Productive & Industrial Co.
HDPE Pipes & Fittings Manufacturer

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Polyethylene Pipe Application

P.E.S has been established in 1977 in Tehran with focus on designing and installation polyethylene pipe . system for water supply, sewage and irrigation systems

In 1981 P.E.S started to produce PE pipe and fittings. Since then, P.E.S has become the leading manufacturer of HD PE pipes and fittings sector in Iran. These, by employing know-how and determined efforts, the company successfully increased its capacity to 7700 tons annually and completed the range of its products up to 2400 mm and became the exclusive manufacturer of solid-wall HD PE large size . pipes and fittings in Iran

Determining quality, technology and customer satisfaction as our first goals to achieve, direct us to supply high quality products to the market and maintain ourselves with the fast renovations in the world . of plastic industry

As an experienced pipe producer, P.E.S applies knowledge, creativity, ability and excellent workshop machinery to manufacture down stream extrusion line. Our manufactured equipments like as Extruder heads, Die heads, Calibrators, Haul-offs, Markers, Vacuum and Cooling tanks are compatible with international standards and compete well-known products worldwide. Our high quality solid wall polyethylene pipes and fittings have been used effectively in many agricultural, industrial and municipal .projects

- Pressure and Gravity water supply

:Some popular application of of our HD PE pipes includes

- Pressure and Gravity municipal and industrial sewage System
- Gas Distribution System
- Marine Intakes and Outfalls
- Marine and river Crossings
- Potable Water Piping
- Power Plant Applications
- Agricultural Drainage System
- Irrigation System
- Directional Drilling and Relining Applications Mining Industry
- Fire Protections Lines
- Perforated Pipes

Mining

Polyethylene pipes are used in mining industry for Water Supply Acid Mine Drainage, Chemical Mineral ms,eExtraction, Slurry and Tailings Lines, Decant Syst Dewatering, Impoundment Piping, Process Pipe and Fittings and Waste Transportation. They are light ey arehweight, flexible, easy to transport and install. T hcorrosion and erosion. resistant, maintain a smoot elbore and when properly installed require very litt maintenance. HD PE pipes and fittings in mining evindustry have major cost advantages over competiti products. They can be installed above and below .ground

Polyethylene molded and fabricated fittings are designed to be joined to polyethylene pipe by a simple heat fusion process. The procedures and principles for fusion are essentially the same as that for joining polyethylene pipe, producing a joint that is as strong as the pipe itself. Fittings are produced from the same HD PE resins used to extrude th pipe. Polyethylene fittings 20 to 400 mm shall be injection molded and from 160 to 2400 mm and larger diameter shall be fabricated from HD PE resin. All fittings shall have the same pressure rating as the pipes have.

P.E.S is one of the middle-east leaders in production and development of polyethylene pipe system. To be able to maintain with the fast growing renovations in the world, P.E.S keeps developing new and needed products with the support of its technical and research division. We also have capabilities to develop technology and manufacture downstream extrusion line equipments like as Die heads, Calibrators, Vacuum tanks, Cooling tanks and Haul-offs. Additionally, our qualified staff assists you to solve problems relating to the design, application, planning and installation of various HD PE pipe system.

The HD PE solid wall pipe is outside diameter controlled pipe which its pressure rating will differ by wall thickness.

The HD PE pipes usually classify by SDR number which is the ratio of outside diameter to minimum wall thickness.

The following table shows dimension and maximum continues operating pressure for HD PE pipes based on PE 100 and PE 80 material and water service temperature at 20°C

- All dimensions are in millimeters - SF: 1.25
- Pipe dimensions are in accordance with EN12201 and DIN8074
- The non-listed diameters and PR classes may be available upon special request

d_n	Nominal Pressure																					
	PE 80	PN 3.2	PN 4		PN 5		PN 6		PN 8		PN 10		PN 12.5		PN 16		PN 20		PN 25		PN 32	
	PE 100	PN 4	PN 5		PN 6		PN 8.0		PN 10		PN 12.5		PN 16		PN 20		PN 25		PN 32		PN 40	
	SDR																					
	41		33		26		21		17		13.6		11		9		7.4		6		5	
	e_{min}	e_{max}	e_{min}	e_{max}	e_{min}	e_{max}	e_{min}	e_{max}	e_{min}	e_{max}	e_{min}	e_{max}	e_{min}	e_{max}	e_{min}	e_{max}	e_{min}	e_{max}	e_{min}	e_{max}	e_{min}	e_{max}
10	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	1.8	2.1	2.0	2.3
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.8	2.1	2.0	2.3	2.4	2.8
16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.8	2.1	2.2	2.6	2.7	3.1	3.3	3.8
20	-				-	-	-	-	-	-	1.8	2.1	1.9	2.2	2.3	2.7	2.8	3.2	3.4	3.9	4.1	4.7
25					-	-	-	-	1.8	2.1	1.9	2.2	2.3	2.7	2.8	3.2	3.5	4.0	4.2	4.8	5.1	5.8
32	-	-	-	-	-	-	-	-	1.9	2.2	2.4	2.8	2.9	3.3	3.6	4.1	4.4	5.0	5.4	6.1	6.5	7.3
40	-	-	-	-	1.8	2.1	1.9	2.2	2.4	2.8	3.0	3.4	3.7	4.2	4.5	5.1	5.5	6.2	6.7	7.5	8.1	9.1
50	-	-	1.8	2.1	2.0	2.3	2.4	2.8	3.0	3.4	3.7	4.2	4.6	5.2	5.6	6.3	6.9	7.7	8.3	9.3	10.1	11.3
63	1.8	2.1	2.0	2.3	2.5	2.9	3.0	3.4	3.8	4.3	4.7	5.3	5.8	6.5	7.1	8.0	8.6	9.6	10.5	11.7	12.7	14.1
75	1.9	2.2	2.3	2.7	2.9	3.3	3.6	4.1	4.5	5.1	5.6	6.3	6.8	7.6	8.4	9.4	10.3	11.5	12.5	13.9	15.1	16.8
90	2.2	2.6	2.8	3.2	3.5	4.0	4.3	4.9	5.4	6.1	6.7	7.5	8.2	9.2	10.1	11.3	12.3	13.7	15.0	16.6	18.1	20.1
110	2.7	3.1	3.4	3.9	4.2	4.8	5.3	6.0	6.6	7.4	8.1	9.1	10.0	11.1	12.3	13.7	15.1	16.8	18.3	20.3	22.1	24.5
125	3.1	3.6	3.9	4.4	4.8	5.4	6.0	6.7	7.4	8.3	9.2	10.3	11.4	12.7	14.0	15.5	17.1	19.0	20.8	23.0	25.1	27.8
140	3.5	4.0	4.3	4.9	5.4	6.1	6.7	7.5	8.3	9.3	10.3	11.5	12.7	14.1	15.7	17.4	19.2	21.3	23.3	25.8	28.1	31.1
160	4.0	4.5	4.9	5.5	6.2	7.0	7.7	8.6	9.5	10.6	11.8	13.1	14.6	16.2	17.9	19.8	21.9	24.2	26.6	29.4	32.1	35.5
180	4.4	5.0	5.5	6.2	6.9	7.7	8.6	9.6	10.7	11.9	13.3	14.8	16.4	18.2	20.1	22.3	24.5	27.1	29.9	33.0	36.1	39.9
200	4.9	5.5	6.2	7.0	7.7	8.6	9.6	10.7	11.9	13.2	14.7	16.3	18.2	20.2	22.4	24.8	27.4	30.3	33.2	36.7	40.1	44.3
225	5.5	6.2	6.9	7.7	8.6	9.6	10.8	12.0	13.4	14.9	16.6	18.4	20.5	22.7	25.2	27.9	30.8	34.0	37.4	41.3	45.1	49.8
250	6.2	7.0	7.7	8.6	9.6	10.7	11.9	13.2	14.8	16.4	18.4	20.4	22.7	25.1	27.9	30.8	34.2	37.8	41.6	45.9	50.1	55.3
280	6.9	7.7	8.6	9.6	10.7	11.9	13.4	14.9	16.6	18.4	20.6	22.8	25.4	28.1	31.3	34.6	38.3	42.3	46.5	51.3	56.2	62.0
315	7.7	8.6	9.7	10.8	12.1	13.5	15.0	16.6	18.7	20.7	23.2	25.7	28.6	31.6	35.2	38.9	43.1	47.6	52.3	57.7	63.2	69.7
355	8.7	9.7	10.9	12.1	13.6	15.1	16.9	18.7	21.1	23.4	26.1	28.9	32.2	35.6	39.7	43.8	48.5	53.5	59.0	65.0	71.2	78.5
400	9.8	10.9	12.3	13.7	15.3	17.0	19.1	21.2	23.7	26.2	29.4	32.5	36.3	40.1	44.7	49.3	54.7	60.3	66.5	73.3	80.2	88.4
450	11.0	12.2	13.8	15.3	17.2	19.1	21.5	23.8	26.7	29.5	33.1	36.6	40.9	45.1	50.3	55.5	61.5	67.8	-	-	-	-
500	12.3	13.7	15.3	17.0	19.1	21.2	23.9	26.4	29.7	32.8	36.8	40.6	45.4	50.1	55.8	61.5	68.3	75.3	-	-	-	-
560	13.7	15.2	17.2	19.1	21.4	23.7	26.7	29.5	33.2	36.7	41.2	45.5	50.8	56.0	62.5	68.9	75.6	83.3	-	-	-	-
630	15.4	17.1	19.3	21.4	24.1	26.7	30.0	33.1	37.4	41.3	46.3	51.1	57.2	63.1	70	77.1	85.1	93.8	-	-	-	-
710	17.4	19.3	21.8	24.1	27.2	30.1	33.9	37.4	42.1	46.5	52.2	57.6	64.5	71.1	79	87.0	96	105.7	-	-	-	-
800	19.6	21.7	24.5	27.1	30.6	33.8	38.1	42.1	47.4	52.3	58.8	64.8	72.7	80.1	89	98.0	108	118.9	-	-	-	-
900	22.0	24.3	27.6	30.5	34.4	38.0	42.9	47.3	53.3	58.8	66.1	72.9	81.8	90.1	100	110.1	121.6	133.9	-	-	-	-
1000	24.5	27.1	30.6	33.8	38.2	42.2	47.7	52.6	59.3	65.4	72.5	79.9	90.9	100.1	111	122.2	165	181.6	-	-	-	-
1200	29.4	32.5	36.7	40.5	45.9	50.6	57.2	63.1	70.6	77.8	88.2	97.2	109	120.0	133	146.4	-	-	-	-	-	-
1400	34.3	37.9	42.9	47.3	53.5	59.0	66.7	73.5	82.4	90.8	102.9	113.3	-	-	-	-	-	-	-	-	-	-
1600	-	-	49	54.0	61.2	67.5	76.2	84.0	94.1	103.7	117.6	129.5	-	-	-	-	-	-	-	-	-	-
1800	-	-	54.5	60.1	69.1	76.2	85.7	94.4	106	116.7	-	-	-	-	-	-	-	-	-	-	-	-
2000	-	-	60.6	66.8	76.9	84.7	95.3	105.0	117.6	129.5	-	-	-	-	-	-	-	-	-	-	-	-
2200	-	-	66.67	73.5	84.6	93.2	104.8	115.4	129.5	142.6	-	-	-	-	-	-	-	-	-	-	-	-
2400	-	-	72.7	80.1	92.4	101.8	114.3	125.9	141.2	155.5	-	-	-	-	-	-	-	-	-	-	-	-

Contact P.E.S for more information of not mentioned SDR

Chemical Resistance

Media	PE	HDPE
Acetone	P	L
Acetyl Bromide	L	L
Acetyl Chloride	L	LG
Air	G	G
Alcohols	G	G
Aluminum Salts	G	G
Ammonia	G	G
Amyl Acetate	G	G
Aniline	L	G
Animal Oils (6)	P	L
Arsenic Salts	G	G
Aromatic Hydrocarbons	P	L
Barium Salts	G	G
Benzaldehyde	P	L
Benzene	P	L
Benzyl Alcohol	P	G
Bleaching Liquors	G	L
Boric Acid Solutions	G	G
Bromine	L	L
Butane (2)	L	G
Butanol	G	G
Butyl Acetate	G	G
Calcium Hypochlorite	L	L
Calcium Salts	G	G
Carbon Dioxide	G	G
Carbon Disulfide	L	L
Carbon Tetrachloride	P	P
Caustic Potash	G	G
Caustic Soda	G	G
Chloracetic Acid	L	G
Chlorine (Dry)	L	L
Chlorine (Wet)	L	L
Chlorobenzene	P	L
Chloroform	P	L
Chromic Acid	L	L
Copper Salts	G	G
Cresol	P	L
Cyclohexanone	L	L
Ethers	L	L
Ethyl Acetate	G	G
Ethyl Alcohol	G	G
Ethylamine	L	G
Ethyl Bromide	P	L
Ethyl Chloride	P	L
Fatty Acids	L	L

Media	PE	HDPE
Ferric Salts	G	G
Formaldehyde	G	G
Formic Acid	G	G
Freon	L	L
Gasoline (2)	P	G
Glucose	G	G
Glycerin	G	G
Hydriodic Acid	L	G
Hydrochloric Acid. (Conc.)	L	G
Hydrochloric Acid. (Med. Conc.)	L	G
Hydrofluoric Acid	L	L
Hydrogen Peroxide (Conc.)	L	G
Hydrogen Peroxide (Dil.)	L	G
Hydrogen Sulfide	G	G
Iodine	L	G
Kerosene (2)	L	L
Ketones	G	G
Lacquer Solvents	L	L
Lactic Acid	G	G
Lead Acetate	G	G
Linseed Oil	L	G
Magnesium Salts	G	G
Naphtha	L	L
Natural Gas	L	L
Nickel Salts	G	G
Nitric Acid (Conc.)	P	L
Nitric Acid (Dil.)	P	G
Nitrobenzene	P	L
Nitrogen Oxides	L	L
Nitrous Acid	L	L
Oils (Animal and Mineral)	L	L
Oils (Vegetable)	L	L
Oxygen (5) (6)	G	G
Perchloric Acid	P	G
Phenols	P	G
Potassium Salts	G	G
Pyridine	L	L
Silver Nitrate	G	G
Soap Solutions	G	G
Sodium Salts	G	G
Stearic Acid	L	L
Sulfur Chloride	L	L
Sulfuris Acid (Conc.)	P	G
Sulfuris Acid (Dil.)	P	G
Sulfurous Acid	P	G

Media	PE	HDPE
Tannic Acid	G	G
Tanning Extracts	G	G
Titanium Salts	G	G
Toluene	P	L
Trichloroacetic Acid	L	L
Trichloroethylene	P	L
Turpentine	P	P
Urea	G	G
Uric Acid	G	G
Water (6)	G	G
Xylene	P	L
Zinc Chloride	G	G

G: Good to Exvellent
L: Marginal or Conditional
P: Poor or Unsatisfactory

Quality
Means a lot in
P.E.S

An important goal of production at P.E.S is to support the development of great products that can be readily assessed in terms of quality and completeness.

Our QC system is designed to:
I. Provide routine and consistent checks to ensure data integrity, correctness and completeness.
II. Identify and address errors and omission.
III. Document and archive products and raw material specifications and record all QC activities.



It is a good practice to implement quality assurance and quality control (QA/QC) procedure in the development of pipe and fitting production to accomplish this goal. The QA/QC practice guidance outlined at P.E.S reflects practically, reflects practically, acceptability, cost-effectiveness, existing experience and the potential for application on a whole products basis.
P.E.S was the first polyethylene pipe and fitting manufacturer in Iran who acquired its quality management system based on IMS (Integrated management system including ISO 9001: 2015 - ISO 14001: 2015, 45001:2018 and promoted its laboratory activity by ISO 17025 basis. Our laboratory is equipped with the last innovative and certified high quality apparatus for testing Our laboratory is equipped with the last PE products from raw material to finished pipe and fitting in accordance with international standards and national standards of Iran.




P.E.S laboratory is honored to be the accredited unit collaborating with ISIRI (Institute of Standard and Industrial Research of Iran) for testing polyethylene pipe, fittings and PE raw materials. We use the best HD PE resin for manufacturing pipe and fittings. Our raw materials are classified as PE 100 bimodal resin with high strength and long service life. By using the best raw material and the finest extrusion machinery, doing the whole mandatory and optional quality control and inspection tests on raw material and finished products, plus years of experience on HD PE industry, we proudly can certify that our products have the highest quality of the same goods worldwide.

Joining Techniques

Polyethylene pipe and fittings are joined using these methods:

- Heat Fusion
  - Butt fusion to connect components end to end
  - Saddle fusion to attach branch outlet to a main pipe
  - Socket fusion to join smaller pipes to socket fittings
- Flanged joined
- Electrofusion, mainly for gas lines
- Mechanical connection that are designed for PE pipe

Heat Fusion

Heat Jusion joints are reliable, leak-free, fully controlled and as strong as the pipe itself when properly made. Butt fusion is fast, cost-effective, very practical and the most popular ones that allows to make long lengths of pipes and set them ready for fast assembling at installation site. Butt welding is the only option for connecting large pipes with diameter bigger than 500 mm. In butt welding the joint faces are heated to welding temperature with hot tool. After removing the hot tool the plasticized pipe ends are pressed together.

Flanged Joined

PE pipe and fittings may also be joined together or connected to other pipe materials or components with flange adapters. In this case the polyethylene flange adapter is butt fused to PE pipe; then the adapter is connected to the mating component by slip-on metal flange. The flange adapter must have the same pressure rating as the pipe.

Electrofusion

Electrofusion is a heat fusion process where a coupling or saddle fitting contains an integral resistance coils. After surface preparation, the fitting is installed on the pipe and the resistance coils are energized. During heating, the fitting and pipe materials melt, expand and fuse together.

Mechanical Joining

Mechanical compression fittings have a body that is a pressure containing component and fits over the outside diameter of pipe. Some connections may require a stiffener in the pipe bore. The reliability of butt fusion joined is depending on welding machinery, welding technician skills and welding guidelines.

P.E.S is a head for improving polyethylene welding techniques in Iran. In 2006, P.E.S made a technical corporation in the field of plastic pipe welding with SKZ institute in Germany. As a result P.E.S carries out training courses at its training center on plastic pipe welding according to guideline DVS 2207 part 1, German Standards and industrial producers acquired from SKZ. Innovations, improvements and updated developments are also developments are also provided by SKZ to P.E.S training centre normally issues an accreditation certificate to successful candidates completing the training course and maintain a register of accredited welders.
Our valued customers can obtain every assist in the efficient PE pipe system installation from our certified and experienced welding technicians.

Handling and Storage of Polyethylene Pipes and Fittings

Polyethylene Pipes and fittings are light in weight and easy to handle. Although they have flexibility and resistance to impact, they can scratch by sharp objects and deform under load, mostly at high temperature. Scores to a depth of 10% or more of the wall thickness are sufficient to cause rejection for any pressure application, so they should not be dropped, crushed or impacted.

Lifting and Handling

PE pipes and fittings should not be subjected to rough handling during loading and unloading operations. For lifting the pipes by crane, apply webbing strings. Chains, wire ropes and hooks should not be used on PE pipe and fittings under any conditions. To avoid flopping of long pipes and consequent scuffing of pipe ends, two lifting points or spreader bars should be used for lifting the pipes exceeding 6 meters in length.

Storage and Transport

Store HD PE pipes and fittings where there are no drilling slugs and mud, lubricating or hydraulic- oil, solvents or other aggressive materials and flammable chemicals. Pipes stack for storage or transport should be continuously and evenly supported to minimize deformation. Horizontal supports, spaced not further apart than 2 meters center-to-center, should be placed beneath the pipes. Pipes of other color than black should be protected from high temperatures and direct sunlight during storage and transport, particularly if they are to be stored for more than 6 months. Pipes with end flanging or preassembled fittings should be stacked so that the end are free from loading and be protected from damage. In storage and employing of pipe and fitting the principle of "first in, first out" should be observed.

Plastic pipe will exhibit the fastest growth due to performance and cost advantages over other materials, as well as improved resins and inroads into larger diameters. High density polyethylene will rise at the fastest pace due to its flexibility, strength, joint integrity, chemical resistant and trench-laying capabilities. Growth areas include gas and potable water distribution and transmission pipes, fire protection underground systems and submarine intakes, outfalls and crossing lines. Our goals in this fast global renovation are to supply all components of HD PE pipe system with highest quality and provide excellent technical back-up and advice for our valued customers. We offer technical information and organized workshops for HD PE raw materials, pipe designing, installation, inspection, test, production process and control of HD PE systems. Our basic policy is to bring together the best raw material, the best operational cycle, the best technical support and the best technical group to keeping the distance with the national and international competitors.

Pipe Calculations

Pipe design and standardization.

1.1 Pipe design and standardization

Pipes are designed using the well-known pipe formula (ISO 161-1), equation 1-1

$$\sigma_s = PN.\frac{d_m}{2e} = PN.\ S \qquad (1.1)$$

where

PN = nominal pressure rating
d_m = mean pipe diameter
d_e = pipe outside diameter
e = wall thickness
S = $d_m/2e$ =pipe series
SDR = Standard Dimension Ratio
= d_e/e=2 S + 1,
σ_s = permissible design stress
(1 MPa = 1 N/mm^2 = 10 bar).

The permissible design stress σ, takes into account the safety factor C as follows

$$\sigma_s = \frac{[MRS]}{C} \qquad (1.2)$$

MRS = minimum required strengh (see table 1-1)

Safety factors can only be established by practical experience. The safety fac- tor, known in ISO/DIS 12 162 as the "overall service (design) coefficient", fulfils a number of functions. It should ensure that pipes that have been correctly designed with regard to the properties of the material still allow a safety margin when stressed to the full extent of their nominal pressure rating and should take into account all uncontrollable additional stresses likely to occur in operation such as pressure surges, heat stresses caused by fluctuating temperature and, in the case of buried lines, vibrations and settlement.

C	PE 80 MRS = 8 MPa 1.25	1.6	2	4	PE 100 MRS = 10 MPa 1.25	1.6	2	4
[MPa]	6.3	5	4	2	8	6.3	5	2.5
PN [bar]				S				
2.5	25	20	16	12.5	32	25	20	16
3.2	20	16	12.5	10	25	20	16	12.5
4	16	12.5	10	8	20	16	12.5	10
5	12.5	10	8	6.3	16	12.5	10	8
6.3	10	8	6.3	5	12.5	10	8	6.3
(8)	8	6.3	5	4	10	8	6.3	5
10	6.3	5	4	3.2	8	6.3	5	4
(12.5)	5	4			6.3	5		
16	4	3.2			5	4		

Tab. 1-1: Pipe series for PE pressure pipes

C and σ_s are also categorized by the Renard number series. The CEN system standards for drinking water and gas specify only a minimum overall service coefficient C_{min}.

for water pipes $C_{min} = 1.25$
for gas pipes $C_{min} = 2.0$

The responsibility for the choice of overall service coefficient to be applied lies with the planning engineer, who must take account of the particular operating conditions and local circumstances.

From equation 1-1 by transformation, we obtain the design equation to calculate pipe series 5 for a given permissible stress σ_s and intended nominal pressure rating:

$$S = \frac{10 \cdot \sigma_s[\mathrm{MPa}]}{\mathrm{PN\ [bar]}} \quad (1\text{-}3)$$

In Table 1-1, by way of example, for various values of C the values for design stress o, and the resulting pipe series S for the intended nominal pressure rating PN are given for PE 80 and PE 100.

If in the definition of $S = d_m/2e$, the mean diameter d_m is replaced by the outside diameter d_e., (the value normally used), we obtain:

$$S = \frac{d_e - e}{2e} \quad (1\text{-}4)$$

and by transformation:

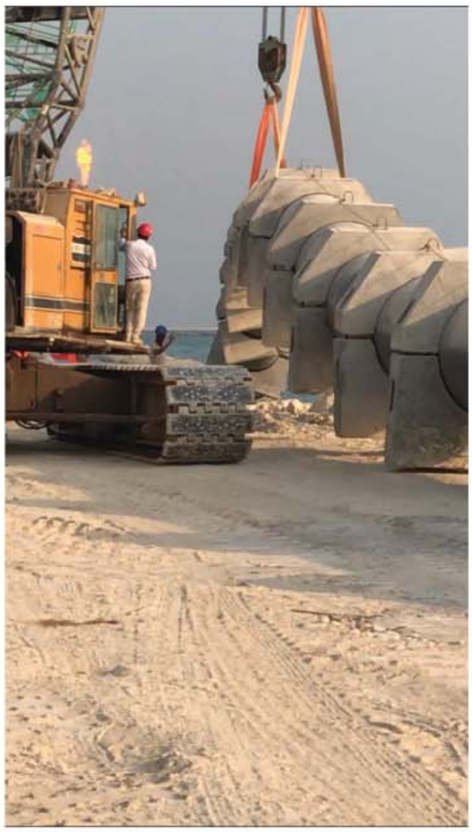
$$e = \frac{d_e}{2S+1} \quad (1\text{-}5)$$

This formula is used to calculate the dimensions of pipes in ISO 4065.

In this calculation, the exact and not the rounded values of S are used. The numerical values for wall thickness are rounded up to 0.1 mm. For safety reasons, in the individual system standards (application standards), larger wall thicknesses than these may be specified for small diameters. The commonly used nominal pressure rating of PN = 6 bar is a special case here because it departs from the 10 number 6.3. In ISO 4065, it has its own table of dimensions.

The tolerances for outside diameter, wall thickness and ovality are specified in ISO 11 922.

The permissible operating pressures are reduced at service temperatures above 20°C. The reduction factors are listed in ISO 13 761. In DIN 8074, the permissible operating pressures and service life expectancy for different overall service coefficients at temperatures up to 70°C are specified. DIN 16 892 contains a table with these values for PEX pipes and DIN 8077 for PP pipes.



1.2 Hydraulic calculation of pipe diameters

Calculation of mass flow rate, flow velocity and pressure drop in pipes made from Hostalen and Lupolen materials is based on the formula for the energy height loss h_v in a pipeline:

1-6

$$h_v = \lambda \frac{l \,.\, V^2}{2 \,.\, g \,.\, d_i} \text{ [m]}$$

or for the pressure drop Δp (Equation 1-7):

1-7

$$\Delta p = \lambda \frac{l \,.\, V^2 \,.\, p \,.\, 10^{-s}}{2 \,.\, d_i} \text{ [bar]}$$

where

d_i = inside diameter (mm)
l = length of the pipeline (mm)
v = average flow velocity (m/s)
S = density of the flow medium (kg/m³)
λ = coefficient of friction
g = 9.81 m/s², acceleration due to gravity.

The energy height loss h is the difference in height between two points in a length of pipe required to produce a gradient sufficient for the flow velocity v.

The friction coefficient λ is contained in the Colebrook equation (1-8):

1-8

$$\frac{1}{\sqrt{\lambda}} = -2 \,.\, \lg \left(\frac{2.51}{Re\sqrt{\lambda}} + \frac{k}{3.71.d_i} \right)$$

where

Re = Reynold's number = $v \cdot d_i/y$, =
Y = $1.31.10^{-6}$ m²/s, kinematic viscosity of water
k [mm] = hydraulically effective roughness dependent on unevennesses in the pipe wall

By transformation, we obtain equa- tion (1-9):

Values for the mass flow rate Q and the flow velocity v for pipes up to 1 000 mm in diameter, gradients from 15% to 0.15% and an effective wall roughness value of k = 0.1 mm, as well as for operating roughness values of k = 0.25, 0.50, 0.75 and 1.50 mm, are contained in the book "Tabellen zur hydraulischen Dimensionierung von Abwasserkanälen und Abwasserleitungen" (Tables for the hydraulic design of sewer pipes and lines) (IngwisVerlag, Lich). This is based on the German Wastewater Association (Abwassertechnische Vereinigung, ATV) Work Sheet A 110, "Guidelines for the hydraulic design and performance testing of sewerage pipes and lines."

1-9

$$v = -2 \,.\, \lg \left(\frac{2.51 \,.\, \nu}{d_i.\sqrt{2 \,.\, g \,.\, h_v \,.\, di/l}} + \frac{k}{3.71.d_i} \right) . \sqrt{2 \,.\, g \,.\, h_v \,.\, di/l}$$

A distinction is made between the normal, hydraulically effective wall roughness k and a so-called operat- ing roughness kb.

The operating roughness values ko are increased roughness values to account for valves, bends etc., whose use overall contributes in calculation terms to the same total losses as would the sum of separately determi- ned continual and local energy height losses.

Losses resulting from wall roughness and local flow resistances (individual losses) have to be determined on an individual basis. For the losses resulting from wall roughness, an effective wall roughness value of k = 104 m = 0.1 mm should be used as the minimum value for pipes in new condition. The individual losses have additionally to be taken into account.

For sewers made from HDPE, effective wall roughness values k significantly below 0.1 mm have been confirmed. The hydraulic dimensions calculated using the roughness values specified in ATV Work Sheet A 110 therefore incorporate high safety margins.

Hydraulic design of drinking-water lines can, for example, be carried out according to the guidelines of the German Association of Gas and Water Engineering (DVGW) Work Sheet W 302. Here, the roughness k in equation 1-8 for pipes made from HDPE/MDPE can be assigned values ranging from 0.1 mm to 1.0 mm, depending on the line. Additional notes are contained in the pressuredrop table published by the German Plastic Pipe Association.

The DVGW Work Sheet W 403 recommends maximum flow velocities of 2.0 m/s for drinking water lines, depending on the application.

1.3 Calculation of static loads on pipes

For buried gravity-flow sewers, the required wall thickness must be determined according to the external stresses imposed by soil pressure and traffic. To understand the effect of such stresses on polyolefin pipe, the special characteristics of a viscoelastic material must be considered, since the methods for calculating static loading of rigid pipes (stoneware and concrete) are not directly applicable.

The ring stiffness SN for solid-wall pipes depends on the pipe series S and the stiffness of the pipe material, characterized by the elastic modulus E_R:

1-10a

$$SN = \frac{E_R \cdot e^3}{12 \cdot d_m^3} = \frac{E_R}{96 \cdot S^3}$$

As dimensional equation:

1-10b

$$SN\ [kN/m^2] = \frac{1000 \cdot E_R\ [MPa]}{96 \cdot S^3}$$

For further information see In table 7-5, p. 90, the ring stiffness values for different polyolefin wastewater pipes with solid wall are listed. These requirements from the different standards can be fulfilled with Basell materials.

In the crushing test, a pipe made from Hostalen materials under specific conditions did not fracture; under increasing load, the pipe deformed to such an extent that the pipe crown finally touched the pipe bottom. When considering the strength properties of buried HDPE pipes, account must be taken of this flexible behavior.

Some deformation occurring under load is elastic (reversible) and some is plastic (irreversible). In fact, the crushing test only indicates the degree of deformability of the material but in no way corresponds to the stress conditions to which the pipe in the backfilled trench is actually subjected. Deformation in such cases will be substantially less than in the crushing test, because the buried pipe is laterally supported by the soil. A material that behaves in such a way is described as flexible. Pipes made from conventional materials such as concrete or stoneware exhibit rigid behavior; that is, the pipe absorbs the applied load and fails.

Basically, it should be noted that, for all sewer pipes, the soil in the vicinity of the pipeline must be very well compacted in accordance with EN 1610 to achieve the required supporting effect, i.e., to activate the soil/pipe system.

As yet, there is no commonly harmonized European basis for calculating static loads on buried, solid-wall, gravity-flow pipes. EN 1295-1 so far only specifies general requirements. For calculating static loads, national rules are still applied. By way of example, reference is made here to the method of calculation recommended in German Wastewater Association (ATV) Work Sheet A 127, "Guidelines on Static Load Calculation for Sewers." The special aspects of static load calculation for seepage-water drainage lines in landfill sites are taken into account in ATV Guideline M 127.

In the context of static load calculation, it is also necessary to calculate pipe deformation and pipe buckling. The general method of calculation is explained below; details are given in ATV Work Sheet A 127.

1.4 Stability calculation (buckling)

By buckling, we mean kidney-shaped deformation of the pipe cross section resulting from external pressure. As a general rule, underwater pipes or pipes laid in soil below the water table and subjected to a hydrostatic pressure of the ground water greater than the internal pressure should be designed to withstand buckling. The same applies to pipes operated under vacuum (pipe internal pressure ≤ 1 N/mm²).To determine the critical buckling pressure crit. p_o [kN/m²] of an undeformed pipe exposed to external water pressure or vacuum and not embedded in soil, the following applies:

1-11

$$Crit.p_o = \frac{E_R}{4 \cdot (1-\mu^2)} \cdot \left(\frac{e}{r_m}\right)^3$$

where:

E_R = elastic modulus of the pipe material [N/mm²]

r_m = mean pipe radius [mm]

e = wall thickness of the pipe [mm]

and $\mu = 0.4$ is the Poisson's ratio for the material.

The maximum permissible long-term buckling pressure values calculated with equation 1-11 for pipes made from Hostalen materials are plotted in Figure 1-1 . These values have been confirmed by test results of Hoechst AG and IKV from 1968.

The maximum permissible buckling pressure value incorporates a safety factor of 2.

The pipe stiffness S_R [N/mm²] is calculated from:

1-12

$$S_R = 8 \,.\, SN = \frac{E_R \cdot e^3}{12 \,.\, r_m^{\,3}}$$

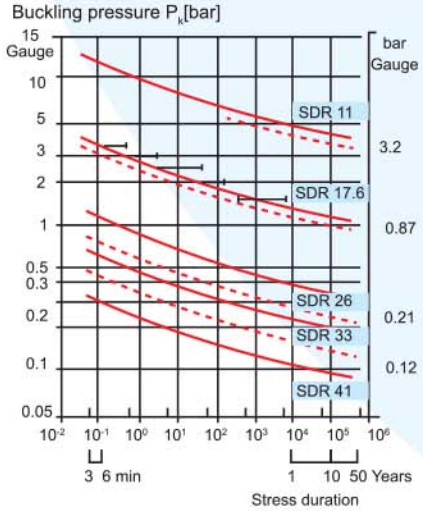


Fig. 1-1: Buckling pressure for pipes made from Hostalen materials under external water pressure at 20 °C. The horizontal lines marked in the figure show the beginning and end of buckling.

By inserting pipe stiffness S_R in equation 1-11, we obtain

1-13

$$Crit.p_o = \frac{3 \,.\, E_R}{1-\mu^2} = 3 \,.\, S_R$$

Trials with unbedded HDPE pipes under hydrostatic pressure i.e., in groundwater without soil compaction have shown that the equation

1-14

$$Crit.p_o = 3 \,.\, S_R$$

can satisfactorily describe buckling behavior, and therefore this equation is used as the limiting value in determining the critical buckling pressure of a pipe under external water

1.5 Pressure surges

Pressure surges can occur in pipelines when shut-off valves or pumps are operated. The maximum theoretical value p_s is:

1-15

$$p_S = a \,.\, v_0 \,.\, p \text{ [N/m}^2\text{]}$$

where

a = propagation rate of the pressure wave [m/s],

v_0 = flow rate of the medium [m/s],

S = density of the medium [kg/m³].

The propagation rate is calculated from (Equation 8-16):

1-16

$$a = \sqrt{\frac{\dfrac{E_M}{P}}{1+\dfrac{E_M}{E_R}\cdot\dfrac{d_m}{e}}} \text{ [m/s]}$$

where

E_m = elastic modulus of the medium (E_{water} = 2100 . 10^6 N/m²),

s = density of the medium =(S_{water} 1000 kg)m³,

Er = elastic modulus of the pipe [N/m²],

dm = mean diameter of the pipe [m],

e = wall thickness of the pipe [m].

In the case of surge stress, the short-term value must be used for the elastic modulus Ep of the pipe. Depending on temperature, the values from Table 8-3 apply for Hostalen GM 5010 T3:

Temperature (°C)	E_R[N/m²]
20	1.680 . 10^6
40	1.230 . 10^6
60	760 . 10^6

Tab. 1-3: Elastic modulus at different temperatures

Pressure surges are not generally damaging for HDPE pipes, provided the nominal pressure rating is not exceeded in the medium to long term as a result of pressure variations and pressure surges. In the case of indi- vidual short-term stress (in the range of seconds), the strength reserve of the pipe can be exploited up to the actual lower confidence limit applic- able to such short periods. Depend- ing on the overall service coefficient C, an HDPE pipe can tolerate the maximum pressure peaks quoted in Table 1-4 without damage at temper- atures less than or equal to 20℃.

Sudden pressure drops down to 0 bar $_{absolut}$. absolut vacuum are theoretically possible in terms of buckling behavior.

The modern bimodal materials Hostalen GM 5010 T3 and Hostalen CRP 100 offer an additional safety margin because of their high resist- ance to rapid crack propagation.

Overall service coefficient C	Short-term pressure of the nominal pressure rating
1.25	50%
1.6	100%

Tab. 1-4: Deviation beyond the nominal pressure rating in short-term pressure surges

1.6 Fatigue damage accumulation

In considering the design of pressure pipes so far, we have assumed a continually acting constant stress. However, if the stress is interrupted by periods in which the pipe is unstressed, or if periods of varying mechanical and/or thermal stress occur, we refer to this as cyclic stress. In this case, it is important to ascertain how damage accumulates during the individual stress periods and what the total service life is likely to be.

To clarify these questions, HDPE pipe specimens with the dimensions 32 × 3 mm produced from the unimodal Hostalen GM 5010 were placed under a stress of 3 N/mm² at a constant temperature of 80 °C for 6 hours and then relieved from the stress for 18 hours. This cycle was repeated until the pipe specimens ruptured. The time to rupture under stress, averaged over six tests (integral stress-endurance time), was 310 hours. In a comparative test, an average time to rupture of 275 hours was achieved at a constant stress (without stress relief). It can be seen, then, that under the given test conditions the cyclic nature of the stress made practically no difference to the assessment of pipe creep strength based on the test under constant stress.

Hence the theory of linear fatigue damage accumulation (Miner's rule, superposition principle, ISO 13 760) applies. This postulates a direct rela- tionship between the point at which the cumulative damage from the tot- ality of stress cycles leads to failure and the service life expectancy under constant stress. To convert lifecycle values under constant stress to ex- pected service life under cyclic stress,

$$\frac{\Delta t_1}{t_R(\sigma_1,\vartheta_1)} + \frac{\Delta t_2}{t_R(\sigma_2,\vartheta_2)} + \ldots + \frac{\Delta t_m}{t_R(\sigma_m,\vartheta_m)} = \sum_{i=1}^{m} \frac{\Delta t_i}{t_R(\sigma_i,\vartheta_i)} \leq 1 \qquad (1\text{-}17)$$

the following approximation can be made: where At is the time under the stress σ at temperature &, and tr is the time to rupture measured in a hydrostatic strength test under the corresponding constant stress.

Figure 1-2 shows the superposition of cumulative damage at different temperatures.

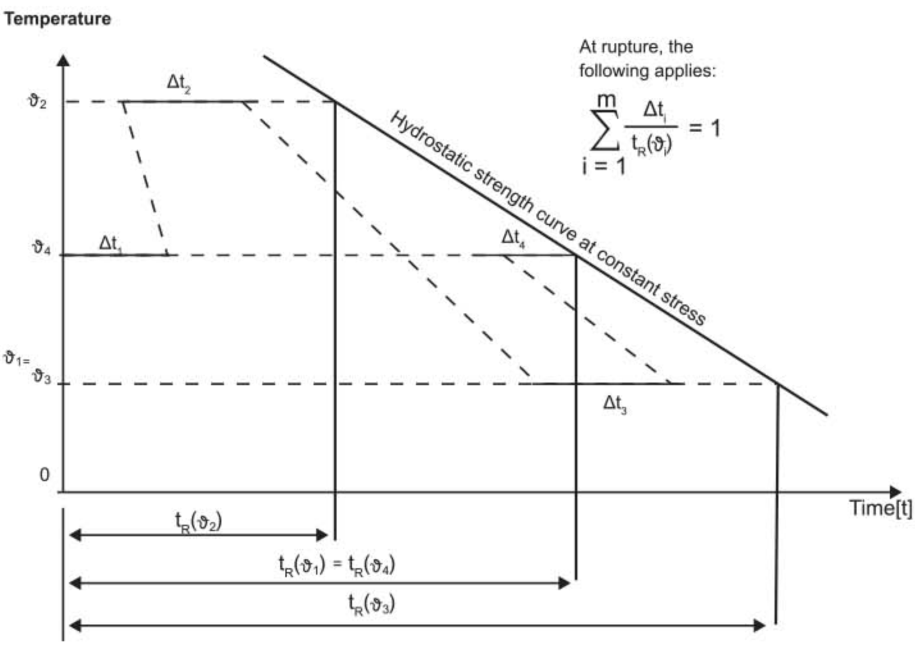


Fig. 1-2: Linear fatigue damage accumulation at different temperatures

Example:
Water is to be conveyed in a pressure line. The operating pressure is a constant 6 bar. The temperature/time curve is specified as follows:

50°C during 3 h per day
30°C during 21 h per day

What SDR class according to DIN 8074 must a PE 80 pipe have to ensure a 50-year service life expectancy?

The overall service coefficient is assumed to be 1.6.

Over the total operating period of 50 years, the temperature-time fractions add up as follows:

at 50°C: Δt_1=6.25 years
at 30°C: Δt_2 = 43.75 years

First, a pipe with a diameter/wall thickness ratio SDR = 11 is chosen.

The operating stress is

$$\sigma = \frac{p(SDR-1)}{20} = \frac{6 \,.\, (11-1)}{20} = 3 N/mm^2$$

Thus

$$\sigma_s = \sigma \,.\, C = 3 \,.\, 1.6 = 4.8 \text{ N/mm}^2$$

From the hydrostatic strength curves for PE 80 pipes according to DIN 8075, the following times to rupture are obtained at a constant stress of 4.8 N/mm²:

at 50°C: $t_B(\vartheta_1)$ = 13 years
at 30°C: $t_B(\vartheta_2)$ > 100 years
(extrapolated).

The damage contributions are thus:
$\Delta t_1/t_R(\vartheta_1)$=6.25/13=0.48 48%,
$\Delta t_2/t_R(\vartheta_2)$ = 43.75/100 = 0.44 = 44%.

According to Equation 1-17:

$$\Delta t_1/t_R(\vartheta_1) + \Delta t_2/t_R(\vartheta_2) = 92\%$$

The value calculated according to equation 1-17 must be ≤ 1 or ≤ 100%.

The chosen diameter/wall thickness ratio (SDR 11) is correct for this appli- cation.

For partially crystalline thermoplastics such as HPDE, a lower overall deformation is obtained under cyclic stress after the same accumulated stress endurance time than is the case under constant stress. Deformation can be approximated using the linear superposition principle.

1.7 Internal pipe stresses

Internal stresses in the pipe wall are created after pipe extrusion as the polyethylene melt is cooled. In this process, it is important to use an external sizing system for the extruded pipe to remove all the heat outwards. As a result, the outside wall of the pipe freezes while the inside layer is still molten. With progressive cooling, the material wants to contract inwards but is prevented from doing so by the outer layer which has already frozen. This forced strain in the inner pipe wall leads to tensile stresses, while compressive stresses are created in the outer pipe wall.

Excessive internal pipe stresses can be a reason for cracking during storage or transport of the pipe. When a pipe is cut, dimensional accuracy is impair- ed because of the release of forced de- formation. As a result, the diameter of the pipe end is reduced.

It has not so far been possible to determine any link between very high internal stresses and creep behavior. In creep testing, for example with a test temperature of 80°C, the internal stresses are relaxed relatively quickly by annealing. They also relax over a corresponding length of time at the lower operating temperature in an installed pipeline.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