TO: URIKO
3/13/85

Syska & Hennessy

March 7, 1985

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BUREAU OF SEWERS
MAR 1 1 1985
DIVISION OF
SEWER REGULATION
AND CONTROL

Mr. Magdi Farag, P.E.
Department of Environmental Protection
Bureau of Sewers
40 Worth Street, Room 922
New York, New York 10013

Re: New York Exposition & Convention Center
PVC Drainage Connection to City Storm Sewer

Dear Mr. Farag:

As a follow up to our letter of February 8, 1985 and your telephone call of last week, I am enclosing the following:

a. Load calculations
b. Johns-Manville "Perma-Loc" brochure

You will note that the anticipated loads and associated deflection on the proposed 24 in. diameter PVC connections are well within the limits allowed by the pipe manufacturer and Uni-Bell.

If you require any additional information, please contact me.

Very truly yours,

SYSKA & HENNESSY

Kenneth E. Klein, P.E.
Associate Partner

KEK:bbm

enclosures

cc: I. M. Pei & Partners
Mr. Robert Milburn

Convention Center Development Corp.
Mr. Alan Holland

Syska & Hennessy, Inc.
Mr. Craig Kalle

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Syska & Hennessy, Inc., Engineers 11 West 42 Street, New York, New York 10036 Telephone (212) 921-2300 Telex 127049/125409
New York • Los Angeles • San Francisco • Cambridge

March 6, 1985

Syska & Hennessy

New York Convention Center
Storm Sewer

References: A. Perma-Loc - PVC Sewer/Drain Pipe - Johns-Manville

B. Handbook of PVC Pipe - Design & Construction

1. Pipe: 24 in. Perma-Loc Series 46 ?

2. Soil: Wc = 120 lb/cu. ft

   Soil type - pipe bedding material

   Class III GM, GC, SM, SC

3. Superload: 600 lb/sq ft How ?

   Equivalent height h0 = $\frac{600 \text{ lb/sq ft}}{120 \text{ lb/cu.ft}}$ = 5.0 ft

4. Pipe cover - see sketch

   Min. hl = 3.66 ft
   Max. hl = 6.71 ft

5. Vertical load on plastic pipe (prism load)

   W = Wc x H + Bc lb/ft

   H = 6.71 + 5.0 = 11.71 ft, say 12.0 ft

   W = 3067 lb/ft See Ref. A, table on page 4

   Soil pressure P = Wc x H = 120 X 12 = 1440 lb/ft = 10 lb/sq in.

6. Pipe deflection - modified "IDWA Deflection Formula" - Ref. B, page 144, Equation No. 25:

$$\frac{\%\Delta}{D} = \frac{D2 \times K \times P \times 100}{0.149 \frac{F}{\Delta Y} + 0.061\ E1}$$

$$\Delta y = \frac{D_L K W_c r^3}{EI + .061 E' r^3}$$

D2 = lag factor Ref. B, table 26
K = bedding factor "
E1 = soil stiffness "
$\frac{F}{\Delta Y}$ = pipe stiffness Ref. A

Sidewalk area

Six connections 9' long 3/4"

Bad soil

City plastic pipe

24" sidewalk

March 6, 1985

Syska & Hennessy

New York Convention Center
Storm Sewer

Bedding Class III Moderate 85% - 95% Proctor

$D2 = 1.50$ (max.)
$K = 0.10$
$E1 = 1000$ lb/sq in.
$\frac{F}{\Delta Y} = 46$ psi → Fig 3.
$P = 10$ lb/sq in.

$$\%\frac{\Delta}{D} = \frac{1.5 \times 0.10 \times 10 \times 100}{0.149 \times 46 + 0.061 \times 1000}$$

$$= \frac{150}{6.85 + 61.0} = \frac{150}{67.85} = 2.21\%$$

Less than maximum 7.5%

Vertical Deflection: $\Delta Y = 2.21\% \times 24$ in. $= 0.53$ in.

Horizontal Deflection:

Chapter V pg 137

$\Delta X = 0.913\ \Delta Y$ (Ref. B, page 139, Equation No. 22)

$\Delta X = 0.913 \times 0.53 = 0.48$ in.

VP:bbm

Johns-Manville

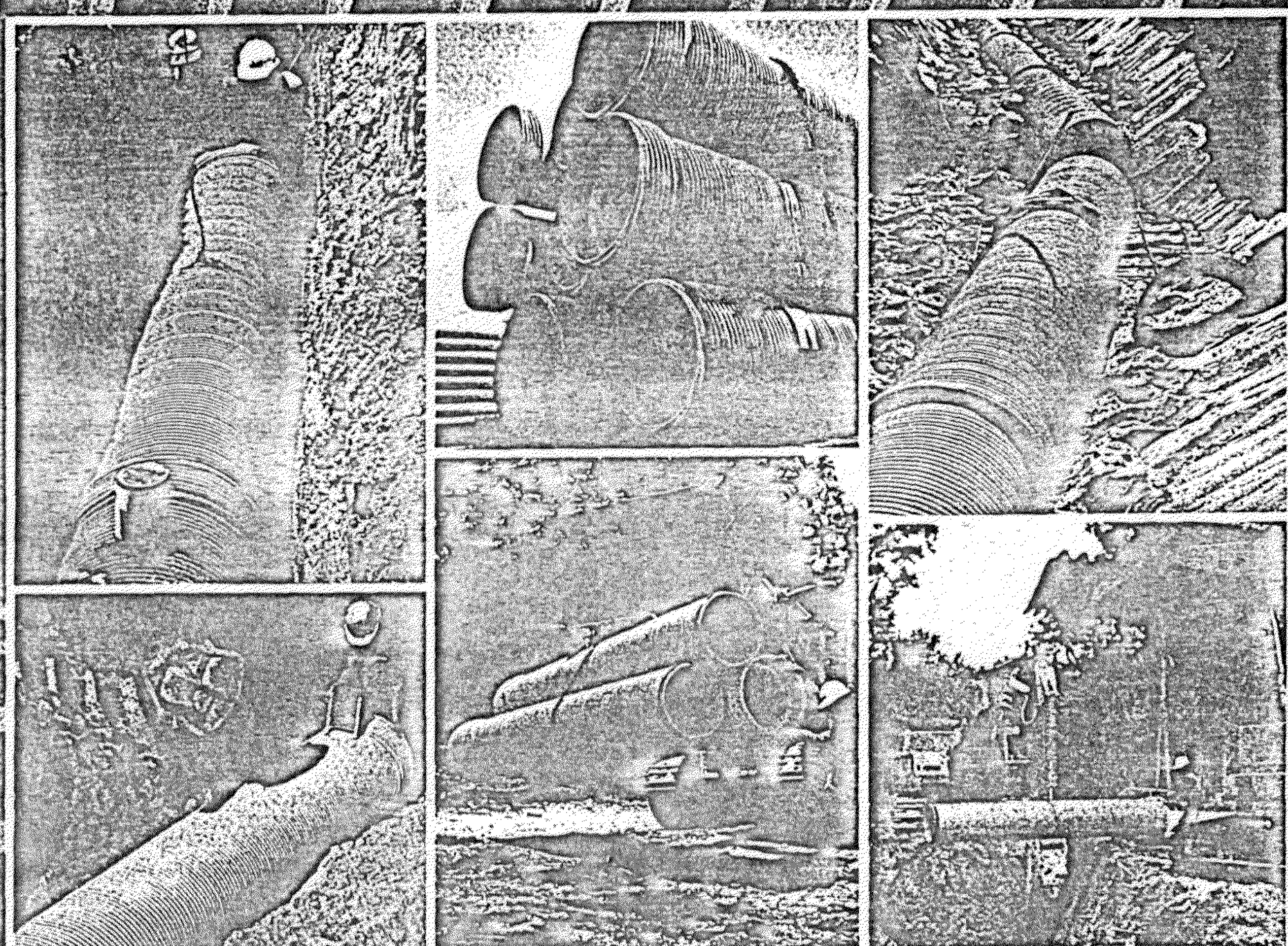
JM

Perma-Loc®

PVC Sewer/Drain Pipe

Series 46

Series 10



Perma-Loc

PVC Sewer/Drain Pipe

Advantages

Johns-Manville large diameter Perma-Loc PVC sewer and drain pipe is suitable for use in conveying ordinary domestic sanitary sewage, many industrial waste materials, and storm water runoff. Its unique design and many product features are the result of research and technology gained from over 50 years of pipe manufacturing. Johns-Manville continues to lead the way in pipe innovations.

Chemical resistance

J-M Perma-Loc pipe is resistant to the fluids found in ordinary sewage. It is also resistant to sewer gases, the sulfuric acid generated by the completion of the hydrogen sulfide cycle, and corrosive soils, both alkaline or acidic.

Abrasion resistance

Perma-Loc offers excellent resistance to abrasion, gouging and scoring and has proven to be superior to most common piping materials.

High flow characteristics

Long lengths, smooth interiors and factory-made close tolerance joints provide a Manning "n" coefficient of .009. This high carrying capacity makes possible the use of flatter grades or smaller diameter pipe in many applications.

Tight joints

Exclusive J-M Ring-Tite® joints assure a tight joint seal to resist infiltration and exfiltration. The factory-installed rubber ring and easy push-together assembly save time and manpower in installation, and the joint makes testing faster and easier. Specify infiltration not to exceed 50 gallons/inch diameter/mile/day.

Long lengths

All Perma-Loc pipe comes in 13' laying lengths. Compared to some other types of sewer pipe, longer lengths mean fewer joints and a savings in installation time.

Light weight

Perma-Loc is a lightweight pipe and can reduce manpower requirements for installation. A length of 18" Series 46 Perma-Loc weighs just 13.4 lb/ft; 21" weighs 18.2 lb/ft; 24" weighs 23.6 lb/ft.

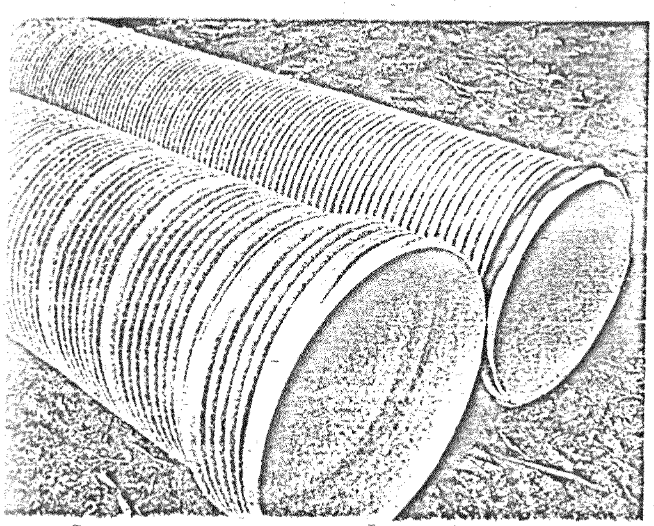
Fittings and accessories

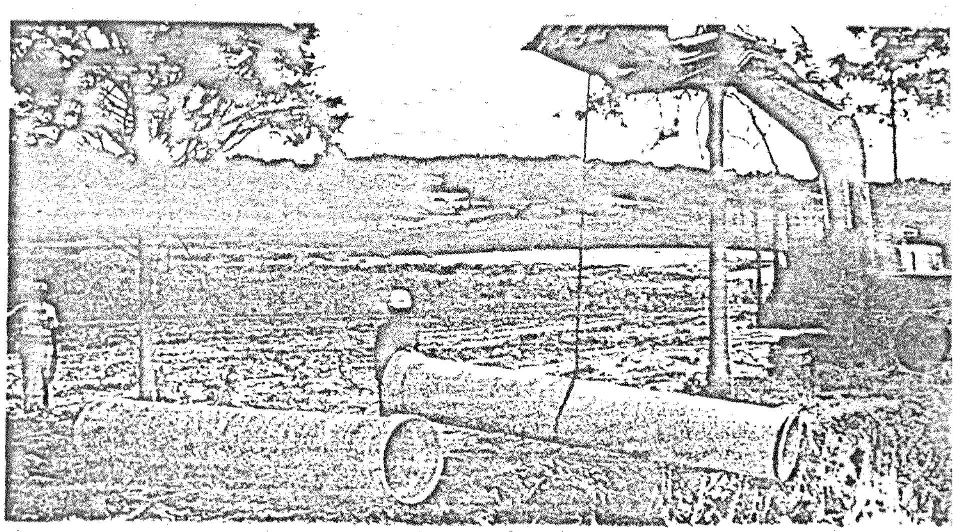
J-M fittings and accessories, as well as saddles manufactured by other vendors, are available for use with Perma-Loc.

Design strength

Perma-Loc is available with a uniform pipe stiffness (FΔy) of 10 psi or 46 psi and is manufactured and tested in compliance with ASTM F 794 specification for "Poly (Vinyl Chloride) (PVC) Large Diameter Ribbed Sewer Pipe and Fittings Based on Controlled Inside Diameter."

Johns-Manville Perma-Loc pipe meets the need for strength and load-bearing capacity in today's sanitary sewage and storm water collection and disposal systems. Unique design and high-performance materials from J-M make it the natural choice in sewage systems from coast to coast.





Loads imposed on buried conduits have, in past practice, been calculated by using the Marston load formula. For trench loads, Marston has a formula for rigid pipe and another formula for flexible pipe. It is important to recognize that under identical conditions of bury, the soil load generated on a flexible conduit is less than the load generated on a rigid conduit. The comparative load on a rigid conduit versus the load on a flexible conduit is expressed as the ratio of trench width to the flexible pipe O.D.

By definition, a flexible conduit is one which will deflect before reaching failure.

Marston's formulas for soil loads:
Rigid pipe $W = C_d\ w\ B_d^2$
Flexible pipe $W = C_d\ w\ B_c\ B_d$

Where:
W = Load on pipe (lb/lin ft)
C_d = Load coefficient
w = Soil unit weight (lb/ft^3)
B_d = Ditch width (ft)
B_c = O.D. of pipe (ft)

Prism load

Loads imposed on buried conduits have been calculated by using the Marston load formulas for rigid and flexible pipe. However, it has been determined that the Marston formula for flexible pipe may not determine the maximum long-term load — the "Prism load" formula is more accurate. The "Prism load" is the weight of the column of soil directly above the pipe. Thus, precautions in keeping the trench narrow are unnecessary for the flexible pipe installation. The important thing is to compact the haunching material from the pipe out to the undisturbed trench walls.

Therefore, Johns-Manville suggests that the maximum long term load be determined by the prism load for design.

Prism load: $P_v = wH$ (lb/ft^2)

Where:
P_v = Pressure at the top of the pipe due to the weight of the soil (lb/ft^2)
w = Soil unit weight (lb/ft^3)
H = Depth from top of pipe to top of ground (ft)

Note: To convert prism load (lb/ft^2) to lb/linear ft, multiply by the O.D. of the pipe in feet, or:
$W = wHB_c$

Live loads

Live loads imposed on buried conduits from traffic must also be considered in a design and become more important at shallow depths. The combination of soil load and live load must be added together to design for the maximum load as shown in curves above.

The soil load and live load must be added to determine the total external load on a buried conduit. This combined load should be used for design. Figure 1 illustrates the magnitude of soil and live loads separately and also charts the magnitude of the combined or total loads. The curves in Figure 1 apply only for H20 highway loading and a soil weight of 120 lb/cu ft.

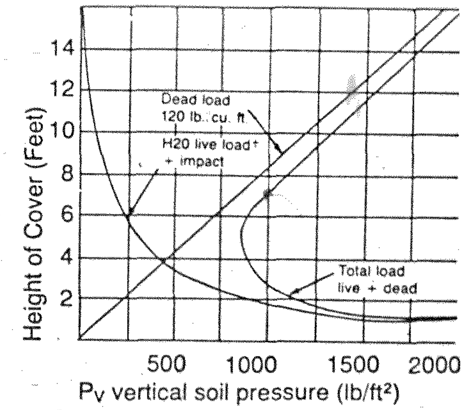


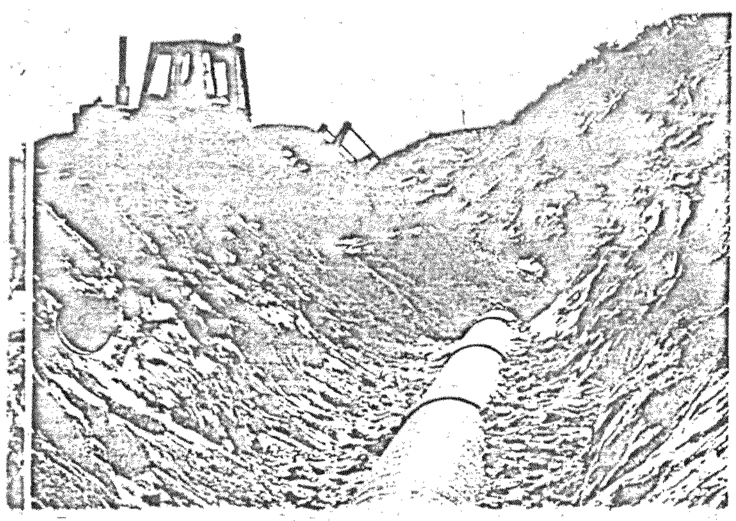
Figure 1.

Note: To convert vertical soil pressure to load on pipe — pounds per lineal foot — multiply by O.D. of pipe in ft.

†Live load applied on assumed area of 36" x 40".

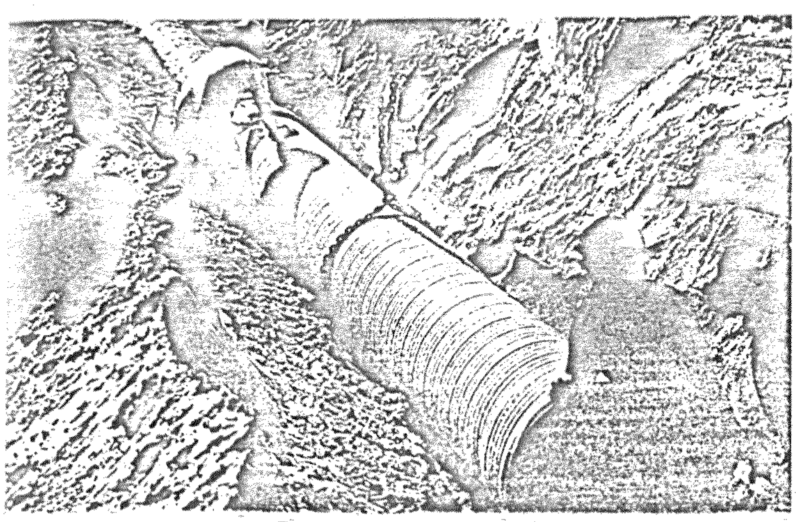
At shallow depths of cover — 3 feet and less, flexible conduits can deflect and rebound under dynamic loading conditions if the trench width is not sufficiently bridged. Unless special precautions are taken to bridge the trench in shallow installations, the breaking up of flexible road surfaces may result. Therefore, for shallow installations under flexible road surfaces (less than 3 feet), J-M recommends Class I * material be used in the pipe zone and up to the road elevation. This recommendation is not meant to conflict with the design engineer's specifications and his specifications will govern.

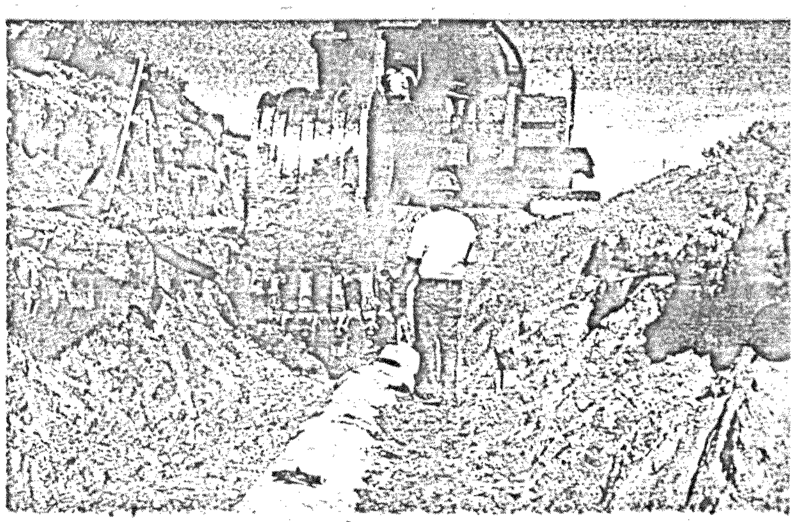
*See page 9 for definition of Class I.



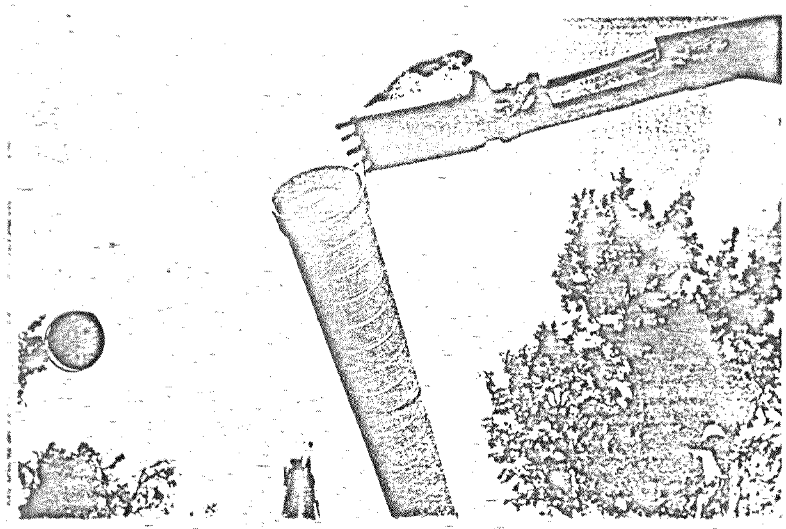
Prism loads on [illegible] sewer pipe (lb [illegible]

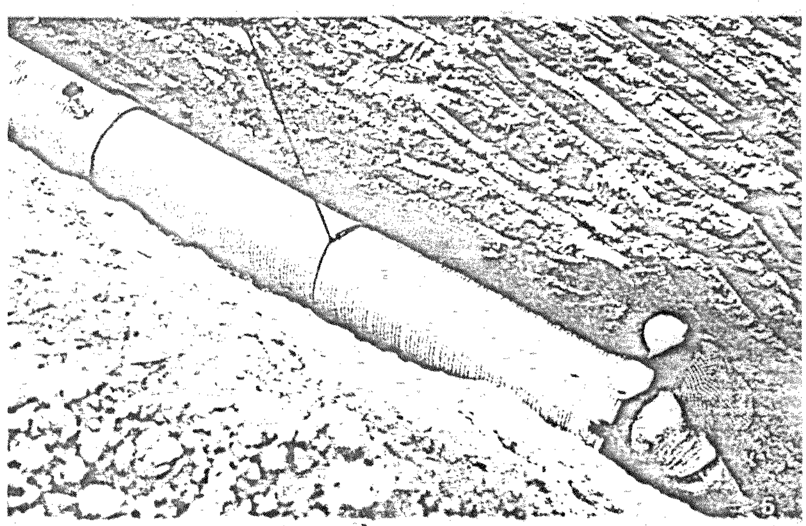
Height of cover (feet)	Soil weight (lb/ft³)	Pipe diameter (inches) 18	21	24
3	100	480	561	636
	110	528	617	703
	120	576	673	767
	130	624	729	831
4	100	640	748	852
	110	704	823	937
	120	768	898	1022
	130	832	972	1108
5	100	800	935	1065
	110	880	1029	1172
	120	960	1122	1278
	130	1040	1216	1385
6	100	960	1122	1278
	110	1056	1234	1406
	120	1152	1346	1536
	130	1248	1459	1661
7	100	1120	1309	1491
	110	1232	1440	1640
	120	1344	1571	1789
	130	1456	1702	1938
8	100	1280	1496	1704
	110	1408	1646	1874
	120	1536	1795	2045
	130	1664	1945	2215
9	100	1440	1683	1917
	110	1584	1851	2109
	120	1728	2020	2300
	130	1872	2188	2492
10	100	1600	1870	2130
	110	1760	2057	2343
	120	1920	2244	2556
	130	2080	2431	2769
11	100	1760	2057	2343
	110	1936	2263	2577
	120	2112	2468	2812
	130	2288	2674	3046
12	100	1920	2244	2556
	110	2112	2462	2812
	120	2304	2693	3067
	130	2496	2917	3323
13	100	2080	2431	2769
	110	2288	2674	3046
	120	2496	2917	3323
	130	2704	3160	3600
14	100	2240	2618	2982
	110	2464	2880	3280
	120	2688	3142	3578
	130	2912	3403	3877
15	100	2400	2805	3195
	110	2640	3086	3515
	120	2880	3366	3834
	130	3120	3647	4153
16	100	2560	2992	3408
	110	2816	3291	3749
	120	3072	3590	4090
	130	3328	3890	4430
17	100	2720	3179	3621
	110	2992	3497	3983
	120	3264	3815	4345
	130	3536	4134	4707
18	100	2880	3366	3834
	110	3168	3703	4217
	120	3456	4039	4601
	130	3744	4376	4984
19	100	3040	3553	4047
	110	3344	3908	4452
	120	3648	4264	4856
	130	3952	4619	5261
20	100	3200	3740	4260
	110	3520	4114	4686
	120	3840	4488	5112
	130	4160	4862	5538





Height of cover (feet)	Soil weight (lb/ft³)	Pipe diameter (inches) 18	21	24
21	100	3360	3927	4473
	110	3696	4320	4920
	120	4032	4712	5368
	130	4368	5105	5815
22	100	3520	4114	4686
	110	3872	4525	5155
	120	4224	4937	5623
	130	4576	5348	6092
23	100	3680	4301	4899
	110	4048	4731	5389
	120	4416	5161	5879
	130	4784	5591	6369
24	100	3840	4488	5112
	110	4224	4937	5623
	120	4608	5386	6134
	130	4992	5834	6646
25	100	4000	4675	5325
	110	4400	5143	5858
	120	4800	5610	6390
	130	5200	6078	6923
26	100	4160	4862	5538
	110	4576	5349	6092
	120	4992	5834	6646
	130	5408	6321	7200
27	100	4320	5049	5751
	110	4752	5554	6327
	120	5184	6059	6901
	130	5616	6564	7477
28	100	4480	5236	5964
	110	4928	5760	6560
	120	5376	6283	7157
	130	5824	6807	7754
29	100	4640	5423	6177
	110	5104	5966	6795
	120	5568	6508	7412
	130	6032	7050	8031
30	100	4800	5610	6390
	110	5280	6172	7030
	120	5760	6732	7668
	130	6240	7294	8308
31	100	4960	5797	6603
	110	5456	6377	7264
	120	5952	6956	7924
	130	6448	7537	8585
32	100	5120	5984	6816
	110	5632	6583	7498
	120	6144	7181	8179
	130	6656	7780	8861
33	100	5280	6171	7029
	110	5808	6789	7733
	120	6336	7405	8435
	130	6864	8023	9138
34	100	5440	6358	7242
	110	5984	6994	7967
	120	6528	7630	8690
	130	7072	8266	9415
35	100	5600	6545	7455
	110	6160	7200	8201
	120	6720	7854	8946
	130	7280	8509	9692





Pipe deflection

Deflection is defined as the change in vertical inside diameter of a flexible conduit when subjected to a vertical load. The amount of deflection that will occur in any flexible conduit is a function of three factors:

1. Pipe stiffness (F/Δy).
2. Soil stiffness.
3. Load on the pipe.

It is important to recognize that flexible conduits perform differently in the ground than they do under laboratory flat plate loading. The interaction of pipe stiffness and soil stiffness combine to give flexible conduits a high effective strength when buried.

Methods for predicting pipe deflection

The most commonly used approach in predicting deflection has been the modified "Iowa Deflection Formula."

Modified Iowa Formula:

$$\Delta y = \frac{D_L K W_c r^3}{EI + .061 E' r^3}$$

Where:

- Δy = Vertical deflection (inches)
- D_L = Lag factor (1.5 maximum)
- K = Bedding factor
- W_c = Earth load (lb/in)
- r = Mean radius* (in)
- E = Modulus of elasticity (lb/in²)
- I = Moment of inertia** (in³)
- E' = Soil stiffness (lb/in²)

*Distance from center of pipe to neutral axis.

Q

**Calculate using standard strength of material formulae.

Although considered a conservative approach, considerable variation in predicted deflection will result depending upon the choice of empirical constants E', K and D_L.

Empirical methods of predicting deflection have evolved in recent years which eliminate the guesswork inherent in the Iowa method. When design is based on actual laboratory test and previous field measurements, it is unnecessary to know the actual load acting on the pipe or the soil stiffness. Thus an installation can be designed with a known factor of safety provided enough empirical data is available.

To accommodate the problem of having to establish data for the number of trench widths that are found in the field, the prism load was chosen because it represents the maximum loading condition on a flexible pipe. Time lag to account for future settlement of the backfill can be included by choosing long-term values of deflection.

Johns-Manville has developed through laboratory tests and actual field data the maximum long-term deflection charts, Figures 2 and 3, shown on page 7. These charts eliminate the guesswork in predicting deflection and give the design engineer a quick ready reference. Figure 2 is for Perma-Loc with a stiffness of 10 psi (Series 10), while Figure 3 is for a stiffness of 46 psi (Series 46). The values given for deflection limits are the ultimate long-term deflection that will occur in a particular soil class having a given density (compaction) in the haunching area of the pipe zone for various heights of cover (feet).

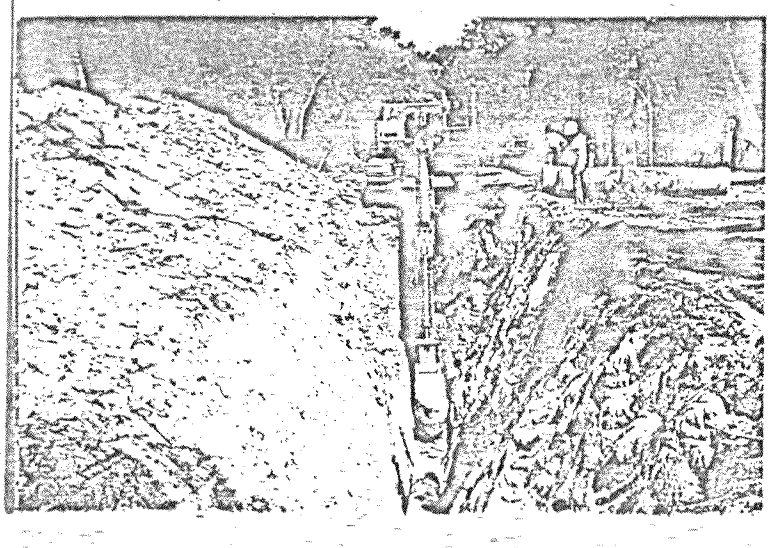
1. Where live loads are not a factor or not involved in the total external load on the pipe, the chart can be used directly to determine the limit of the maximum long-term deflection of the PVC pipe.

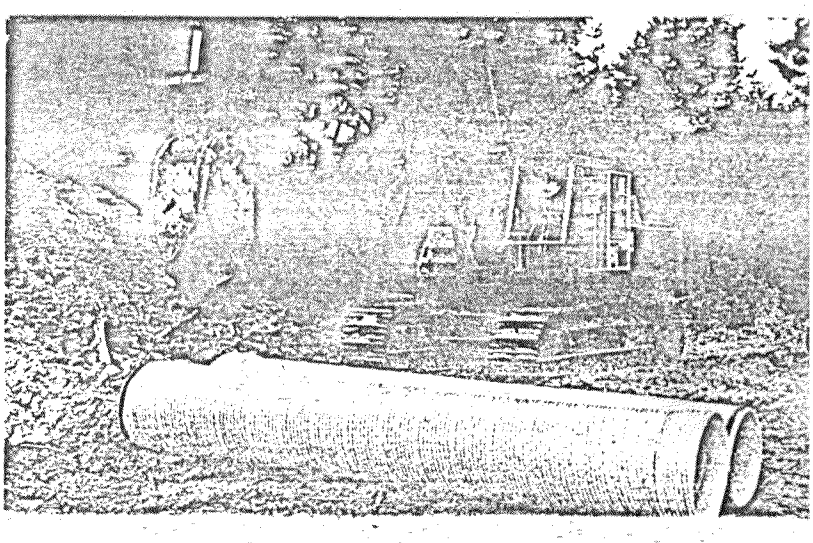
Example: If a 24" Perma-Loc Series 10 pipe is installed in Class IV material, having 85% compaction in the pipe zone and with 12 feet of cover, will this recommended maximum long-term deflection of 7½% be met?

Answer: Enter Figure 2 at 12 feet of cover, Class IV material at 85% compaction, pipe will never deflect more than 7½% (color code — green).

2. Where live loads must be considered, determine first the combined total external load on the pipe. Next determine the equivalent prism load (without live load) for the particular pipe size involved using the table of prism loads. Read across to the left for the height of cover (ft) for the equivalent prism load. Using this height of cover with the bedding class and Proctor density, enter the maximum long-term deflection chart, Figure 2, to determine the maximum long-term deflection limit.

Fig 2 & Fig 3 ?





F/Δy 10 PSI (SERIES 10) PVC PIPE (7½ percent)

Figure 2. Maximum long-term ections of F/Δy 10 psi (Series FIGURE 2

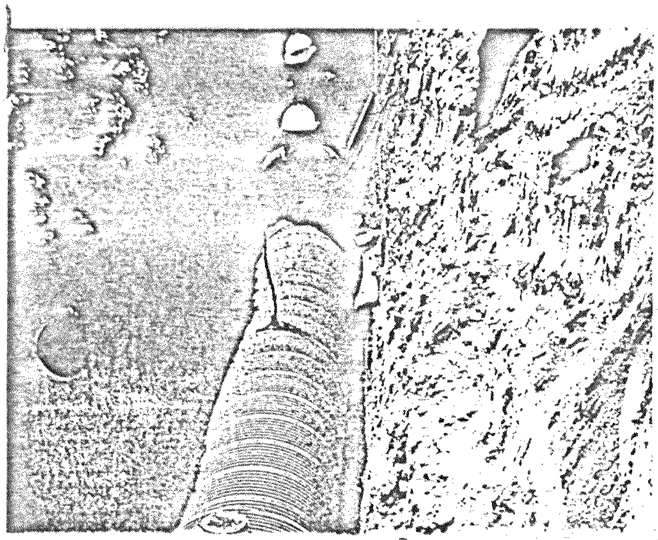
ASTM Bedding Classification		Density (Proctor) AASHTO T-99	Height of cover (feet)																
			3	5	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36
Gravel	Class I	95%																	
	Class II	90%	Maximum 7.5% deflection																
		80%	This zone not recommended																
Sand	Class III	90%																	
		85%			✓														
		75%																	
		65%																	
Clay	Class IV	85%					GREEN												
		75%																	
		65%																	
Peat	Class V		This soil class not recommended.																

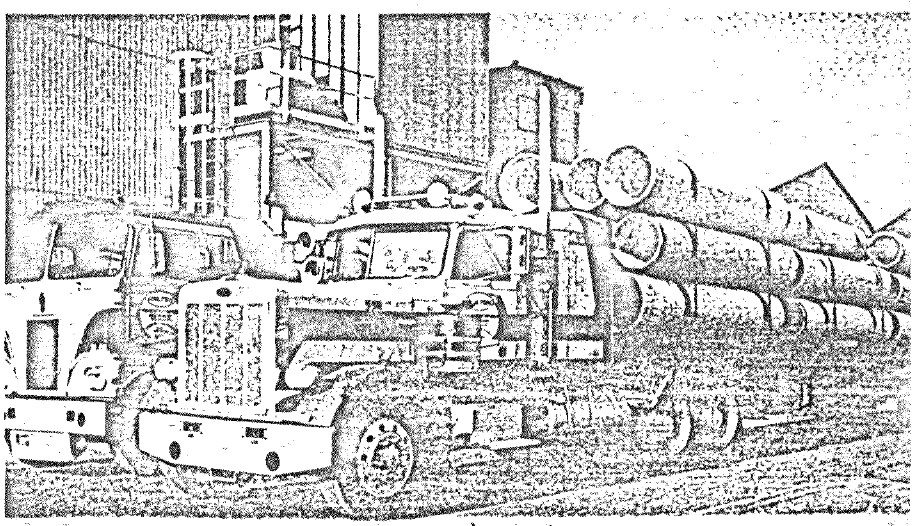
Figure 3. Maximum long-term deflections of F/Δy 46 psi (Series 46) PVC pipe (7½ percent)

ASTM Bedding Classification		Density (Proctor) AASHTO T-99	Height of cover (feet)																
			3	5	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36
Gravel	Class I	95%																	
	Class II	90%	Maximum 7.5% deflection																
		80%	This zone not recommended																
Sand	Class III	90%																	
		85%																	
		75%																	
		65%																	
Clay	Class IV	85%																	
		75%																	
		65%																	
Peat	Class V		This soil class not recommended.																

Note: Deflection values shown do not include effect of live load or longitudinal bending.

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. External loading based upon soil weight of 120 lbs per cubic foot.
3. Deflections predicted are based upon pipe which was initially circular prior to installation. Actual deflections may differ because of initial out-of-roundness caused by storage and/or handling. These variations should be taken into account when measured deflections are compared with those in the table.
4. Bedding classifications are as indicated on page 9 and correspond to ASTM D 2321.
5. Deflections listed in table are maximum long-term values. The recommended maximum long-term value is 7.5 percent.





Example: If an 18" Perma-Loc sewer pipe is installed in Class III material, having 75% compaction in the pipe zone with 7 feet of cover and 120 lb/ft³ soil, and H20 (highway load) live load are imposed on the buried pipe, will the recommended maximum long-term *deflection of 7½% be exceeded?*

Answer: 1. The combined (dead and live) load on the pipe will be approximately 1000 lb/ft² or 1000 x 1.6 ft (pipe outside diameter [top of ribs] in feet) = 1600 lb/lin ft (per Figure 1). Enter table of prism loads under column 18 — Pipe diameter (inches) — and read down until nearest figure to 1600 is reached, across from soil weight of 120 lb/ft³. In this case, 1536 appears opposite 120 lb/ft³ and 8 ft — height of cover. This represents the equivalent prism load for the combined (dead and live) load given above. Now enter maximum long-term deflection chart (Figure 2) for Class III bedding classification, 75% density, and 8 ft of cover, and determine if the maximum long-term deflection of 7½% is exceeded. The green color code shows it will not exceed 7½%. This is true for either Series 10 or Series 46.

In working with these charts, it becomes apparent that:

1. Soil density in the pipe zone plays a greater role than soil type in the control of deflection in buried flexible conduits.

2. The amount of deflection is independent of pipe size, providing all pipe sizes are a stiffness of F/Δy 10 psi (Figure 2) or F/Δy 46 psi (Figure 3). Note pipe size does not appear in the chart for maximum long-term deflections.

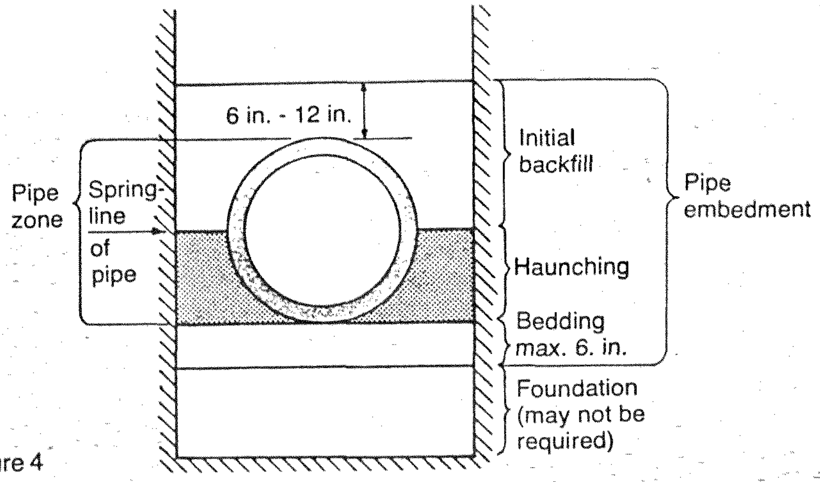


Figure 4

Foundation
Preparation is only required when the trench bottom is unstable. Any foundation that will support a rigid pipe without causing loss of grade or flexural breaking of pipe will be more than adequate for PVC pipes.

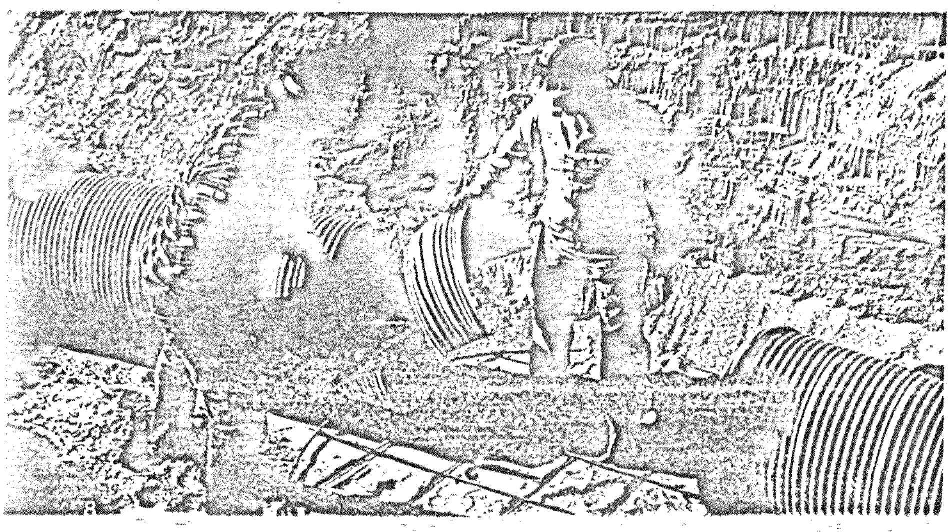
Bedding
The bedding directly underneath the pipe is required only to bring the trench bottom up to grade. It should not be so thick or soft that the pipe will settle and lose grade. The purpose of the bedding is to provide uniform longitudinal support of the pipe.

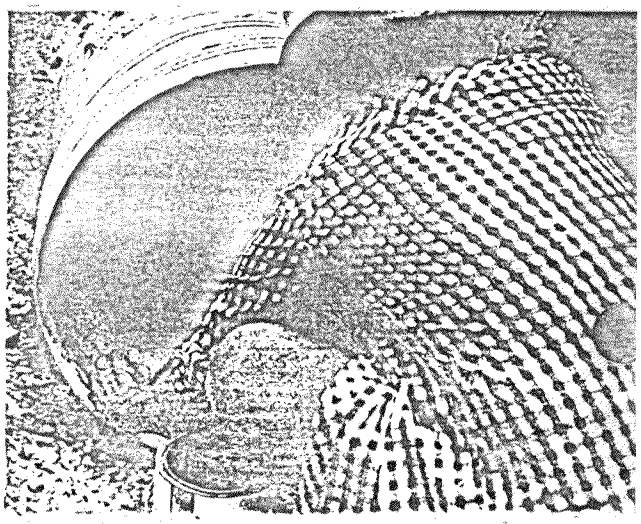
Haunching
The haunching area is the most important in terms of limiting the deflection of a flexible pipe. This is the area that should be compacted to the Proctor densities shown in charts on page 7.

Initial backfill
Initial backfill begins above the springline of the pipe to a plane 6 inches to 12 inches above the pipe. Compacting soils to levels above the springline gives little additional side support.

Most of the support is accomplished by compacting the soil surrounding the lower half of the pipe.

Caution: If hydro-hammers are used to prepare the bedding and backfill for the road surface, they should not be used within 3 feet of the top of the pipe and then only if the pipe zone soil density has been previously compacted to a minimum 85% standard Proctor density.





Pipe zone materials include the material in the haunching area and the initial backfill (see Figure 4). They include a number of processed materials plus the soil types listed under USCS Soil Classification System (FHA Bulletin No. 373). These materials are grouped into five broad categories according to their suitability for this application, as follows.

Class I. Angular, ¼" to 1½" graded stone, including a number of fill materials that have regional significance such as coral, slag, cinders, crushed stone and crushed shells.

Class II. Coarse sands and gravels with maximum particle size of 1½", including variously graded sands and gravels containing small percentages of fines, generally granular and noncohesive, either wet or dry: Soil type GW, GP, SW and SP are included in this class.

Class III. Fine sand and clayey gravels, including fine sands, sand-clay mixtures, and gravel-clay mixtures. Soil types GM, GC and SM and SC are included in this class.

Class IV. Silt, silty clays, and clays, including inorganic clays and silts of medium to high plasticity and liquid limits. Soil types MH, ML, CH and CL are included in this class.

Class V. These materials are not recommended for bedding, haunching or initial backfill.

The performance of a flexible conduit does not depend only on the class of embedment materials used, but more importantly, on the density of the material in the haunching zone. Figure 3 on page 7 shows that a Series 46 Perma-Loc pipe will perform in Class III material equally as well as in a Class I material if adequate compaction is achieved. A further comparison of Figure 2 and Figure 3 shows that a Series 10 Perma-Loc pipe will perform as well as a Series 46 pipe at the same height of cover when the appropriate bedding class and compaction are utilized. By using a combination of soil class, soil density, and series classification of Perma-Loc, the design engineer can achieve the most economical installation within the recommended deflection limits.

Excavation and pipe laying

As with other pipes, the trench for PVC is excavated with bell holes to give uniform bearing along the full length of each pipe section. The ditch should be wide enough to allow for proper placement and compaction of the selected materials in the haunching area.

Sheeting

If unstable soil conditions or regulations require the use of sheeting or boxes, they should be used in a manner not to disturb the embedment material within three pipe diameters on each side of the installed pipe.

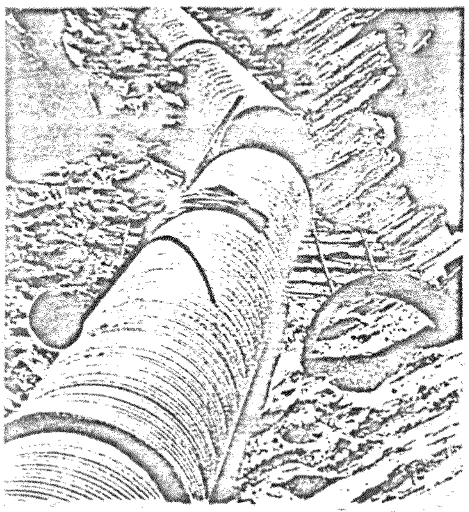
Compaction techniques

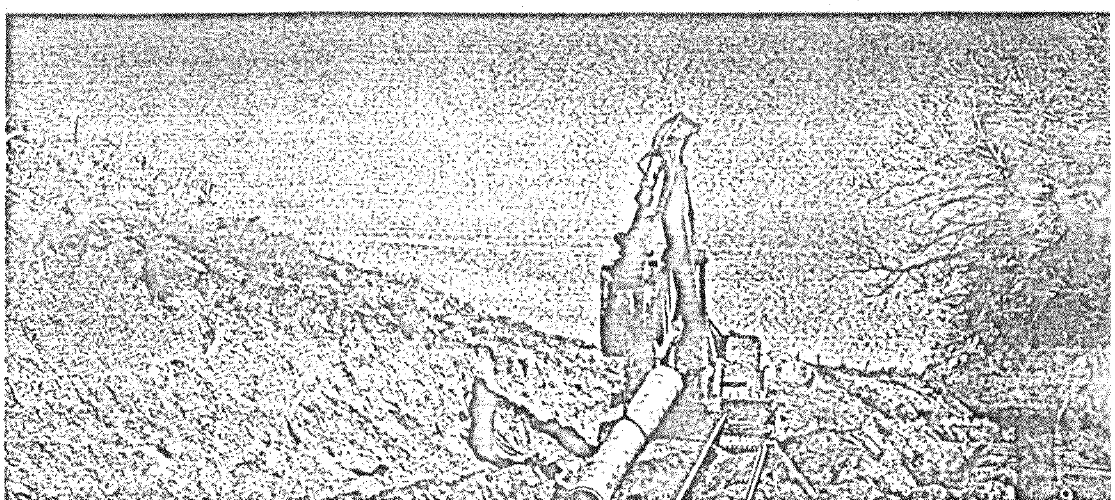
Flooding or jetting are commonly used methods for obtaining desired densities of granular embedment materials. If flooding is used, the embedment materials should be allowed to dry *below* optimum moisture before final backfill operations are begun. If jetting is used, desired density of the embedment materials should be previously obtained by other methods. Neither flooding or jetting should be used if the possibility of washing away side support exists.

Deflection testing

Johns-Manville's position on deflection testing is that routine measurement of deflection of installed Perma-Loc may be unnecessary, uneconomical, and an added construction cost for Perma-Loc PVC pipe installations. This position applies to all routine deflection testing whether performed by the "Go-No Go Gauge" method for compliance to maximum deflection limits or by instruments which measure and record actual pipe deflections. When recommended installation practices are followed, including required compaction in the haunching area, pipe deflection will not exceed our recommended long-term deflection limit of 7.5%. At this deflection limit, the PVC sewer pipe will have a minimum factor of safety of 4 in structural failure. Proof of this position is that more than 500,000,000 feet of PVC sewer pipe are performing satisfactorily in the field today.

On the other hand, where improper installation practices are known or suspected, questionable bedding materials are employed and/or installation conditions are severe, deflection testing of these sections of the installation should be considered advisable by the engineer.





Short form spec

This specification designates general requirements for unplasticized polyvinyl chloride (PVC) plastic (spiral wound) gravity sewer pipe with integral wall bell and spigot joints for the conveyance of domestic sewage and storm water.

Materials

All pipe and fittings shall be manufactured and tested in accordance with ASTM F 794 specification for "Poly (Vinyl Chloride) (PVC) Large Diameter Ribbed Gravity Sewer Pipe and Fittings Based on Controlled Inside Diameter."

The pipe and fittings shall be made of PVC plastic having a minimum cell classification of 12454C or 13364C as defined in ASTM D 1784. The pipe shall be colored green for in-ground identification as sewer/drain pipe.

Pipe

All pipe shall be either Series 10 or Series 46, depending on the height of cover, soil class and percent of Proctor density in the haunching area. Provisions must be made for contraction and expansion at each joint with a rubber ring. The bell shall consist of an integral wall section. The solid cross section rubber ring shall be factory assembled in either the bell or spigot. Sizes and dimensions shall be as shown in this specification. Standard laying lengths shall be 13 ft. ±1 inch. At manufacturer's option, random lengths of not more than 15% of total footage may be shipped in lieu of standard lengths.

Joining system

Integral bell gasketed joint: The joint shall be designed so that when assembled, the gasket (which is attached to either the bell or spigot) will be compressed radially on the pipe spigot or in the bell to form a watertight seal in accordance with ASTM D 3212.

The joint shall be designed to avoid displacement of the gasket when installed in accordance with the manufacturer's recommendation.

The assembly of joints shall be in accordance with the manufacturer's recommendations.

Determine the impact resistance of the pipe in accordance with ASTM D 2444, using the 30 lb. (15 kg.) Tup B and flat plate holder B. Ten specimens shall be tested. The specimens should be oriented so that one of the ribs receives the strike essentially centered on the tup face. Failure in the test specimens shall be any shattering or any crack or split extending through the main wall of the pipe that was created by the impact and that can be seen by the naked eye. Nine out of ten specimens passing constitute an acceptable product. The impact strength shall not be less than 220 ft. lbs.

Note: Shorter sections, not less than 12 inches in length, may be tested to accommodate the impact testing machine since this will be a more severe impact resistance test.

Fittings

All fittings and accessories shall be as manufactured and furnished by the pipe supplier or approved equal and have bell and/or spigot configurations compatible with that of the pipe.

All fittings are fabricated fittings. Fabricated fittings with solvent cemented components shall be made in accordance with ASTM D 2855 and taking cognizance of ASTM F 402.

Pipe shall be designed to pass all tests described here at 73°F (±3°F).

The pipe stiffness shall equal or exceed 10 psi or 46 psi when tested in accordance with ASTM D 2412. Test three specimens, minimum one diameter long, and determine the average pipe stiffness.

Note: Pipe may be restrained in flat plate test to prevent twisting in the test apparatus.

Joint tightness

Two sections of pipe shall be assembled in accordance with the manufacturer's recommendation. Joint shall be tested in accordance with ASTM D 3212, "Joints for Drain and Sewer Plastic Pipes Using Flexible Elastomeric Seals."

Flattening

Flatten three specimens of pipe, each a minimum of 6 inches long, between parallel plates in a suitable press until the distance between the plates is 40% of the outside diameter of the pipe. The rate of loading shall be uniform and such that the compression is completed within 2 to 5 minutes. The specimen shall pass if no splitting, cracking, or breaking is observed under normal light with the unaided eye. Small tears initiated at the cut end of the rib shall not constitute failure.

Dimensions

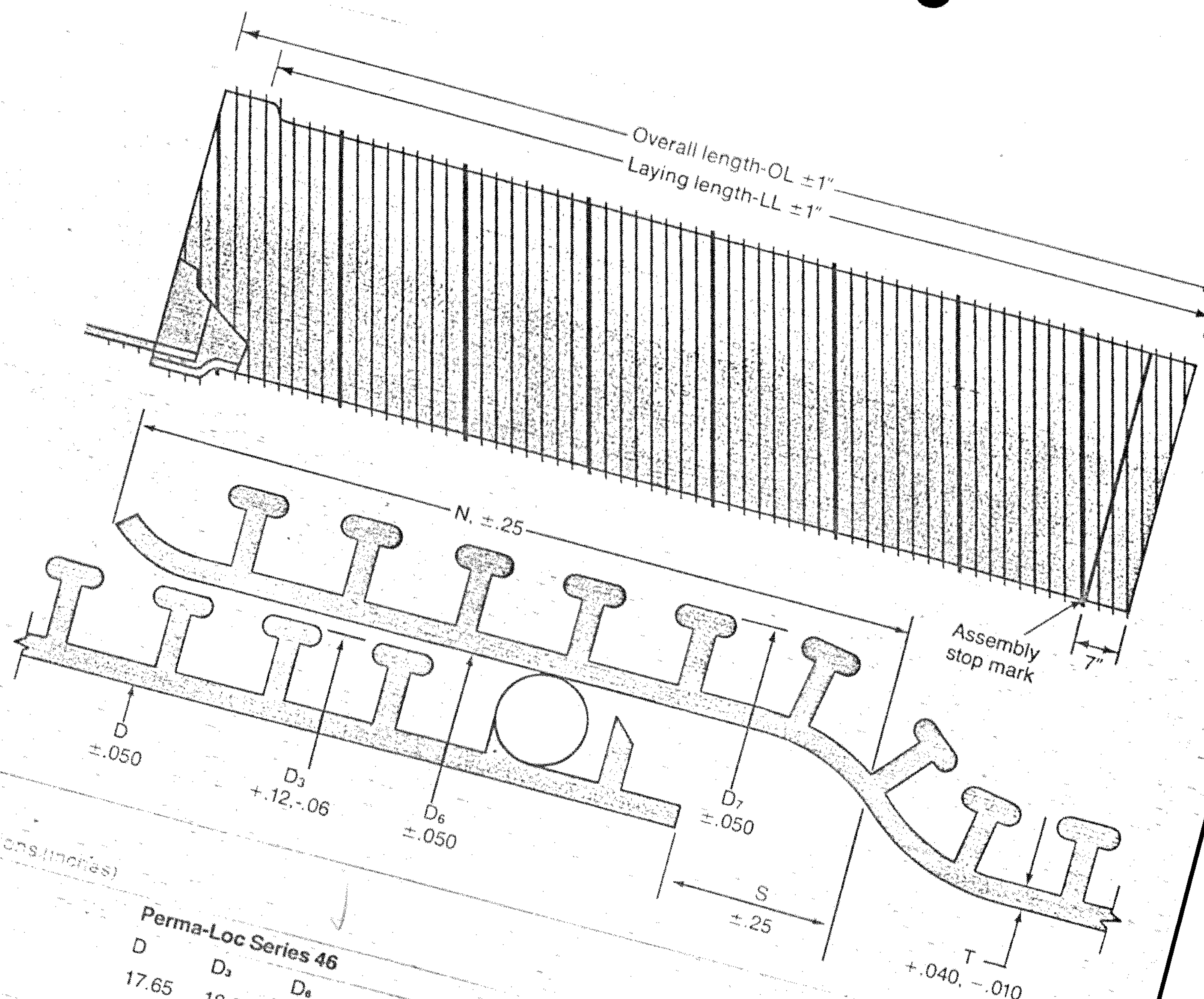
Dimensions shall comply with those in the table below.

Pipe size (inches)	Average ID (inches)	Tolerance on average ID (inches)	Minimum wall thickness (inches) Series 46 (46 psi)	Minimum wall thickness (inches) Series 10 (10 psi)
18	17.65	±.055	.130	.070
21	20.75	±.060	.160	.085
24	23.65	±.070	.180	.105

The above sizes, dimensions and tolerances for Series 10 and 46 are in inches to correspond respectively to Series 10 and 46 per latest Uni-Bell Plastic Pipe Association Specification UNI-B-9 and ASTM F 794.

Inside diameter: Determine the average inside diameter using an internal micrometer or telescoping gauge accurate to ±0.001 inch. Take sufficient readings, a minimum of 4, to ensure that the maximum and minimum have been determined. Calculate the average diameter as the arithmetic mean of the diameters measured. As an alternate method, an ID type circumferential tape may be used if proper care is taken to align it at right angles to the pipe axis.

Wall thickness: Measure the wall thickness of the waterway in the gaps between ribs in accordance with Section 4 of ASTM D 2122. Make sufficient readings, a minimum of 8, to ensure that the minimum thickness has been determined.



Dimensions (inches)

Pipe size	Perma-Loc Series 46 D	D_3	D_6	D_7	T	S	N	LL	OL	Perma-Loc Series 10 D	D_3	T
18	17.65	19.23	19.38	20.97	.18	1.0	7.0	13'-0"	13'-7"	17.65	18.65	.10
21	20.75	22.47	22.64	24.45	.21	1.0	7.0	13'-0"	13'-7"	20.75	21.91	.12
24	23.65	25.60	25.78	27.70	.24	1.0	7.0	13'-0"	13'-7"	23.50	24.82	.14

Weight*

Pipe size (in)	Series 46 Lbs/ft	Lbs/length	Series 10 Lbs/ft	Lbs/length
18	13.4	181	7.4	96.2
21	18.2	251	10.3	133.9
24	23.6	318	13.1	170.3

*Weights are approximate and may vary.

Warranty
We warrant that our products are manufactured in accordance with our applicable material specifications and are free from defects in workmanship and materials using our specifications as a standard. Every claim under this warranty shall be deemed waived unless received in writing by Johns-Manville Corporation within thirty (30) days of the date the defect was discovered or should have been discovered and within one (1) year of the date of the shipment of the product. JOHNS-MANVILLE CORPORATION MAKES NO OTHER REPRESENTATION OR WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, IN FACT OR IN LAW, INCLUDING WITHOUT LIMITATION, THE WARRANTY OF MERCHANTABILITY OR THE WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE, OTHER THAN THE LIMITED WARRANTY SET FORTH ABOVE.

Limitation of Liability
The limit and exclusive remedy for J-M liability shall be the resupply of a like quantity of nondefective product, regardless of whether the defect was latent or obvious, and J-M shall have no such liability except where the damage or claim results solely from breach of J-M's warranty. J-M SHALL NOT BE LIABLE FOR ANY INCIDENTAL, CONSEQUENTIAL, OR OTHER DAMAGES FOR ANY ALLEGED NEGLIGENCE, BREACH OF WARRANTY, STRICT LIABILITY, OR ANY OTHER THEORY, OTHER THAN THE LIMITED LIABILITY SET FORTH ABOVE.

The physical (or chemical) properties of Johns-Manville Perma-Loc PVC sewer/drain pipe represent typical average values obtained in accordance with accepted test methods and are subject to normal manufacturing variations. They are supplied as a technical service and are subject to change without notice. Check the Johns-Manville district office to assure current information.

For information on other products and systems, call Johns-Manville at (303) 978-4900.

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Ken-Caryl Ranch
P.O. Box 5108
Denver, Colorado 80217

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Customer Service Centers

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P.O. Box 185
Green Cove Springs, FL 32043
(904) 284-3091

California
P.O. Box 1587
Stockton, CA 95201
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Central
Highway 75 North
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(214) 465-6390

Western
2600 Campus Drive
San Mateo, CA 94403
(415) 349-9500

Manville Canada Inc.
295 The West Mall
Etobicoke, Ontario M9C 4Z7
Toronto • Montreal • Ottawa • Edmonton • Vancouver

Manville International Corp.
For Export
P.O. Box 5705 Int.
Denver, Colorado 80217
(303) 978-2000
Telex: Johnmanvl Dvr 454404

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TABLE 26 – 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

[a] ASTM Designation D-2487, USBR Designation E-3.
[b] LL = Liquid limit.
[c] Or any borderline soil beginning with one of these symbols (i.e., GM-GC, GC-SC).
[d] For ±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-lb/cu ft (598,000 J/m³) (ASTM D-698, AASHO T-99, USBR Designation E-11). 1 psi = 6.9 kN/m².

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 JOURNAL OF GEOTECHNICAL ENGINEERING DIVISION, JANUARY 1977, PP. 33-43.

The only parameter remaining in the Iowa Formula now needed to calculate deflections is the deflection lag factor D_L. Spangler recognized that in pipe-soil systems, as with all engineering systems involving soil, the soil consolidation at the sides of the pipe continues with time after the maximum load reaches the top of the pipe. His experience had shown that deflections could increase by as much as 30 percent over a period of 40 years. For this reason he recommended the incorporation of a deflection lag factor of 1.5 as a conservative design procedure.

Time lag will be discussed in much greater detail in another section of this chapter.

Under most soil conditions, flexible PVC pipe tends to deflect into an elliptical shape and the horizontal and vertical deflections may be considered equal for small deflections (Δ). Since most PVC pipe is described by either pipe stiffness (**F/ΔY**) or outside diameter to thickness ratio (**DR**), the Iowa Equation (24) can be transposed and rewritten as follows:

EQUATION 25

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

EQUATION 26

$$\% \frac{\Delta}{D} = \frac{D_L KP(100)}{[2E/3\,(DR - 1)^3] + 0.061E'}$$

Where: **P** = Prism Load (Soil Pressure), psi

The above equations may be used in conjunction with the values for the empirical constants **E′**, D_L and **K**. The following example illustrates their use.

Example: What is the deflection of a DR 18 PVC pipe if buried on a flat bottom trench in a fine grained soil with unit weight of 120 lbs per ft³ and with liquid limit less than 50% if the depth of burial is 10 feet?

From Table 26, **E′** = 200 psi and incorporating a bedding constant, **K** = 0.1, and the prism load as assumed in the derivation of Table 27 along with a deflection lag factor of D_L = 1.5, the following results are derived:

$$P = wH \qquad \% \frac{\Delta}{D} = \frac{D_L KP\,(100)}{[2E/3(DR - 1)^3] + 0.061E'}$$

$$P = 120 \frac{lb}{ft^3} \times 10\ ft \times \frac{1\ ft^2}{144\ in^2} = 8.33\ psi$$

$$\frac{2E}{3(DR - 1)^3} = \frac{2(400{,}000)}{3(18 - 1)^3} = 54.28\ psi$$

$$\% \frac{\Delta}{D} = \frac{1.5(0.1)(8.33)(100)}{54.28 + 0.061(200)} = 1.9\ percent$$

For the general case, live loads should be added to the earth load to determine the total load at the depth being considered.

In Table 27, results of calculations of deflections of buried AWWA C900 DR 14, 18, and 25 PVC pipe are presented for cases where either highway or railway loads are present.

TABLE 25 – VALUES OF BEDDING CONSTANT, K

BEDDING ANGLE (DEGREES)	K
0	0.110
30	0.108
45	0.105
60	0.102
90	0.096
120	0.090
180	0.083

Two other observations from Watkins' work are of particular note: (1) There is little point in evaluating E′ by a model test and then using the modulus to predict ring deflection. The model gives ring deflection directly. (2) Ring deflection may not be the only performance limit.

Many research efforts have attempted to measure E′ without success. The most useful method has involved the measure of deflections for a pipe under which other conditions were known followed by back-calculation through the modified Iowa Formula to determine the correct value of E′. This requires assumptions regarding the load, bedding factor and deflection lag factor to be used and has led to a wide range of reported values of E′.

One of the most recent attempts to acquire information on values of E′ was conducted by Amster K. Howard, of the United States Bureau of Reclamation. Howard reviewed both laboratory and field data from many sources. Using information from over 100 laboratory and field tests, Howard compiled a table of average E′ values for various soil types and densities (See Table 26). He was able to do this by assuming values of E′, K and W_c and then back-calculating through the Modified Iowa Formula to calculate a theoretical value of deflection. This theoretical deflection was then compared with actual measurements. By assuming the E′ values of Table 26, a bedding constant K = 0.1, and deflection lag factor D_L = 1.0, Howard was able to correlate the theoretical and empirical results to within ± 2 percent deflection if he used the prism soil load. This means that if theoretical deflections, using Table 26, were approximately 5%, measured deflection would range between 3 and 7%. Although the vast majority of data from this study was taken from tests on steel and reinforced plastic mortar pipe with diameters greater than 24 in., it does provide some useful information to guide designers of all flexible pipe including PVC pipe since it helps to give an understanding of the Modified Iowa Deflection Formula.

TABLE 26 – AVI

Soil type-pi
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Fine-grained Soils (LL
Soils with medium to
CH, MH, CH-MH
Fine-grained Soils (LL
Soils with medium to
ML-CL, with less
particles
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Soils with medium to
ML-CL, with mor
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Crushed Rock
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