.2	5.1	1.6	0.7	1.5
4.0	3.5	3.7	8.7	2.1	1.1	2.5
5.0	4.4	5.6	12.9	2.7	1.6	3.8
6.0	5.3	7.7	17.9	3.2	2.3	5.3
7.0	6.2	10.3	23.6	3.7	3.0	7.0
8.0	7.1	13.0	30.0	4.3	3.9	9.0
9.0	8.0	16.1	37.1	4.8	4.8	11.0
10.0	8.8	19.5	44.9	5.3	5.8	13.4
12.0	10.6	27.0	62.3	6.4	8.0	18.6
14.0				7.5	10.5	24.5
16.0	*Flow of water @ 60ºF			8.5	13.5	31.2
18.0				9.6	16.7	38.5
20.0				10.7	20.2	46.6

*All numbers are approximate.

Table 4.4:
MUNICIPEX pressure loss

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