AQUALIFE
PE100 PRESSURE PIPES FOR WATER SUPPLY

AQUALIFE
PE100 pressure pipes for water supply

PIPELIFE
always part of your life

CONTENTS

POLYETHYLENE TECHNICAL PROPERTIES

	Specification	Units	High density PE MRS 6.3	Middle density PE MRS 8	High polymer PE MRS 10
Mechanical properties					
Density	ASTM D 792	Kg/m^3	955	949	960
Melting index (load 5 kg)	ISO 1133	g/10min	0.48	0.85	0.45
Elasticity module (50 mm/min, 23°C)	ISO 527	MPa	1150	650	1400
Tensile strength (50 mm/min, 23°C DIN)	DIN 53455	MPa	39	28	38
Yield strength (50 mm/min, 23°C DIN)	DIN 53455	MPa	25	20	25
Elongation at break (50 mm/min, 23°C DIN)	DIN 53455	%	>500	>600	>600
Resistance to cracking due to environment load	Bell Telephone Test F50	h	>500	>1000	>1000
Physical properties					
Softening (1Kg)	DIN 53460	°C	128	121	127
Heat conductivity	DIN 52612	W/m•K	0.4	0.38	0.38
Specific heat	Calorimetric	Kj/Kg•K	1.8	3.4	1.9
Coefficient of thermal expansion	ASTM D 696	K-1	1.3•10-4	1.3•10-4	1.3•10-4
Brittleness temperature (Tg)	ASTM D 746	°C	<-100	<-100	<-100
Electrical properties					
Dielectric constant	DIN 53483		2.6	2.6	2.6
Dielectric strength	DIN 53481	KV/cm	2.2•102	2.2•102	2.2•102
Special volume resistivity	DIN 53482	Ω.cm	≥1017	≥1017	≥1017
Surface resistivity	DIN 53482	Ω	≥1014	≥1014	≥1014

The above values are indicative.

According to ISO 9080, the minimum required strength (MRS) is the value of long-term hydrostatic strength with a lower limit of confidence of 97.5% shown by one pipe after 50 years of constant work at 20°C.

POLYETHYLENE CHEMICAL PROPERTIES

CHEMICALS	CHEMICAL CONCENTRATION*	LDPE		HDPE	
		TEMPERATURE**			
		20°C	60°C	20°C	60°C
Gasses, containing:	-	-	-	-	
Carbon dioxide		1	1	1	1
Sulphur dioxide	l.c.	1	1	1	1
Sulphuric acid		1	1	1	1
Carbon oxide		1	1	1	1
Nitric vapours	admixtures	1	1	1	1
Fluorine hydrogen	admixtures	1	1	1	1
Salt		1	1	1	1
Ethereal oils		-	-	2	2
Ethyl alcohol	96%	1-2	3	1	1
Acetone	100%	2	3	3	2
Acetone	admixtures	1	1	1	1
Saturated salt solution		1	1	1	1
Gaseous ammonia		1	1	1	1
Ammonia solution	100%	1	-	1	1
Starch		1	1	1	1
Sodium carbon		1	1	1	1
Washing agents		1	1	1	1
Petrol		2	3	1	2
Benzene		3	3	2	2
Borax		1	1	1	1
Potassium borate	w.s. 1%	1	1	1	1
Boron acid		1	1	1	1
Butanol		1	1	1	1
Potassium bromate		1	1	1	1
Lactic acid		1	1	1	1
Glycerin		1	1	1	1
Glucose		-	-	-	-
Dextrine	w.s. 18%	1	-	1	1
Diethyl ether		3	3	2	2
Carbon sulphide		3	-	2	-
Sodium bisulfate	t.w.s.	1	1	1	1
Carbon dioxide		1	1	1	1
Sulphur dioxide		1	1	1	1
Dichlorethan		2	2	2	2
Dichlorethylene		3	3	3	3
Potassium dichromate	w.s. 40%	1	1	1	1
Animal and vegetable oils		-	1	1	2
Transformer oils		-	1	2	1
Sulphuric acids of different metals		1	1	1	1
Sulphuric acid	w.s. 40%	1	1	1	1
Sulphuric acid	98%	2	3	2	3
Sulphuric acid	with vapours	3	3	3	3
Sulphurous acid		1	1	1	1
Potassium		1	1	1	1
Sodium		1	1	1	1
Ketones		2	3	1	2
Citric acid		1	1	1	1
Acids, containing fats		1	3	1	2
Methanol		1	2	1	1
Molasses		-	-	1	1
Beer		1	1	1	1
Formic acid		1	1	1	1
Naphtha		1	2	1	2
Naphthalene		1	2	1	2
Nitrogen salts of different metals		1	1	1	1

CHEMICALS	CHEMICAL CONCENTRATION*	LDPE		HDPE	
		TEMPERATURE**			
		20°C	60°C	20°C	60°C
Nitric acid	w.s. 25%	1	1	1	1
Nitric acid	w.s. 50%	2	3	2	3
Nitrobenzene		2	3	1	2
Nitric vapours		1	-	1	1
Ozone		2	3	2	3
Acetic acid	w.s. 10%	1	1	1	1
Acetic acid	w.s. 100%	2	3	1	2
Acetic etileter		2	3	2	3
Acetic anhydride		2	-	1	2
Vinegar		-	-	1	1
Mineral oils		2	3	1	2
Urea		1	1	1	1
Petroleum on paraffinic base		1	1	1	1
Petroleum ether		2	3	1	2
Petroleum		2	3	1	2
Diesel fuel		2	3	1	2
Propanol		1	1	1	1
Propylene glycol		1	1	1	1
Sodium silicate		1	1	1	1
Stearic acid		1	3	1	2
Alum		1	1	1	1
Tannin	w.s. 10%	1	1	1	1
Turpentine		2	3	2	3
Carbon tetrachloride		3	3	3	3
Tetrachloride		3	3	3	3
Toluene		3	3	3	3
Ferric chloride		1	1	1	1
Trichloroethylene		3	3	3	3
Tartaric acid		1	1	1	1
Mercury		1	1	1	1
Brominenytrogen acid	50%	1	1	1	1
Nytrogen		1	1	1	1
Hydrosulphuric acid		1	1	1	1
Hydrochloric acid	w.s. 36%	1	2	1	1
Hydrochloric acid (dry gas or liquid)		1	1	1	1
Potassium permanganate	s.w.s.	1	2	1	2
Hydrogen peroxide	w.s. 30%	1	1	1	1
Hydrogen peroxide	w.s. 90%	1	3	1	3
Perchloric acid	w.s. 20%	1	-	1	1
Calcium nitrate		1	1	1	1
Calcium hypochlorite		2	2	1	1
Phenol		2	3	1	2
Formaldehyde	w.s. 40%	1	1	1	1
Phosphoric acid	w.s. 25%	1	1	1	1
Phosphoric acid	w.s. 50%	1	1	1	1
Phosphoric acid	w.s. 85%	1	2	1	2
Fixer emulsion		1	1	1	-
Chlorides of dry gasses		2	3	3	3
Chloroacetic acid		3	3	1	1
Perchloric acids of different metals		1	1	1	1
Methyl chloride		3	3	2	2
Sodium chloride	w.s. 50%	2	3	1	1
Chloroform		3	3	3	3
Chromic acid	w.s. 50%	3	3	1	3
Fruit juices		1	1	1	1

* Without indication = pure substance   **Without indication = unregistered

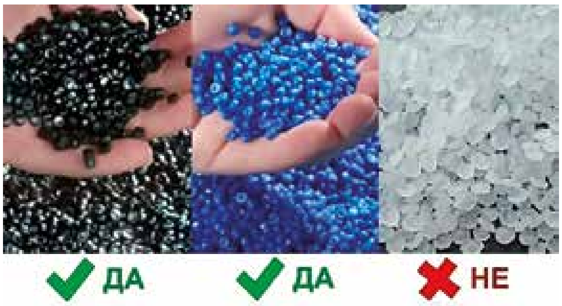
1 = Good resistance
2 = Moderate resistance
3 = Not recommended
w.s. = water solution with concentration higher than 10%, but unsaturated

l.w.s. = water solution low concentration (under 10%)
s.s. = saturated solution
l.c. = low concentration
h.c. = high concentration
% = weight percentage

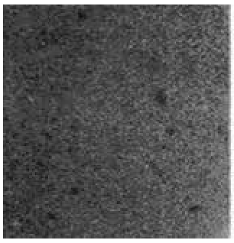
This information concerns only ordinary chemical resistance. When giving an account of other factors like resistance to cracking due to load, conductivity and others, it is necessary to put to specific tests for compatibility.

COMPOUND FOR PRODUCTION OF PE100 PRESSURE PIPES

Compound from which polyethylene water pipes are being produced must be preliminary colored in the color of the final product according to the production standard BDS EN 12201-1. If pipes must be black compound is black. If they must be blue compound is blue and so on. Standard BDS EN12201-1 **FORBIDS** the usage of colorless (natural) PE compound in production of polyethylene water pipes.



Only preliminary colored compound guarantees a homogeneous structure of the produced pipes, good longtime pressure resistance and good elasticity of the material.
The usage of a colorless compound and its sequential coloring during the production causes bad homogeneity of the material, which can be seen only with microscope:

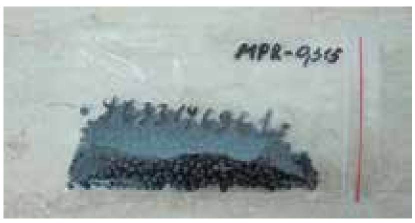


Good homogeneous structure of a pipe produced from preliminary colored compound.

Bad heterogeneous structure of a pipe produced from preliminary colored compound.

The quality of the PE pipe is deteriorated due to bad homogeneity. This leads both to substantial reduction of the operational life of the pipe and to eventual bursting of the pipe. Such pipes cannot bear the laboratory tests for internal hydrostatic pressure and tensile stress, which basically depend on the material that is used for the production of the pipe. In some rare cases mixing of the pigment and the compound during the extrusion is so bad that separated layers in the pipe cross-section could be noticed with the naked eye.

Some producers buy colorless compound and after that they color it during the extrusion because in this way they save money (the colorless compound is cheaper than the preliminary colored compound). They gain lower price by worsening quality and safety.
Pipelife Bulgaria EOOD is producing its own polyethylene pipes entirely from **VERGIN AND CERTIFIED COMPOUND** from established manufacturers of the international market like “Sabic”, “Borealis”, “Basell” and “Ineos”. These manufacturers guarantee **CONSTANT** high quality of their compound. Each delivery of polyethylene compound in the factory in Botevgrad comes with a Quality Certificate issued by the manufacturer of this compound. Our laboratory staff takes 50 grams of polyethylene compound and tests a certain part of that quantity and the rest part of the sample is conserved for six months.



The material for production of polyethylene pipes for water and gas is **preliminary colored high density polyethylene** (PE100). The PE water pipes are produced in black color with blue stripes.

POLYETHYLENE PRESSURE PIPES DIMENSIONS

POLYETHYLENE PIPES PE100 AQUALIFE
(BDS EN12201-2)

Outer diameter (mm)		6 BAR (SDR 26)			10 BAR (SDR 17)			12,5 BAR (SDR13.6)			16 BAR (SDR 11)			20 BAR (SDR 9)			25 BAR (SDR 7,4)			32 BAR (SDR 6)		
		Wall thickness (mm)		Weight	Wall thickness (mm)		Weight	Wall thickness (mm)		Weight	Wall thickness (mm)		Weight	Wall thickness (mm)		Weight	Wall thickness (mm)		Weight	Wall thickness (mm)		Weight
min	max	min	max	(Kg/m)	min	max	(Kg/m)	min	max	(Kg/m)	min	max	(Kg/m)	min	max	(Kg/m)	min	max	(Kg/m)	min	max	(Kg/m)
16	16.3																					
20	20.3										2.0	2.3	0.116	2.3	2.7	0.132	3.0	3.4	0.162	3.4	3.9	0.180
25	25.3							2.0	2.3	0.148	2.3	2.7	0.170	3.0	3.4	0.210	3.5	4.0	0.240	4.2	4.8	0.278
32	32.3				2.0	2.3	0.193	2.4	2.8	0.230	3.0	3.4	0.278	3.6	4.1	0.327	4.4	5.0	0.387	5.4	6.1	0.455
40	40.4				2.4	2.8	0.293	3.0	3.5	0.360	3.7	4.2	0.429	4.5	5.1	0.509	5.5	6.2	0.602	6.7	7.5	0.704
50	50.5	2.0	2.3	0.310	3.0	3.4	0.451	3.7	4.2	0.548	4.6	5.2	0.666	5.6	6.2	0.790	6.9	8.7	0.94	8.3	9.3	1.09
63	63.6	2.5	2.9	0.491	3.8	4.3	0.720	4.7	5.3	0.874	5.8	6.5	1.05	7.1	8.0	1.26	8.6	9.6	1.48	10.5	11.7	1.74
75	75.7	2.9	3.3	0.672	4.5	5.1	1.01	5.6	6.3	1.24	6.8	7.6	1.47	8.4	9.4	1.77	10.3	11.5	2.11	12.5	13.9	2.46
90	90.9	3.5	4.0	0.975	5.4	6.1	1.46	6.7	7.5	1.78	8.2	9.2	2.13	10.1	11.3	2.56	12.3	13.7	3.02	15.0	16.7	3.54
110	111.0	4.2	4.8	1.43	6.6	7.4	2.17	8.1	9.1	2.63	10.0	11.1	3.16	12.3	13.7	3.80	15.1	16.8	4.52	18.3	20.3	5.28
125	126.2	4.8	5.4	1.84	7.4	8.3	2.77	9.2	10.3	3.39	11.4	12.7	4.10	14.0	15.6	4.92	17.1	19.0	5.82	20.8	23.0	6.81
140	141.3	5.4	6.1	2.33	8.3	9.3	3.48	10.3	11.5	4.24	12.7	14.1	5.11	15.7	17.4	6.16	19.2	21.3	7.31	23.3	25.8	8.54
160	161.5	6.2	7.0	3.05	9.5	10.6	4.54	11.8	13.1	5.54	14.6	16.2	6.71	17.9	19.8	8.02	21.9	24.2	9.52	26.6	29.4	11.1
180	181.7	6.9	7.7	3.80	10.7	11.9	5.75	13.3	14.8	7.03	16.4	18.2	8.49	20.1	22.3	10.1	24.6	27.2	12.0	29.9	33.0	14.1
200	201.8	7.7	8.6	4.71	11.9	13.2	7.09	14.7	16.3	8.62	18.2	20.2	10.5	22.4	24.8	12.5	27.4	30.3	14.9	33.2	36.7	17.4
225	227.1	8.6	9.6	5.92	13.4	14.9	8.99	16.6	18.4	10.9	20.5	22.7	13.2	25.2	27.9	15.9	30.8	34.0	18.8	37.4	41.3	22.0
250	252.3	9.6	10.7	7.34	14.8	16.4	11.0	18.4	20.4	13.5	22.7	25.1	16.3	27.9	30.8	19.5	34.2	37.8	23.2	41.5	45.8	27.1
280	282.6	10.7	11.9	9.15	16.6	18.4	13.8	20.6	22.8	16.9	25.4	28.1	20.4	31.3	34.6	24.5	38.3	42.3	29.1	46.5	51.3	34.1
315	317.9	12.1	13.5	11.7	18.7	20.7	17.5	23.2	25.7	21.4	28.6	31.6	25.9	35.2	38.9	31.0	43.1	47.6	36.9	52.3	57.7	43.1
355	358.2	13.6	15.1	14.7	21.1	23.4	22.3	26.1	28.9	27.2	32.2	35.6	32.8	39.7	43.8	39.4	48.5	53.5	46.7	59.0	65.0	54.8
400	403.6	15.3	17.0	18.7	23.7	26.2	28.2	29.4	32.5	34.4	36.3	40.1	41.7	44.7	49.3	50.0	54.7	60.3	59.4			
450	453.8	17.2	19.1	23.6	26.7	29.5	35.7	33.1	36.6	43.6	40.9	45.1	52.8	50.3	55.5	63.3	61.5	67.8	75.1			
500	504.0	19.1	21.2	29.1	29.7	32.8	44.2	36.8	40.6	53.8	45.4	50.1	65.1	55.8	61.5	78.0						
560	564.3	21.4	23.7	36.5	33.2	36.7	55.3	41.2	45.5	67.5	50.8	56.0	81.5									
630	634.6	24.1	26.7	46.3	37.4	41.3	70.1	46.3	51.1	85.3	57.2	63.1	103.3									
710	714.9	27.2	30.1	58.8	42.1	46.5	88.9	52.2	57.6	108.4												
800	805.0	30.6	33.8	74.5	47.4	52.3	112.7	58.8	64.8	137.5												
900	905.0	34.4	38.3	94.6	53.3	58.8	142.6															
1000	1005.0	38.2	42.2	116.3	59.3	65.4	176.2															
1200	1206.0	45.9	50.6	167.5																		

POLYETHYLENE PIPES PE100 AQUALIFE BDS EN12201-2
BOTEVGRAD PRODUCTION

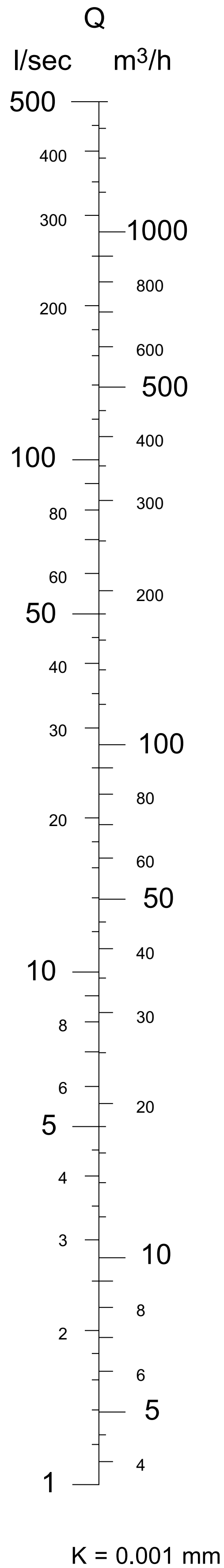
DN (mm)	Wall thickness (mm)	PN (bar)	SDR	Bars/coils	*PACKING			
					Pipes/Pallet	Pallets/Truck	Pipes/Truck	Meters/Truck
50	2,0-2,3	6.0	26.0	100.00				
50	2,0-2,3	6.0	26.0	12.00				
63	2,5-2,9	6.0	26.0	100.00				
63	2,5-2,9	6.0	26.0	12.00	116	10	1 160	13 920
75	2,9-3,3	6.0	26.0	100.00				
75	2,9-3,3	6.0	26.0	12.00	102	8	816	9 792
90	3,5-4,0	6.0	26.0	100.00				
90	3,5-4,0	6.0	26.0	12.00	58	10	580	6 960
110	4,2-4,8	6.0	26.0	100.00				
110	4,2-4,8	6.0	26.0	12.00	48	8	384	4 608
125	4,8-5,4	6.0	26.0	12.00	43	8	344	4 128
140	5,4-6,1	6.0	26.0	12.00	38	6	228	2 736
160	6,2-7,0	6.0	26.0	12.00	33	6	198	2 376
180	6,9-7,7	6.0	26.0	12.00	17	8	136	1 632
200	7,7-8,6	6.0	26.0	12.00	14	8	112	1 344
225	8,6-9,6	6.0	26.0	12.00	14	6	84	1 008
250	9,6-10,7	6.0	26.0	12.00	11	6	66	792
280	10,7-11,9	6.0	26.0	12.00	7	8	56	672
315	12,1-13,5	6.0	26.0	12.00	3	12	36	432
355	13,6-15,1	6.0	26.0	12.00	3	12	36	432
400	15,3-17,0	6.0	26.0	12.00	3	10	30	360

DN (mm]	Wall thickness (mm)	PN (bar)	SDR	Bars/coils	*PACKING			
					Pipes/Pallet	Pallets/Truck	Pipes/Truck	Meters/Truck
32	2,0-2,3	10.0	17.0	100.00				
40	2,4-2,8	10.0	17.0	100.00				
50	3,0-3,4	10.0	17.0	100.00				
50	3,0-3,4	10.0	17.0	12.00				
63	3,8-4,3	10.0	17.0	100.00				
63	3,8-4,3	10.0	17.0	12.00	116	10	1 160	13 920
75	4,5-5,1	10.0	17.0	100.00				
75	4,5-5,1	10.0	17.0	12.00	102	8	816	9 792
90	5,4-6,1	10.0	17.0	100.00				
90	5,4-6,1	10.0	17.0	12.00	58	10	580	6 960
110	6,6-7,4	10.0	17.0	100.00				
110	6,6-7,4	10.0	17.0	12.00	48	8	384	4 608
125	7,4-8,3	10.0	17.0	12.00	43	8	344	4 128
140	8,3-9,3	10.0	17.0	12.00	38	6	228	2 736
160	9,5-10,6	10.0	17.0	12.00	33	6	198	2 376
180	10,7-11,9	10.0	17.0	12.00	17	8	136	1 632
200	11,9-13,2	10.0	17.0	12.00	14	8	112	1 344
225	13,4-14,9	10.0	17.0	12.00	14	6	84	1 008
250	14,8-16,4	10.0	17.0	12.00	11	6	66	792
280	16,6-18,4	10.0	17.0	12.00	7	8	56	672
315	18,7-20,7	10.0	17.0	12.00	3	12	36	432
355	21,1-23,4	10.0	17.0	12.00	3	12	36	432
400	23,7-26,2	10.0	17.0	12.00	3	10	30	360

POLYETHYLENE PIPES PE100 AQUALIFE BDS EN12201-2
BOTEVGRAD PRODUCTION

DN [mm]	Wall thickness [mm]	PN [bar]	SDR	Bars/coils	*PACKING			
					Pipes/Pallet	Pallets/Truck	Pipes/Truck	Meters/Truck
20	2,0-2,3	16.0	11.0	100.00				
25	2,0-2,3	12.5	13.6	100.00				
32	3,0-3,4	16.0	11.0	100.00				
40	3,7-4,2	16.0	11.0	100.00				
50	4,6-5,2	16.0	11.0	100.00				
50	4,6-5,2	16.0	11.0	12.00				
63	5,8-6,5	16.0	11.0	100.00				
63	5,8-6,5	16.0	11.0	12.00	116	10	1 160	13 920
75	6,8-7,6	16.0	11.0	100.00				
75	6,8-7,6	16.0	11.0	12.00	102	8	816	9 792
90	8,2-9,2	16.0	11.0	100.00				
90	8,2-9,2	16.0	11.0	12.00	58	10	580	6 960
110	10,0-11,1	16.0	11.0	100.00				
110	10,0-11,1	16.0	11.0	12.00	48	8	384	4 608
125	11,4-12,7	16.0	11.0	12.00	43	8	344	4 128
140	12,7-14,1	16.0	11.0	12.00	38	6	228	2 736
160	14,6-16,2	16.0	11.0	12.00	33	6	198	2 376
180	16,4-18,2	16.0	11.0	12.00	17	8	136	1 632
200	18,2-20,2	16.0	11.0	12.00	14	8	112	1 344
225	20,5-22,7	16.0	11.0	12.00	14	6	84	1 008
250	22,7-25,1	16.0	11.0	12.00	11	6	66	792
280	25,4-28,1	16.0	11.0	12.00	7	8	56	672
315	28,6-31,6	16.0	11.0	12.00	3	12	36	432
355	32,2-35,6	16.0	11.0	12.00	3	12	36	432
400	36,3-40,1	16.0	11.0	12.00	3	10	30	360

POLYETHYLENE PRESSURE PIPES DIAGRAM OF FRICTION LOSSES



$$h = \frac{\lambda \cdot v^2}{2 \cdot g \cdot d}$$ (water at 15°C)

h = hydraulic gradient (pressure loss from friction) (m/100 m)

v = average flow velocity (m/sec)

Q = flow (l/sec или m3/h)

I.D. = outer diameter (mm)

λ = coefficient of losses

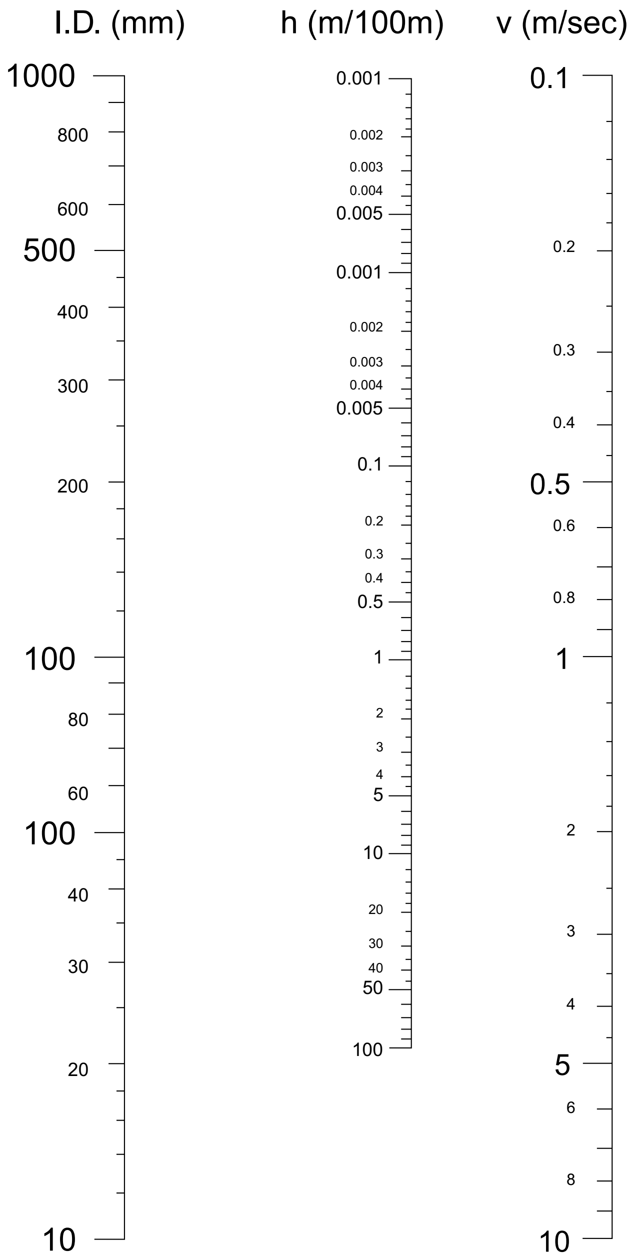
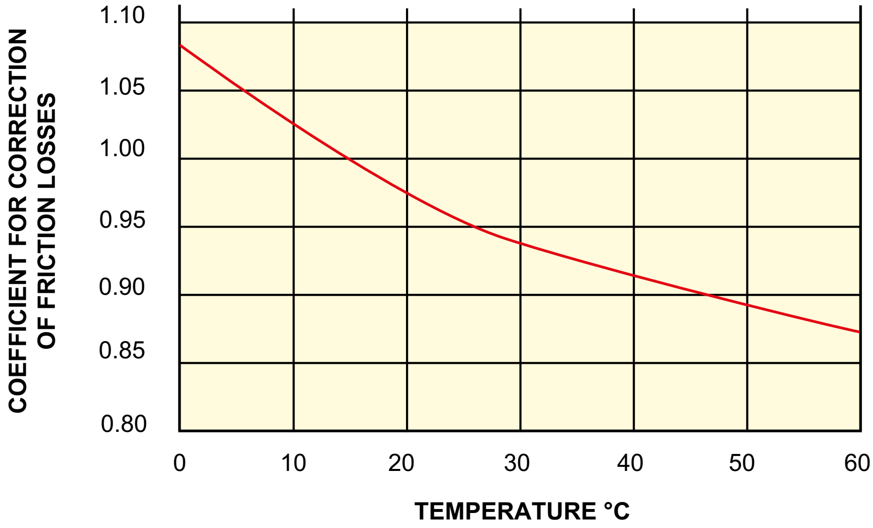


DIAGRAM OF THE COEFFICIENT FOR CORRECTION OF FRICTION LOSSES IN POLYETHYLENE PRESSURE PIPES (as function of the temperature)

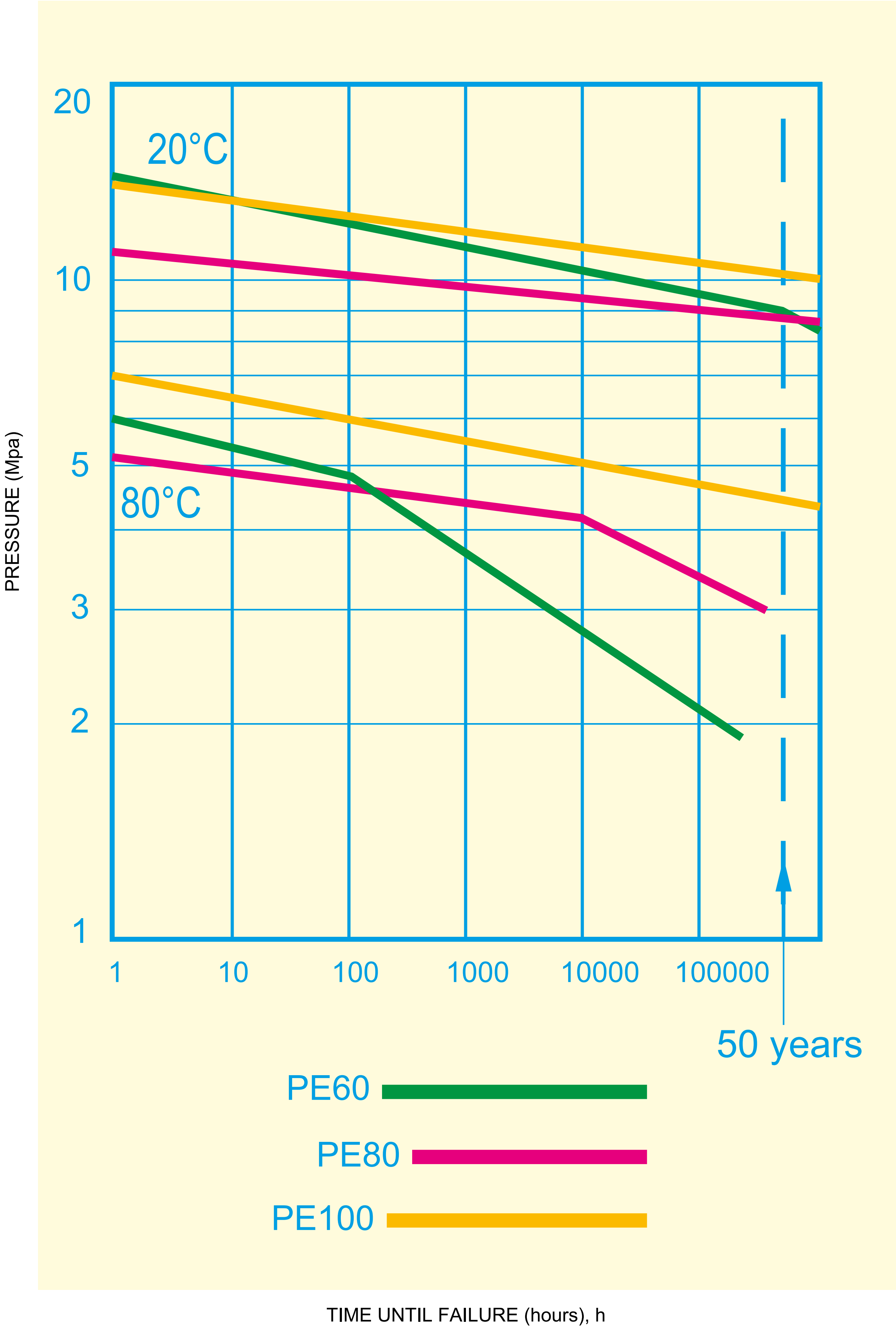


HIGH DENSITY POLYETHYLENE PIPES: CORRELATION BETWEEN THE PRESSURE NORMS AND THE ALLOWED TEMPERATURES UNDER DIFFERENT CONDITIONS OF CONSTANT USE

To use a certain system at temperatures, different from 20°C or for a period of 50 years, it is necessary its values to be reduced or raised in accordance with the maximum work pressure or the term of operation or a combination of both.

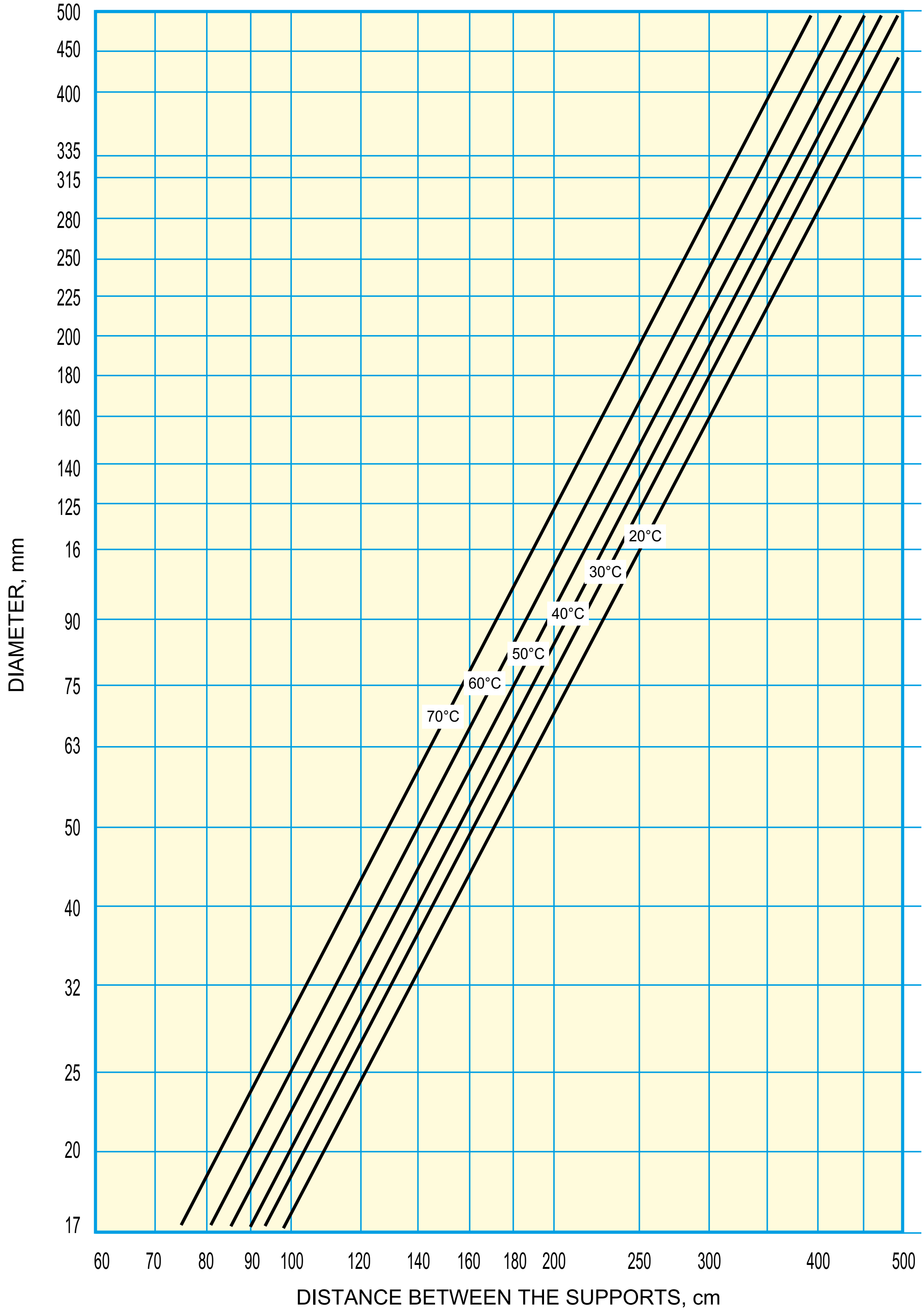
TEMPERATURE (°C)	YEARS OF EXPLOITATION	PN 2.5 Series 1	PN 3.2 Series 2	PN 4 Series 3	PN 6 Series 4	PN 10 Series 5	PN 12.5	PN 16 Series 6
10	1	3.4	4.3	5.4	8.0	13.4	16.7	21.4
	5	3.2	4.1	5.1	7.7	12.8	16.0	20.5
	10	3.2	4.0	5.0	7.6	12.6	15.8	20.2
	25	3.1	3.9	4.9	7.3	12.2	15.2	19.5
	50	3.0	3.8	4.8	7.2	12.0	15.0	19.2
20	1	2.9	3.6	4.6	6.8	11.4	14.2	18.2
	5	2.7	3.5	4.3	6.5	10.8	13.5	17.3
	10	2.7	3.4	4.2	6.4	10.6	13.3	17.0
	25	2.6	3.3	4.2	6.2	10.4	13.0	16.6
	50	2.5	3.2	4.0	6.0	10.0	12.5	16.0
30	1	2.5	3.1	3.9	5.9	9.8	12.2	15.7
	5	2.4	3.0	3.8	5.6	9.4	11.7	15.0
	10	2.3	2.9	3.7	5.5	9.2	11.5	14.7
	25	2.0	2.5	3.1	4.7	7.8	9.8	12.5
	50	1.7	2.2	2.7	4.1	6.8	8.5	10.9
40	1	2.1	2.7	3.4	5.0	8.0	10.0	12.8
	5	1.8	2.3	2.9	4.3	7.2	9.0	11.5
	10	1.6	2.0	2.5	3.7	6.2	7.8	9.9
	25	1.3	1.7	2.1	3.1	5.2	6.5	8.3
	50	1.2	1.5	1.8	2.8	4.6	5.8	7.4
50	2	1.7	2.2	2.7	4.1	6.8	8.5	10.9
	5	1.2	1.5	1.9	2.9	4.8	6.0	7.7
	10	1.1	1.3	1.7	2.5	4.2	5.3	6.7
	30	1.0	1.3	1.6	2.4	4.0	5.0	6.4
60	1	1.2	1.5	1.9	2.9	4.8	6.0	7.7
	5	0.8	1.1	1.4	2.0	3.4	4.2	5.4
70	1	0.8	1.0	1.3	1.9	3.2	4.0	5.1

REGRESSIVE CURVES



HIGH DENSITY POLYETHYLENE PIPES FOR PRESSURE OF 10 atm,
DIAGRAM OF SUPPORTS ARRANGEMENT

(Pipe with water, d 1000 kg/m³, radius of bending max 10 mm for 10 years)



The distances between the supports according to the diagram concern only the horizontal pipes.
For the vertical pipes, the indicated distances must be multiplied by coefficient of 1.3.

HIGH DENSITY POLYETHYLENE PIPES, COEFFICIENT FOR CORRECTIONS OF THE SUPPORT ARRANGEMENT

The following tables indicate the coefficient for correction in the distances between the supports for high density polyethylene pipes (HDPE) or PVC-U, during the pipeline installation under conditions which are different from the ones, indicated in the previous diagram.

TABLE WITH CORRECTIONS FOR DIFFERENT NOMINAL PRESSURES

	COEFFICIENT FOR CORRECTION	
NOMINAL PRESSURE (atm)	HDPE	PVC-U
PN 25		1.064
PN 16	1.07	1.000
PN 12.5	1.03	
PN 10	1.00	0.930
PN 6	0.91	0.830
PN 4	0.84	0.720
PN 3.2	0.80	
PN 2.5	0.75	0.640

TABLE WITH CORRECTIONS FOR DIFFERENT RADII OF BENDING

	COEFFICIENT FOR CORRECTION	
RADIUS OF BENDING (mm)	HDPE	PVC-U
20	1.19	
15	1.11	
10	1.00	
5	0.84	1.00
2.5	0.70	0.84
1	0.56	0.67

TABLE WITH CORRECTIONS FOR FLUIDS WITH DENSITY WHCH IS DIFFERENT FROM THE WATER ONE

	COEFFICIENT FOR CORRECTION	
FLUID DENSITY (Kg/m^3)	HDPE	PVC-U
1000	1.00	1.00
1250	0.96	0.97
1500	0.93	0.94
1750	0.90	0.92

WATER HAMMER

Water hammer is an inconstant effect caused by rapid changes of flow conditions. The water hammer is passed on as a wave which leads to brief pressure changes. The water hammer can damage the network or the control and measurement instruments especially at high values of flow change. In this case the pipe is under the influence of considerable pressure increases and decreases (excess pressure or subpressure) in relation to the normal one. The network length, the short duration of the transitional influence (for example very fast closing of a valve) and the turning on and off of pumps or water turbine are the most common reasons for the problem.

For every network there is a constant

$$\frac{2L}{\alpha}$$

Where
L = pipe's length
α = velocity of the pressure wave in the pipe

The hydraulic shock or if we have to be more accurate the creation of high excess pressure or subpressure in the pipe network appears when the time (t) of the transitional influence, which generates the flow state change, is shorter than the network time constant (T):

$$t < T$$

The water hammer can be described with the help of Figure 1.
Let's examine a pipeline with a length l, in which flows liquid from a reservoir with big dimensions, situated at point A. It is accepted that the flow is not influenced by the friction and that at the moment t=0 a instantaneous closing of a valve is made at the end of the pipe, point B.

At point B appears excess pressure (P) which passes along the pipe as a wave with velocity called wave velocity (a), determined by the pipe and fluid's properties. When after time t=T/2 the pressure reaches point A, the whole pipeline is under the influence of excess pressure (P). Due to the fact that the condition is not stable, the wave caused by the pressure is reflected by the reservoir. Thus a back wave is created which passes along the pipe with the same velocity (a) and when it reaches point B at the moment t=T it restores the pipeline pressure to its initial value. At this moment the kinetic energy of the flowing fluid transforms into potential energy and the pressure falls. This pressure change (subpressure – P), caused by the energy transformation, passes along the pipeline to point A. At the moment t=3T/2, the pressure change reaches point A and the whole pipeline is under the influence of subpressure (-P). This situation is unstable, the subpressure wave reflects in the reservoir and a pressure change appears in the opposite direction, as it restores the pipeline pressure to its initial value. At the moment t=2T the pressure change has reached the valve and the pressure of the fluid along the pipeline is in its initial value. It is the same situation as at the moment t=0 and if there are no energy losses, the process would continue to repeat. But in practice, energy losses exist like fluid friction, while the pressure changes disappear after a few cycles.
On Figure 1 we see three-dimensional representation of this effect.

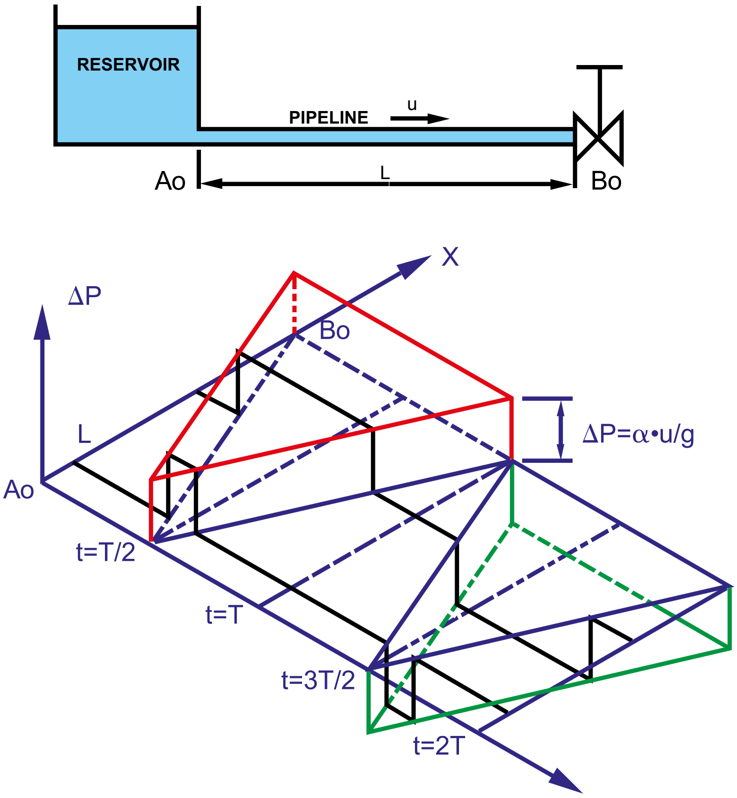


Figure 1

The rapid changes of the basic velocity and of the water in the pipe lead to increase in the pressure which is defined by the following formula for a flow without friction:

$$\Delta P = \frac{\alpha . \Delta u}{g}$$

Where
ΔP = overpressure (m, of water column)
α = wave velocity (m/sec)
Δu = change in the basic velocity (m/sec)
g = gravity acceleration (9.81 m/sec^2)

The wave velocity is defined by the following formula:

$$\alpha = \sqrt{\rho\left(\frac{1}{k} + \frac{D \cdot c}{E \cdot s}\right)}$$

Where
α = wave velocity (m/sec)
ρ = fluid density (kg/m^3)
k = coefficient of contractibility (N/m^2) (κ_{water} = 2•10^9 N/m^2)
E = модул на еластичност на стената на тръбата (N/m2)
s = thickness of the pipe wall (m)
D = internal diameter (m)
c = coefficient, depending on the way of pipe's installation
coefficient of lateral shrinkage v (Poisson's coefficient)

The overpressure, calculated according to the above formulae is the maximum possible overpressure (or subpressure).

When transitional effect lasts longer than T (t > T), overpressure is calculated by the formula:

$$\Delta P = \frac{2L}{g} \cdot \frac{\Delta u}{T}$$

and depends on the pipe's length.

In Table 1 are given the modulus of elasticity of some conventional materials for pipe.

TABLE 1
MODULUS OF ELASTICITY OF CONVENTIONAL MATERIALS FOR PIPES

MATERIAL	MODULUS OF ELASTICITY (N / m^2)
PVC-U	$3 \cdot 10^{9}$
MDPE (PE 80)	$6.5 \cdot 10^{8}$
HDPE (PE 100)	$1.4 \cdot 10^{9}$
Steel	$2.1 \cdot 10^{11}$
Cast iron	$1.6 \cdot 10^{11}$
Asbestos	$1.9 \cdot 10^{10}$

It must be mentioned that the plastic pipes have a certain capability to withstand the pressure which exceeds the pressure of the class i.e. the nominal pressure. In case of often water hammers occurrences in a pipeline, the pipes are influenced by pressures which are above the nominal values, for which they are designed. Under these conditions i.e. when

ΔP + pipeline work pressure > pipe nominal pressure,

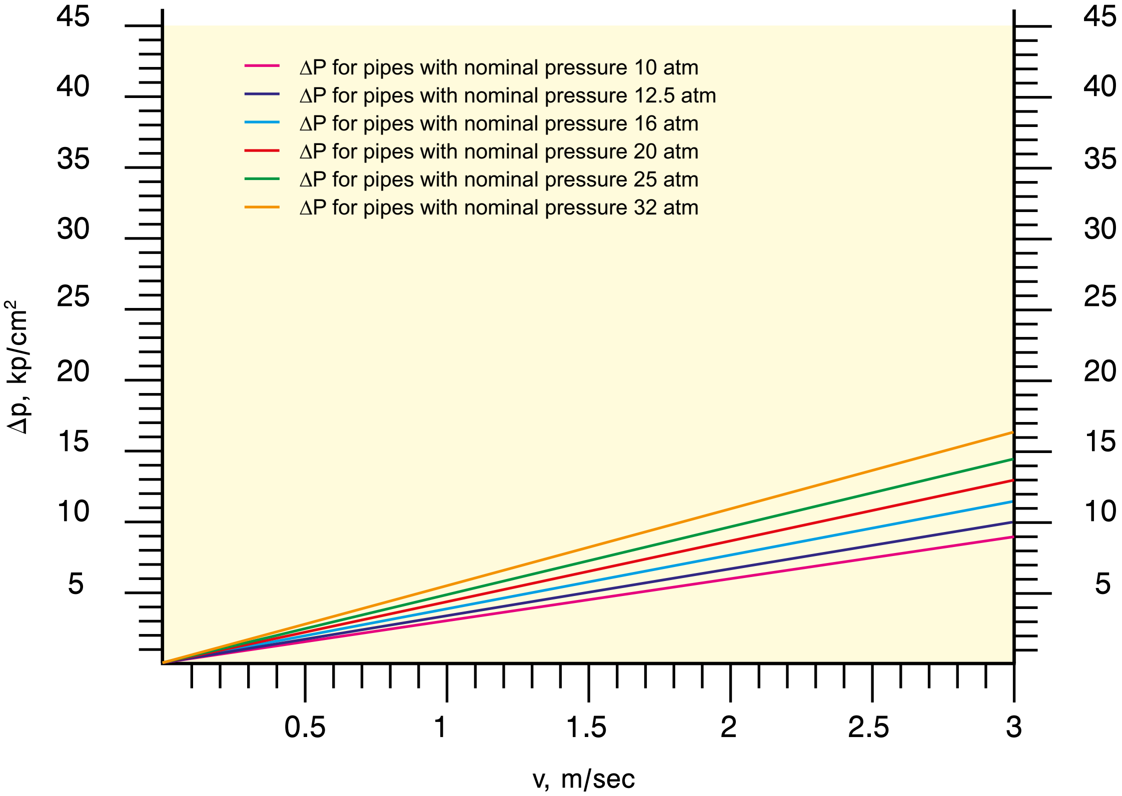
the consequences with regard to the pipe's strength are very important. Due to this reason, in cases when the water hammer effect appears, it is recommended the pipeline to be designed by giving an account to the fact that the sum of the work pressure and the overpressure, caused by the water hammer, must be lower than the nominal pressure of the used pipes.

The following diagrams represent the overpressure as a result of the water hammer in pipes, made from:

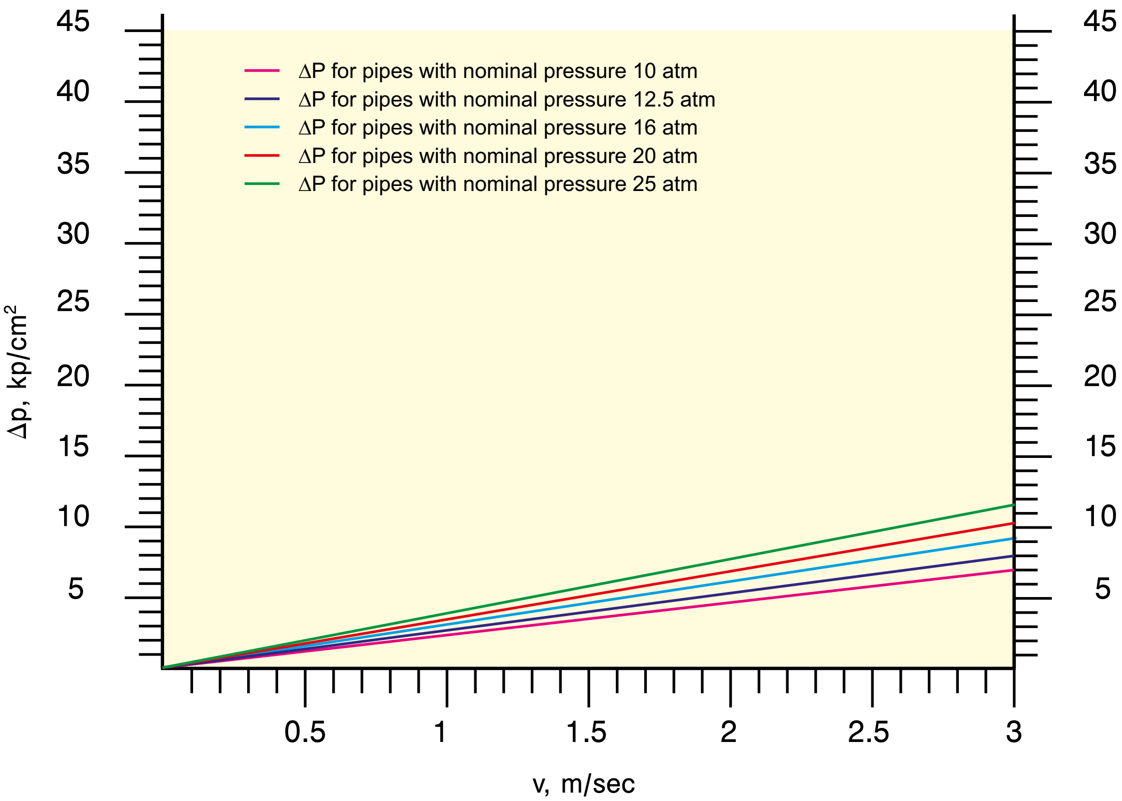
- PE 100 (third generation), according to EN 12201-2
- PE 80 (second generation), according to EN 12201-2

DIAGRAMS OF EXCESS PRESSURE AS A RESULT OF WATER HAMMER

PE 100 PRESSURE PIPES, EN 12201-2 and DIN 8074-8075



PE 80 PRESSURE PIPES, EN 12201-2 and DIN 8074-8075



CALCULATION OF PLAST PIPES DEFLECTIONS

For the calculation of plastic pipe deflection under the soil pressure with which it is covered, the following procedure is observed.

Calculation of the soil static pressure, Ps (Figure 2)

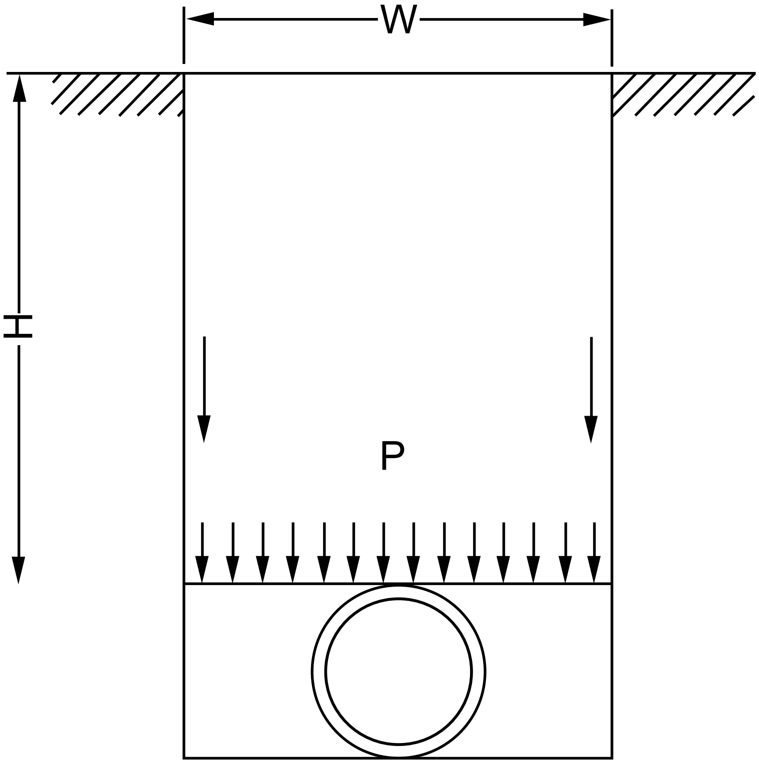


Figure 2

$$Ps=c\bullet\gamma\bullet H$$

and

$$c=\frac{1-e^{-2\bullet k\bullet\varepsilon\varphi\delta\bullet H/W}}{2\bullet k\bullet\varepsilon\varphi\delta\bullet H/W}$$

Where
Ps = soil pressure over the upper part of the pipe (kg/m^2)
γ = soil specific weight (kg/m3)
H = depth of the cover (m)
W = trench width (m)
c = coefficient of pressure according to the soil type
k = coefficient related to the vertical and horizontal pressure
δ = angle of friction of the filling material (bedding angle)
The values of k and δ are taken from Table II.

TABLE II

Properties of the material for filling the trenches	K	δ (Table IV)
- The material for filling is compacted to a certain degree - There is a trench	0.5	δ = ρ
- The material for filling is not compacted enough - Vertical walls of the trench are set up for support of the soil - There are underground waters	0.5	δ = 2/3ρ
- The material is compacted enough dense soil Dp > 95% crumbly soil Dp > 97%	0.7	δ = ρ

Calculation of traffic load, Pw (Figure 3)

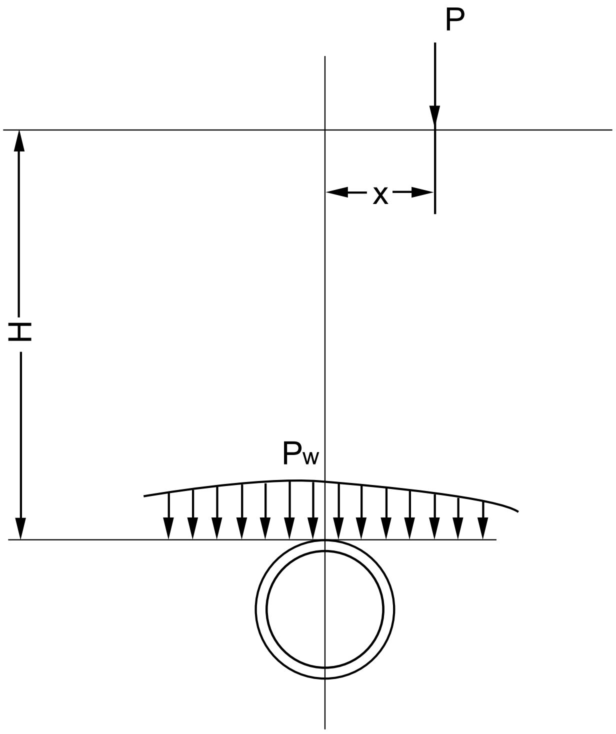


Figure 3

It is recommended in all cases the cover layer to be deeper (H) than 0.8 m.
The following formula is not valid for H < 0.5 m.

$$P_w = \frac{3 \cdot P}{2 \cdot \pi \cdot H^2 \left\{ 1 + \frac{x^2}{H^2} \right\}^{5/2}}$$

Where
P = car's weight (kg)
X, H = distances in m, as shown on Figure 3 (m).

Total load

The total load (q) is calculated with the formula:

$$q = P_s + P_w \ \ kg/m^2 = q \ / \ 10000 \ kg/cm^2$$

If the pipe is ideally buried on the trench bottom and if the soil filled in laterally, above and at the ends is well compacted, only part of the load influences the pipeline walls. That is why the formula changes as:

$$q_r = 0{,}5 \bullet q = q_r / 10000 \ kg/cm^2$$

Calculation of the pipe's section stiffness, Rt

$$R_t = \frac{2 \bullet E \bullet s^3}{3\,(Dn\text{-}s)^3}$$

Where
Dn = pipe's nominal diameter (cm)
s = pipe's thickness (cm)
E = modulus of elasticity (kg/cm²)

TABLE III
Modulus of elasticity

Et	uPVC	PE 80 (2-u)	PE 100 (3-u)
Long-term elasticity	30000	6500	14000
Short-term modulus	20000	1650	3500

Calculation of soil stiffness, Re

$$R_e = 0{,}6 \bullet e \bullet E_e$$

Where
e = coefficient for correction
Ee = modulus of elasticity, second modulus of the surrounding burying material (Table IV)

TABLE IV
Modulus of elasticity of the soil around the pipe

Soil group (according to ATV)	Specific weight γ (gr/cm³)	Angle of friction ρ (°)	Ee (kg/cm²), Depending on				
			85%	90%	95%	97%	100%
Crumbly soil, big granules (gravel)	2	35	25	60	160	230	400
Lightly compacted soil, fine granules (sand)	2	30	12	30	45	80	200
Dense mixed soil, slime (sand and gravel)	2.1	25	10	20	30	60	160
Dense soils (clay)	2	20	6	15	20	40	100

Calculation of the system stiffness (pipe's section-surrounding soil), Rs

$$R_s = \frac{R_t}{R_e}$$

Calculation of pipe's deflection, Dn and Def

$$\Delta Dn = \frac{q_r \cdot Dn}{2R_t} \cdot \xi \quad \text{and} \quad \xi = -0.166 + 0.128 \cdot L$$

$$L = \frac{0{,}083}{R_s + 0{,}066} \quad \text{and} \quad Def = \frac{\Delta Dn}{Dn} \cdot 100\ \%$$

Where
ΔDn = diameter change (cm)
Def = deflection (%)

An example of deflection calculation

Sewer pipes PE 100 0400 (thickness 14 mm) are buried in the ground at the depth of 2.6 m, in a trench which is 1 m. wide. The trench is filled with lightly compacted gravel (Dp = 90% according to Proctor). The soil specific weight is = 2000 kg/m³ and the angle of friction is p = 35%. The load of the passing vehicles is 30.000 kg.

Calculation of the static pressure of the soil, Ps

$$c = \frac{1 - e^{-2 \cdot 0.5 \cdot \varepsilon\varphi 35 \cdot 2.6/1}}{2 \cdot 0{,}5 \cdot \varepsilon\varphi 35 \cdot 2{,}6/1} = 0{,}46$$

and

$$P_s = 0{,}46 \cdot 2000 \cdot 2{,}6 = 2393{,}75\ kg/m^2$$

Calculation of the traffic load

$$P_w = \frac{3 \cdot 30{,}000}{3 \cdot \pi \cdot 2{,}6^2} = 2{,}120\ kg/m^2$$

$$q = 2{,}393 + 2{,}120 = 4{,}513\ kg/m^2 = 0{,}4513\ kg/cm^2$$

$$qr = q \cdot 0{,}5 = 0{,}2256\ kg/cm^2$$

Calculation of the pipe's section stiffness, Rt

$$R_t = \frac{2 \cdot 3{,}500 \cdot 1{,}4^3}{3 \cdot (40 - 1{,}4)^3} = 0{,}111$$

Calculation of the soil stiffness, Re

$$R_e = 0{,}6 \cdot 1 \cdot 60 = 36\ kg/m^2$$

Calculation of the system stiffness (soil - pipe), Rs

$$R_s = 0{,}111/36 = 0{,}0031$$

Calculation of pipe's deflection, ΔDn and Def

$$L = \frac{0{,}083}{0{,}00031 + 0{,}066} = 1{,}201 \qquad \xi = -0.166 + 0.128 \cdot L = -0.012$$

$$\Delta Dn = \frac{0{,}2256 \cdot 40}{2 \cdot 0{,}111}(-0{,}012) = 0{,}488\ cm$$

$$Def = \frac{0{,}488}{40}\ 100 = 1{,}22\ \%$$

STRENGTH AT LONGITUDINAL BENDING OF PIPES UNDER THE INFLUENCE OF EXTERNAL HYDROSTATIC PRESSURE

The external pressure for example of the soils and of the underground waters creates contraction forces around the pipe's wall. When the contraction forces around the pipe's walls exceed a certain limit, it is possible the elliptical deformed pipe to crumple due to the bending of the wall.

The theoretical resistance to longitudinal bending (Pb) is calculated according to the following equation:

$$P_b = \frac{24 \cdot E \cdot I}{(1-\nu^2) \cdot D_m^3}$$

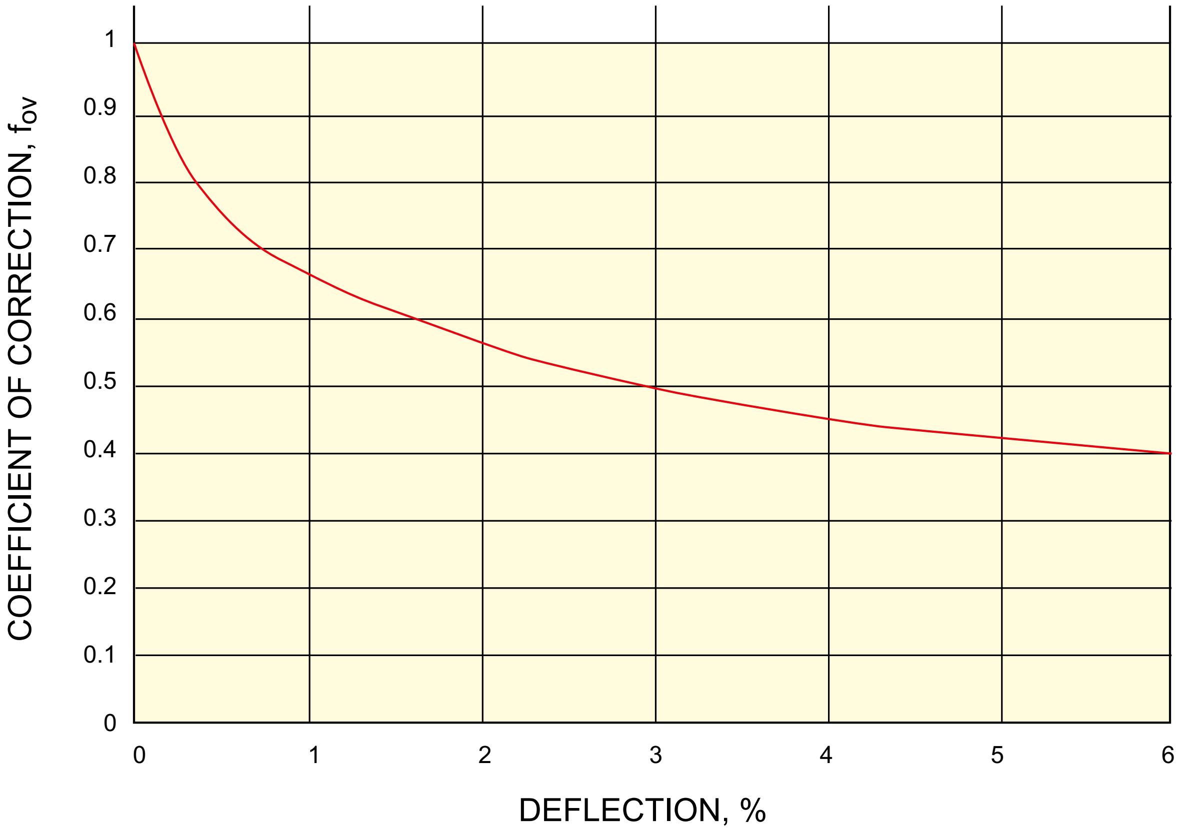
And because $$I = \frac{s^3}{12}$$

$$P_b = \frac{2 \cdot E}{(1-\nu^2)} \left(\frac{s}{D_m}\right)^3$$

Where
Pb = load with longitudinal bending (kgf/cm^2)
E = modulus of elasticity of pipe's material (kgf/cm^2)
s = wall thickness (cm)
Dm = average diameter of the pipe (cm)
ν = coefficient of Poisson

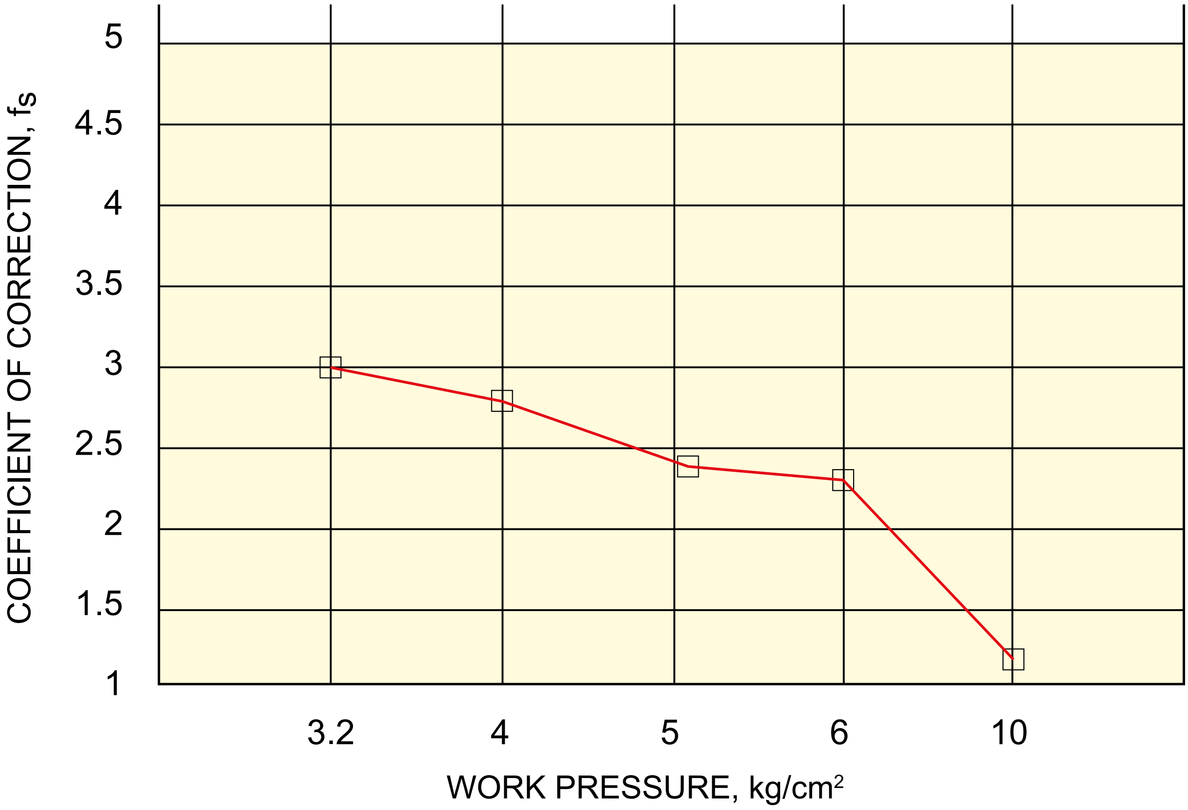
The formula validity depends on the pipe's elasticity and circumference. If the pipe has deflections and elliptic shape, then the load with longitudinal bending Pb must be corrected with a coefficient whose value, according to the pipe's deflection, is taken from Diagram 1.

DIAGRAM 1



When the pipe is buried in the ground, it touches the surrounding soil. If the soil is well compacted and has a high modulus of elasticity, then the pipe's support is considerable and must be taken into account by using the coefficient fs, which is taken from Diagram 2 in accordance with the work pressure of the pipe.

DIAGRAM 2



That is why when we lay a pipe in the ground, we have the following:

$$P'_b = P_b \cdot f_{ov} \cdot f_s$$

The pipes which are submerged at the depth Hw, are under the influence of external (hydrostatic) pressure, calculated according to the following formula:

$$P_w = \frac{\gamma_w \cdot H_w}{10{,}000}$$

Where
Pw = external (hydrostatic) pressure (kgf/m^2)
γw = specific weight of water (kgf/m^3)
Hw = water depth above the pipe (m)

With the help of the safety coefficient (S = 2) we can calculate the maximum depth (Hwmax), at which the pipe can work reliably.

$$H_{wmax} = \frac{10{,}000 \cdot P'_b}{2 \cdot \gamma}$$

POLYETHYLENE PIPES TRANSPORTATION AND STORAGE

To preserve their technical properties the polyethylene pipes must be used, transported and stored in accordance with the following instructions.

A. TRANSPORTATION

- The pipes must be transported in suitable vehicles with smooth inner surface which doesn't allow the damage of the pipes.

- The pipes must not be pulled over the surfaces of the vehicle, must be properly loaded, put one over other on smooth surfaces and unloaded. If the pipe's wall has a scratch, deep 10% of the wall's thickness, it is recommended this part to be replaced.

B. STORAGE

- During the storage the pipes must not be bended or damaged. Such problems are possible if the pipes are not arranged properly to a certain height. The pipes must not be arranged standing and one over other higher than 1.5 m, and the areas for storage must be smooth without stones and other sharp objects along the pipe. If the pipes are manufactured with fittings, the fittings must be sticking out.

- The pipes with different diameters must be stored separately. If this is impossible, the pipes with bigger diameter must be stored at the bottom of the package.

- When the pipes are stored for a long period, spirally rolled, they must be stored horizontally.

POLYETHYLENE PIPES INSTALLATION

A. UNDERGROUND NETWORKS

Compared to the conventional, the polyethylene pipes can be buried in trenches with smaller dimensions. The long, butt welded pipes, connected above ground, can be buried in narrow trenches, after being left to cool. In principle the dimensions of the trenches are defined according to the diameter of the pipes, the method of connection and the soil type.

The trench depth must exceed:

- 50 см for roads without traffic;
- 60 см for roads with poor traffic;
- 80 см for roads with normal or busy traffic.

The trench width can be as small as possible but not smaller than the pipe's diameter plus 20 cm in order to allow proper compacting of the lateral filling material and proper distribution of the soil pressure over the pipe. The bottom of the trench must be smooth without stones and other sharp or hard objects. It is necessary to be covered with a layer of sand 10-15 cm thick (bedding layer) which provides an even support of the buried polyethylene pipe. If it has no stones the dug soil can be used as a lateral material for filling.

B. ABOVE-GROUND NETWORKS

Using of above-ground networks allows utilizing of the inherent properties and characteristics of the material as resistance to deterioration from sunlight, good resistance to impacts even at low temperatures, big flexibility and others.

The basic precautions in this case are:

- Protection from overheating. The pipelines must not be placed near steam generators, steam pipelines and others due to the danger of overheating above the allowed value.

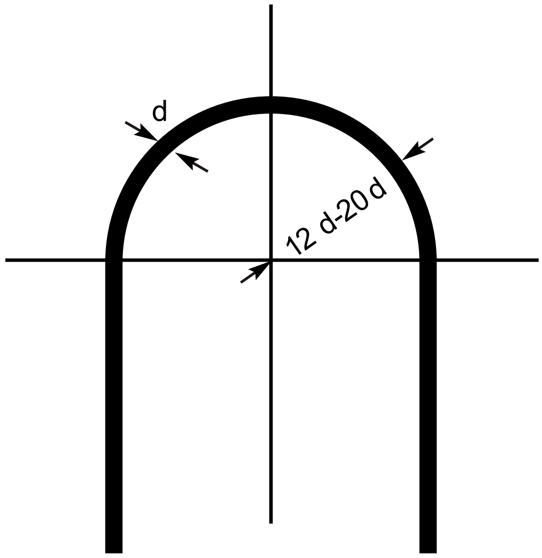
- Providing of supports for the pipelines at certain intervals, especially for the parts with heavy fittings (for example valves).

C. SUBMERGED NETWORKS

The decision for burying underground and the responsibility for this procedure execution depend totally on the sub-contractor and most of all on the means which he has. The work site must be smooth and close to the bank. If the pipes are delivered rolled on spiral, enough space must be provided (at least 100 m) for their unwinding.
The polyethylene density is lower than 1 gr/cm3. Due to this the pipes must be buried with additional weights (ballast), which hold the pipes steady on the sea bottom. The weights are made of concrete (armored or not) and can be in different shapes. To avoid damaging of the external surfaces of the pipes from the concrete weights, usually the latter are coated with soft material (for example polyethylene foil).

D. RADIUS OF BENDING

At normal temperatures the polyethylene pipes can be bended to a radius Rs, which is equal to 12-20 times their external diameter (DIN 16933). The inherent flexibility of the polyethylene pipes allows being avoided significant number of fittings during the design and building of pipeline system. If the pipes are delivered rolled on spiral or on spools, they must be bended at the direction of winding.



POLYETHYLENE PIPES CONNECTION

A. WELDING

Polyethylene can be welded. Welding is a process of thermal connecting by heating to 220°C of the surfaces of the circle openings of the connected polyethylene pipes until reaching a state of melting of every contact surface. After that the two surfaces are joined under controlled pressure for a certain period for cooling and by joining the molecules of the two pipes a homogeneous welding is achieved.

- The spots for joining are resistant to axial pressure and under pressure their strength can be compared with the pipe's one.
- Polyethylene pipes flexibility and the flexibility of the joining allow the designer to connect the pipes on the ground surface and after that to bury them in the trench, regardless of the used burying technique.
- Continuity and smoothness of the internal surface of the pipes are preserved and the coefficient of roughness (k) is not increased. Even if it is necessary the stripe which is formed as a result of the welding can be easily removed.

1. BUTT WELDINGE

For the butt welding of polyethylene pipes a special welding machine is necessary with heating plate (“mirror”) for heating the pipe’s end to melting point which later on are connected under pressure. The principle sequence of the welding procedure is illustrated on Figure 4.

- The pipes’ ends, tightened up in the welding machine, are made smooth with the help of a smoothing device. In this device the pipe’s ends are checked for axial alignment.

- The pipes’ ends are pressed towards the heating element with the necessary pressure P for smoothening until the moment when the joining surfaces are melted all around their circumference and on the internal and the external parts of the pipes a stripe is formed which 2 mm high.

- The pressure for aligning is reduces almost to zero and the time for heating begins to go by. The heating without pressure continues until the melting of the necessary polyethylene mass around the heated area.

- The pipes’ ends are released from the heating element which is removed without touching the fusion surfaces and then immediate connecting of the pipes is made under welding pressure P.

- The welding pressure P is maintained during the whole period of cooling.

The time for cooling, the heating pressure and the welding and the height of the formed welding stripe depend on the parameters of the welded pipes (diameter, wall thickness).

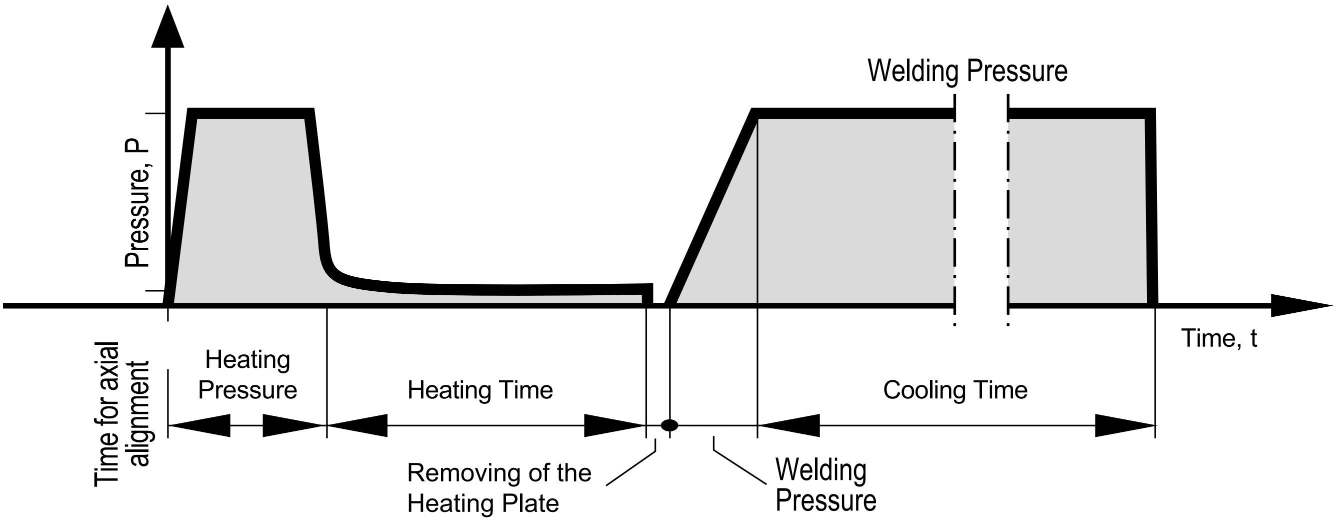


Figure 4

2. FUSION WELDING

During the fusion welding it is required a special aggregate for welding control, which sends heat energy (direct current) towards the special polyethylene fitting for melting.

The fitting is a connecting device with two nests with a heating element (wire), formed along the surface for welding at the joining points. When the two leveled ends of the pipe are inserted into the device and electricity is applied, the heat, generated at the element welds together the joined surfaces. The time for welding and the application of electricity, which depend on the diameter and the fitting type, are regulated manually or automatically by a control panel.

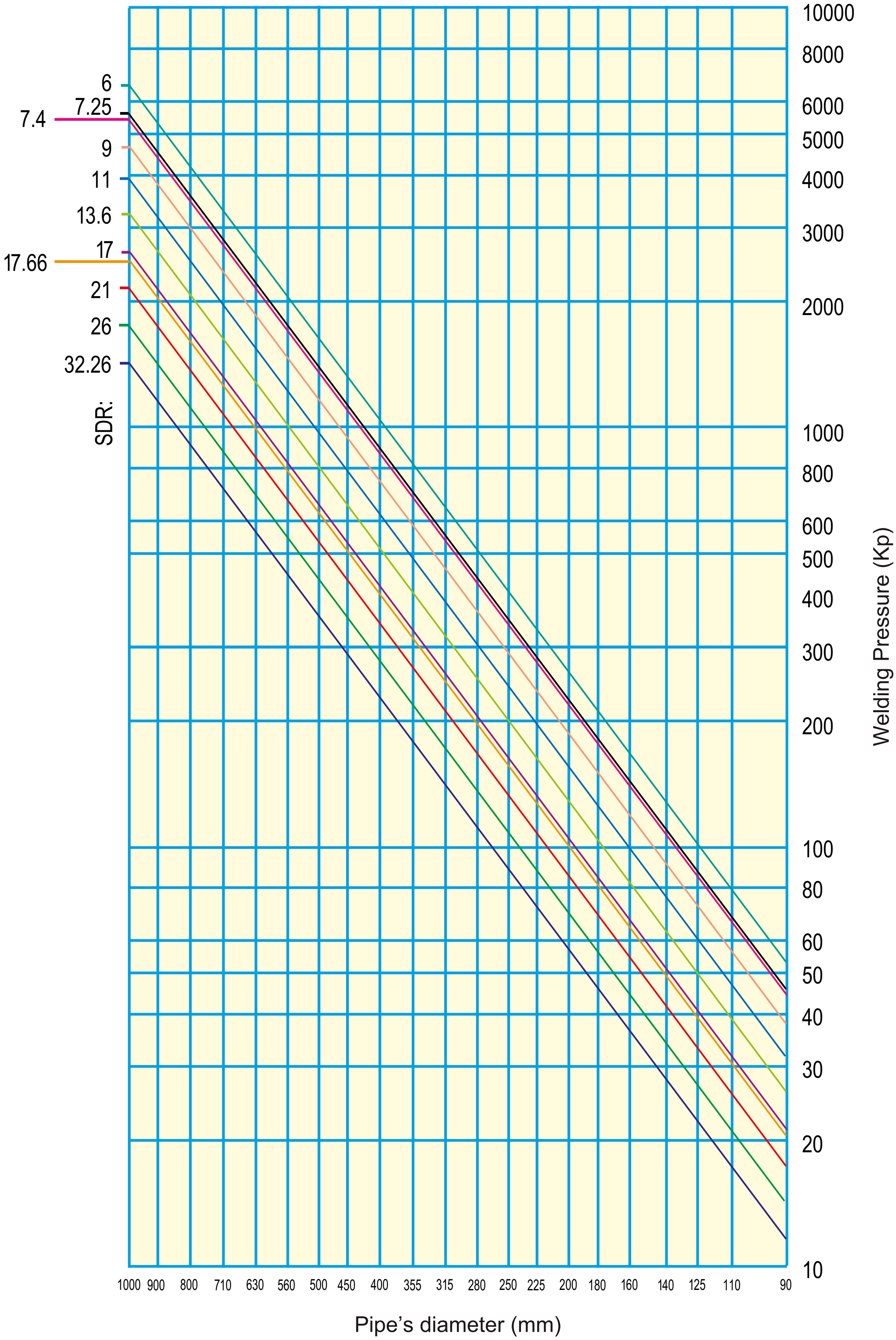
B. MECHANICAL CONNECTION

The mechanical connection of polyethylene pipes is achieved by appropriate mechanical fittings. They are made of different materials (plastic and metal) and are two types:

- Fittings for multiple uses which can be taken off the pipe and used again.

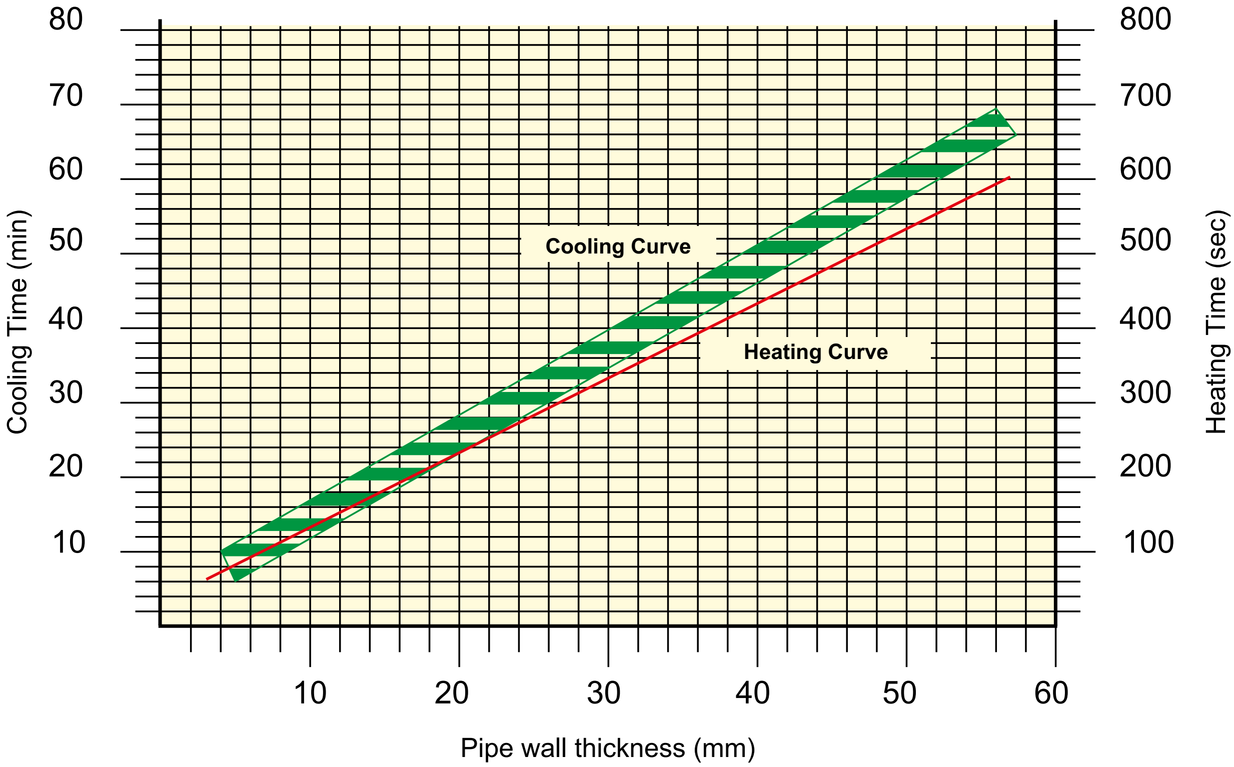
- Permanently mounted fittings which cannot be taken off the pipe.

BUTT WELDING
WELDING PRESSURE (Kp)



Manometer readings (bar) = welding force /f*
*The coefficient f is usually indicated by the manufacturer of the machine, with usual value 1bar = fKp.

UTT WELDING: TIME OF HEATING AND COOLING



Again the total time for butt welding is determined to a great extend by the time for preparation i.e. the time necessary for:
- Joining the pipes
- Leveling
- Providing of axial alignment
- Cleaning

It is obvious that properly prepared work site and the welders’ experience play a significant role for the total time, necessary for the butt welding procedure.

Note: The time for cooling varies according to the temperature of the environment.

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