

CHAPTER IV: PLASTIC AND POLYETHYLENE (PE)

IV. Plastic and Polyethylene (PE) Pipes

IV.1. Polyethylene (PE)

Polyethylene is a thermoplastic material polymerized from ethylene (C₂H₄). Complex macromolecules are created by repeating -(CH₂)- patterns (Figure IV-1). In 1933, in the laboratory of the British company I.C.I., E. Fawcett and R. Gibson discovered a manufacturing process for polyethylene based on the radical polymerization of ethylene under high pressure to produce branched chains. This synthesis was used on an industrial scale starting in 1939. The irregular macromolecular structure produced by this technique made it difficult for the material to crystallize, known as low-density polyethylene (LDPE).

The discovery of the linear form of polyethylene, known as HDPE or PE-L, dates back to the 1950s, thanks to four teams from three different laboratories. Today, HDPE is obtained through the catalytic cationic polymerization of ethylene, primarily using Ziegler-Natta catalysts and chromium catalysts (Douminge, 2010)

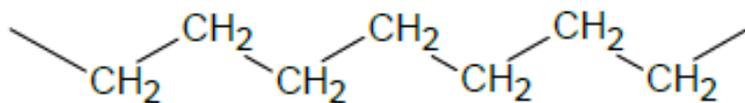


Figure IV. 1. Semi-Developed Representation of the Polyethylene Macromolecular Chain (Douminge, 2010)

IV.1.1. Quality of Pipes and Fittings

IV.1.1.1. Base Material for Pipe Manufacturing

The base material used for the manufacture of polyethylene pipes must consist only of polymer resin and additives necessary for the manufacturing process and the use of the pipes (Figure IV.2).



Figure IV. 2. Polyethylene Polymer Resin

Polyethylene is a thermoplastic polymer, non-brittle, more or less flexible, impact-resistant, and highly chemically inert. For drinking water pipes, only pure polyethylene (non-recycled) should be used, with approximately 2% carbon black and less than 1% additives. Storage must be done in a dry place, at a temperature below 60°C, and protected from ultraviolet rays. Pipes are available in PE 100 (high density, called HDPE), PE 80 (medium density, called MDPE), and PE 32 (low density, called LDPE). There are also PE 63 and PE 40, as well as LLDPE (linear low-density polyethylene), combining the flexibility of LDPE with the performance of MDPE. PE pipes are commonly available in diameters ranging from Ø20 mm to Ø63 mm for connections, in coils or straight lengths, in PN 10 or PN 16 (PN: nominal pressure); connections are made using mechanical joints or electrofusion. From Ø75 mm to Ø500 mm, PN 10, 12.5, and 16 are available in coils or straight lengths for larger diameters; connections are made by electrofusion or butt welding (called "mirror" welding). Pipes can even go up to Ø800 mm. PE pipes have good flexibility, as they are available in coils or drums up to Ø160 mm. They adapt well to the terrain and, due to the low number of connections per kilometer and connections without additional thickness, they are particularly suited to new trenchless installation constraints. This also improves the network's tightness. Since the pipeline is self-restrained, almost all thrust blocks are eliminated. The chemical inertness of the pipe prevents the dissolution or abrasion of metals, even if the water is not perfectly balanced.

The additives used in the manufacturing process must not pose any toxic, organoleptic, or microbiological risk to consumers. They must also not affect the long-term mechanical strength of the pipe. The use of recycled and regrinded materials from external sources for the manufacture of drinking water supply pipelines is strictly prohibited. Internally regrinded material is allowed up to 5% of the total material used for pipe manufacturing (MRE, 2008)

IV.1.1.2. Composition of Pipe Marking Material

The material used for marking pipes and fittings must have the same composition as the base material.

IV.1.2. Specifications for Pipes

IV.1.2.1. Color

Polyethylene pipes must be blue or black with blue stripes. Black pipes must have at least three (3) small marking stripes.

IV.1.2.2. Visual Appearance

The inner and outer surfaces of the pipe must be clean and smooth, free from grooves, cavities, notches, and other defects that could affect its quality.

IV.1.2.3. Pipe Dimensions

The outer and nominal diameters, absolute ovality, and diameter tolerances must comply with the values indicated in Table IV.1.

The wall thicknesses of the pipes are related to the pipe diameters and their nominal pressure; their values are indicated in Tables IV.2 and IV.3.

Table IV. 1. Outer Diameter and Ovality

Nominal Outer Diameter dn (mm)	Mean Outer Diameter		Ovality (Maximum Out-of-Roundness)
	dmin (mm)	dmax (mm)	
16	16,0	16,3	1,2
20	20,0	20,3	1,2
25	25,0	25,3	1,2
32	32,0	32,3	1,3
40	40,0	40,4	1,4
50	50,0	50,4	1,4
63	63,0	63,4	1,5
75	75,0	75,5	1,6
90	90,0	90,6	1,8
110	110,0	110,7	2,2
125	125,0	125,8	2,5
140	140,0	140,9	2,8
160	160,0	161,0	3,2
180	180,0	181,1	3,6
200	200,0	201,2	4,0
225	225,0	226,4	4,5

250	250,0	251,5	5,0
280	280,0	281,7	9,8
315	315,0	316,9	11,1
355	355,0	357,2	12,5
400	400,0	402,4	14,0
450	450,0	452,7	15,6
500	500,0	503,0	17,5
560	560,0	563,4	19,6
630	630,0	633,8	22,1
710	710,0	716,4	-
800	800,0	807,2	-
900	900,0	908,1	-
1000	1000,0	1009,0	-
1200	1200,0	1210,8	-
1400	1400,0	1412,6	-
1600	1600,0	1614,4	-

Table IV. 2. Wall Thicknesses

Wall Thicknesses						
Pipe Series						
	SDR 6	SDR 7,4	SDR 9	SDR 11	SDR 13,6	SDR 17
	S 2,5	S 3,2	S 4	S 5	S 6,3	S 8
Nominal Pressure PN in bar						

PE 40	-	PN 10	PN 8	-	PN 5	PN 4
PE 63	-	-	-	PN 10	PN 8	-
PE 80	PN 25	PN 20	PN 16	PN 12,5	PN 10	PN 8
PE 100	-	PN 25	PN 20	PN 16	PN 12,5	PN 10

Wall Thicknesses

Dim. Nom.	emin	emax										
16	3,0C)	3,4	2,3C)	2,7	2,0C)	2,3	-	-	-	-	-	-
20	3,4	3,9	3,0C)	3,4	2,3	2,7	2,0C)	2,3	-	-	-	-
25	4,2	4,8	3,5	4,0	3,0C)	3,4	2,3	2,7	2,0C)	2,3	-	-
32	5,4	6,1	4,4	5,0	3,6	4,1	3,0C)	3,4	2,4	2,8	2,0C)	2,3
40	6,7	7,5	5,5	6,2	4,5	5,1	3,7	4,2	3,0	3,5	2,4	2,8
50	8,3	9,3	6,9	7,7	5,6	6,3	4,6	5,2	3,7	4,2	3,0	3,4
63	10,5	11,7	8,6	9,6	7,1	8,0	5,8	6,5	4,7	5,3	3,8	4,3
75	12,5	13,9	10,3	11,5	8,4	9,4	6,8	7,6	5,6	6,3	4,5	5,1
90	15,0	19,7	12,3	13,7	10,1	11,3	8,2	9,2	6,7	7,5	5,4	6,1
110	18,3	20,3	15,1	16,8	12,3	13,7	10,0	11,1	8,1	9,1	6,6	7,4
125	20,8	23,0	17,1	19,0	14,0	15,6	11,4	12,7	9,2	10,3	7,4	8,3
140	23,3	25,8	19,2	21,3	15,7	17,4	12,7	14,1	10,3	11,5	8,3	9,3
160	26,6	29,4	21,9	24,2	17,9	19,8	14,6	16,2	11,8	13,1	9,5	10,6
180	29,9	33,0	24,6	27,2	20,1	22,3	16,4	18,2	13,3	14,8	10,7	11,9
200	33,2	36,7	27,4	30,3	22,4	24,8	18,2	20,3	14,7	16,3	11,9	13,2
225	37,4	41,3	30,8	34,0	25,2	27,9	20,5	22,7	16,6	18,4	13,4	14,9
250	41,5	45,8	34,2	37,8	27,9	30,8	22,7	25,1	18,4	20,4	14,8	16,4

280	46,5	51,3	38,3	42,3	31,3	34,6	25,4	28,1	20,6	22,8	16,6	18,4
315	52,3	57,7	43,1	47,6	35,2	38,9	28,6	31,6	23,2	25,7	18,7	20,7
355	59,0	65,0	48,5	53,5	39,7	43,8	32,2	35,6	26,1	28,9	21,2	23,4
400	-	-	54,7	60,3	44,7	49,3	36,3	40,1	29,4	32,5	23,7	26,2
450	-	-	61,5	67,8	50,3	55,5	40,9	45,1	33,1	36,6	26,7	29,5
500	-	-	-	-	55,8	61,5	45,4	50,1	36,8	40,6	29,7	32,8
560	-	-	-	-	-	-	50,8	56,0	41,2	45,5	33,2	36,7
630	-	-	-	-	-	-	57,2	63,1	46,3	51,1	37,4	41,3
710	-	-	-	-	-	-	-	-	52,2	57,6	42,1	46,5
800	-	-	-	-	-	-	-	-	58,8	64,8	47,4	52,3
900	-	-	-	-	-	-	-	-	-	-	53,3	58,8
1 000	-	-	-	-	-	-	-	-	-	-	59,3	65,4
1 200	-	-	-	-	-	-	-	-	-	-	-	-
1 400	-	-	-	-	-	-	-	-	-	-	-	-
1 600	-	-	-	-	-	-	-	-	-	-	-	-

Table IV. 3. Wall Thicknesses (Continued)

Wall Thicknesses (End)					
Pipe Series					
	SDR 17,6	SDR 21	SDR 26	SDR 33	SDR 41
	S 8,3	S 10	S 12,5	S 16	S 20
Nominal Pressure PN in bar					
PE 40	-	PN 3,2	PN 2,5	-	-

PE 63	PN 6	PN 5	PN 4	PN 3,2	PN 2,5
PE 80	-	PN 6	PN 5	PN 4	PN 3,2
PE 100	-	PN 8	PN 6	PN 5	PN 4

Wall Thicknesses

Dim. Nom.	emin	emax	emin	emax	emin	emax	emin	emax	emin	Emax
16	-	-	-	-	-	-	-	-	-	-
20	-	-	-	-	-	-	-	-	-	-
25	-	-	-	-	-	-	-	-	-	-
32	2,0 d)	2,3	-	-	-	-	-	-	-	-
40	2,3	2,7	2,0 d)	2,3	-	-	-	-	-	-
50	2,9	3,3	2,4	2,8	2,0	2,3	-	-	-	-
63	3,6	4,1	3,0	3,4	2,5	2,9	-	-	-	-
75	4,3	4,9	3,6	4,1	2,9	3,3	-	-	-	-
90	5,1	5,9	4,3	4,9	3,5	4,0	-	-	-	-
110	6,3	7,1	5,3	6,0	4,2	4,8	-	-	-	-
125	7,1	8,0	6,0	6,7	4,8	5,4	-	-	-	-
140	8,0	9,0	6,7	7,5	5,4	6,1	-	-	-	-
160	9,1	10,2	7,7	8,6	6,2	7,0	-	-	-	-
180	10,2	11,4	8,6	9,6	6,9	7,7	-	-	-	-
200	11,4	12,7	9,6	10,7	7,7	8,6	-	-	-	-
225	12,8	14,2	10,8	12,0	8,6	9,6	-	-	-	-
250	14,2	15,8	11,9	13,2	9,6	10,7	-	-	-	-

280	15,9	17,6	13,4	14,9	10,7	11,9	-	-	-	-
315	17,9	19,8	15,0	16,6	12,1	13,5	9,7	10,8	7,7	8,6
355	20,1	22,3	16,9	16,7	13,6	15,1	10,9	12,1	8,7	9,7
400	22,7	25,1	19,1	21,2	15,3	17,0	12,3	13,7	9,8	10,9
450	25,5	28,2	21,5	23,8	17,2	19,1	13,8	15,3	11,0	12,2
500	28,3	31,3	23,9	26,4	19,1	21,2	15,3	17,0	12,3	13,7
560	31,5	35,0	26,7	29,5	21,4	23,7	17,2	19,1	13,7	15,2
630	35,7	39,4	30,0	33,1	24,1	26,7	19,3	21,4	15,4	17,1
710	40,2	44,4	33,9	37,4	27,2	30,1	21,8	24,1	17,4	19,3
800	45,3	50,0	38,1	42,1	30,6	33,8	24,5	27,1	19,6	21,7
900	51,0	56,2	42,9	47,3	34,4	38,3	27,6	30,5	22,0	24,3
1 000	56,6	62,4	47,7	52,6	38,2	42,2	30,6	33,5	24,5	27,1
1 200	-	-	57,2	63,1	45,9	50,6	36,7	40,5	29,4	32,5
1 400	-	-	-	-	53,5	59,0	42,9	47,3	34,3	37,9
1 600	-	-	-	-	61,2	67,5	49,0	54,0	39,2	43,3

IV.1.2.4. Strength and Allowable Stresses

The minimum strengths and allowable stresses of polyethylene pipes are set in the table below based on the type of resin used for their manufacture.

Table IV. 4. Minimum Strengths and Allowable Stresses of Polyethylene Pipes

Type of Resin	Minimum Required Strength (MPa)	Allowable Stress (MPa)
PE 100	10,0	8,0
PE 80	8,0	6,3
PE 63	6,3	5,0
PE 40	4,0	3,2

IV.1.2.5. Derating Based on Temperature

The nominal pressures and pipe series are defined for a water temperature of 20°C or lower. For temperatures above 20°C and up to 40°C, a reduction coefficient called the derating coefficient must be applied to the nominal pressure.

The maximum operating pressure (MOP) will therefore be equal to:

$$\text{MOP} = \text{ft} \times \text{PN}$$

where **ft** represents the derating coefficient.

The values of **ft** are indicated in Table IV.5 based on the water temperature.

Note: The use of polyethylene pipes for transporting water with a temperature above 40°C is prohibited.

Table IV. 5. Derating Coefficients

Water Temperature (°C)	Derating Coefficient (ft)
20	1,00
30	0,87
40	0,74

Table IV. 6. Technical Specifications of Polyethylene Pipes

Characteristic	Test Method	Requirements	Test Parameters
Melt Flow Index	ISO 1133	0.2–1.4 g/10min	190°C, 5 kg, 10 min
Density	ISO 1183	≥ 0.930 g/cm ³	Method A
Oxidation Induction Time (OIT)	ISO 11357	≥ 20 min	210°C
Carbon Black Content	ISO 6964	2.0–2.5 %	Pyrolysis at 550°C, Calcination at 900°C
Carbon Black Dispersion	ISO 18553	≤ 3 Note	*****
Hot Shrinkage	EN ISO 2505	≤ 3 %, Appearance Preserved	2 h, 110°C
Elongation at Break	ISO 6259-1/3	≥ 350 %	Thickness ≤ 5 mm, Speed: 100 mm/min; 5 < Thickness ≤ 12 mm, Speed: 50 mm/min; Thickness > 12 mm, Speed: 25 mm/min
Yield Stress	ISO 6259-1/3	≥ 19 MPa	
Hydrostatic Pressure Resistance	EN ISO 1167	No Failure	20°C, 100 h; 80°C, 165 h; 80°C, 1000 h

IV.2. Polyvinyl Chloride

Polyvinyl chloride, also known by the acronym PVC, is a type of unplasticized plastic material often used in the manufacture of pipes for drinking water networks. PVC is made from vinyl chloride resin, to which additives are added to improve its mechanical and physical properties. The material is resistant to impact, pressure, corrosion, water, and many chemicals. Pipes can only be made from recycled or external raw materials if they meet certain criteria. The proportion of recycled material in pipes made from internal materials is limited to 5%.

IV.2. Specifications for Pipes

IV.2.1. Color

The pipes must be gray or dark blue in color.

IV.2.2. Visual Appearance

The internal and external surfaces of the pipes must be smooth, clean, and free from grooves, cavities, and other surface defects that could compromise their quality.

IV.2.3. Pipe Dimensions

a) Nominal Outer Diameters

The nominal diameters, diameter tolerances, and ovality tolerances are indicated in Table IV.7.

Table IV. 7. Nominal Outer Diameters and Tolerances

Nominal Outer Diameter (mm) dn	Tolerance on Mean Outer Diameter dem (mm) x	Ovality Tolerance	
		S 20 à S 16	S 12,5 à S 5
12	0,2	-	0,5
16	0,2	-	0,5
20	0,2	-	0,5
25	0,2	-	0,5
32	0,2	-	0,5
40	0,2	1,4	0,5
50	0,2	1,4	0,6
63	0,3	1,5	0,8
75	0,3	1,6	0,9
90	0,3	1,8	1,1
110	0,4	2,2	1,4
125	0,4	2,5	1,5
140	0,5	2,8	1,7
160	0,5	3,2	2,0
180	0,6	3,6	2,2

200	0,6	4,0	2,4
225	0,7	4,5	2,7
250	0,8	5,0	3,0
280	0,9	6,8	3,4
315	1,0	7,6	3,8
355	1,1	8,6	4,3
400	1,2	9,6	4,8
450	1,4	10,8	5,4
500	1,5	12,0	6,0
560	1,7	13,5	6,8
630	1,9	15,2	7,6
710	2,0	17,1	8,6
800	2,0	19,2	9,6
900	2,0	21,6	-
1000	2,0	24,0	-

b) Wall Thicknesses and Tolerances

The nominal wall thicknesses (e_n) are classified into pipe series (S) and assigned positive tolerances. The nominal thicknesses and tolerances are presented in Tables **IV. 8** and **IV. 9**, respectively.

Table IV. 8. Nominal Wall Thicknesses

Nominal Outer Diameter d_n (mm)	Nominal (Minimum) Wall Thickness						
	Pipe Series S						
	S 20 (SDR 41)	S 16 (SDR 33)	S 12,5 (SDR 26)	S 10 (SDR 21)	S 8 (SDR 17)	S 6,3 (SDR 13,6)	S 5 (SDR 11)
	Nominal Pressure PN based on a design coefficient C = 2.5						
		PN 6	PN 8	PN 10	PN 12,5	PN 16	PN 20
12			-	-	-	-	1,5
16			-	-	-	-	1,5
20			-	-	-	1,5	1,9
25			-	-	1,5	1,9	2,3
32			1,5	1,6	1,9	2,4	2,9
40		1,5	1,6	1,9	2,4	3,0	3,7
50		1,6	2,0	2,4	3,0	3,7	4,6
63		2,0	2,5	3,0	3,8	4,7	5,8
75		2,3	2,9	3,6	4,5	5,6	6,8
90		2,8	3,5	4,3	5,4	6,7	8,2
	Nominal Pressure PN based on a design coefficient C = 2.0						
	PN 6	PN 8	PN 10	PN 12,5	PN 16	PN 20	PN 25
110	2,7	3,4	4,2	5,3	6,6	8,1	10,0
125	3,1	3,9	4,8	6,0	7,4	9,2	11,4
140	3,5	4,3	5,4	6,7	8,3	10,3	12,7
160	4,0	4,9	6,2	7,7	9,5	11,8	14,6
180	4,4	5,5	6,9	8,6	10,7	13,3	16,4
200	4,9	6,2	7,7	9,6	11,9	14,7	18,2
225	5,5	6,9	8,6	10,8	13,4	16,6	-

250	6,2	7,7	9,6	11,9	14,8	18,4	-
280	6,9	8,6	10,7	13,4	16,6	20,6	-
315	7,7	9,7	12,1	15,0	18,7	23,2	-
355	8,7	10,9	13,6	16,9	21,1	26,1	-
400	9,8	12,3	15,3	19,1	23,7	29,4	-
450	11,0	13,8	17,2	21,5	26,7	33,1	-
500	12,3	15,3	19,1	23,9	29,7	36,8	-
560	13,7	17,2	21,4	26,7	-	-	-
630	15,4	19,3	24,1	30,0	-	-	-
710	17,4	21,8	27,2	-	-	-	-
800	19,6	24,5	30,6	-	-	-	-
900	22,0	27,6	-	-	-	-	-
1000	24,5	30,6	-	-	-	-	-

Table IV. 9. Tolerances on Wall Thickness

Nominal Wall Thickness en		Tolerance on Mean Wall Thicknessparoi	Nominal Wall Thickness en		Tolerance on Mean Wall Thickness
>	≤	x	>	≤	x
1,0	2,0	0,4	21,0	22,0	2,4
2,0	3,0	0,5	22,0	23,0	2,5
3,0	4,0	0,6	23,0	24,0	2,6
4,0	5,0	0,7	24,0	25,0	2,7
5,0	6,0	0,8	25,0	26,0	2,8
6,0	7,0	0,9	26,0	27,0	2,9
7,0	8,0	1,0	27,0	28,0	3,0
8,0	9,0	1,1	28,0	29,0	3,1
9,0	10,0	1,2	29,0	30,0	3,2
10,0	11,0	1,3	30,0	31,0	3,3
11,0	12,0	1,4	31,0	32,0	3,4
12,0	13,0	1,5	32,0	33,0	3,5

13,0	14,0	1,6	33,0	34,0	3,6
14,0	15,0	1,7	34,0	35,0	3,7
15,0	16,0	1,8	35,0	36,0	3,8
16,0	17,0	1,9	36,0	37,0	3,9
17,0	18,0	2,0	37,0	38,0	4,0
18,0	19,0	2,1			
19,0	20,0	2,2			
20,0	21,0	2,3			

c) Nominal length of tubes

The nominal length of the tubes is a minimum length that does not include the depth of the socket parts.

IV.2.4. Dimensions of socketed tubes

IV.2.4.1. Sockets for gluing

The dimensions of the sockets must comply with the values indicated in Table IV.10.

The inner diameter of a socket must necessarily be equal to the nominal outer diameter of the tube.

Table IV.10. Dimensions of sockets for gluing

Inner Diameter of the Socket dn (mm)	Mean Inner Diameter of the Socket		Maximum Ovality for di (mm)	Minimum Socket Length Lmin (mm)
	$d_{im,min}$ (mm)	$d_{im,max}$ (mm)		
12	12,1	12,3	0,25	12,0
16	16,1	16,3	0,25	14,0
20	20,1	20,3	0,25	16,0
25	25,1	25,3	0,25	18,5
32	32,1	32,3	0,25	22,0
40	40,1	40,3	0,25	26,0
50	50,1	50,3	0,3	31,0
63	63,1	63,3	0,4	37,5

75	75,1	75,3	0,5	43,5
90	90,1	90,3	0,6	51,0
110	110,1	110,4	0,7	61,0
125	125,1	125,4	0,8	68,5
140	140,2	140,5	0,9	76,0
160	160,2	160,5	1,0	86,0
180	180,2	180,6	1,1	96,0
200	200,2	200,6	1,2	106,0
225	225,3	225,7	1,4	118,5
250	250,3	250,8	1,5	131,0
280	280,3	280,9	1,7	146,0
315	315,4	316,0	1,9	163,5

IV.2.4.2. Sockets for Seal Ring Type Joints

The minimum engagement depth of simple sockets with elastomer seal rings for tube lengths up to 6 meters is shown in Figure IV.3.

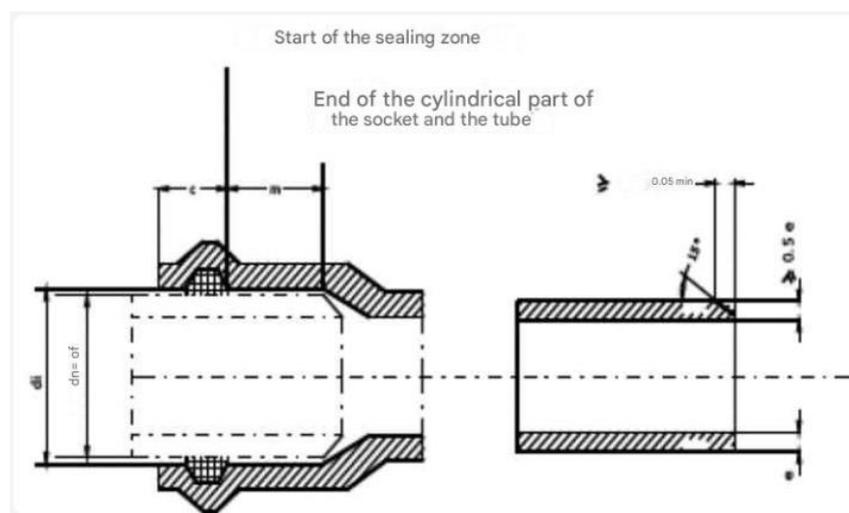


Figure IV.3. Socketing of Tubes for Seal Ring Type Joints

The dimensions of the sockets and the engagement depths are provided in Table IV.11.

Table IV.11. Dimensions of Sockets for Seal Ring Type Joints

Nominal Inner Diameter of the Socket d_n (mm)	Minimum Mean Inner Diameter of the Socket dim_{min} (mm)	Maximum Allowable Ovality for d_i (mm)		Minimum Engagement Depth m_{min} (mm)	Length of the Socket Entry and Sealing Zone (c) (mm)
		S20,8 à S16	S12,5 à S5		
32	32,3	0,6	0,3	55	27
40	40,3	0,8	0,4	55	28
50	50,3	0,9	0,5	56	30
63	63,4	1,2	0,6	58	32
75	75,4	1,2	0,7	60	34
90	90,4	1,4	0,9	61	36
110	110,5	1,7	1,1	64	40
125	125,5	1,9	1,2	66	42
140	140,6	2,1	1,3	68	44
160	160,6	2,4	1,5	71	48
180	180,7	2,7	1,7	73	51
200	200,7	3,0	1,8	75	54
225	225,8	3,4	2,1	78	58
250	250,9	3,8	2,3	81	62
280	281,0	5,1	2,6	85	67
315	316,1	5,7	2,9	88	72

355	356,2	6,5	3,3	90	79
400	401,3	7,2	3,6	92	86
450	451,5	8,1	4,1	95	94
500	501,6	9,0	4,5	97	102
560	561,8	10,2	5,1	101	112
630	632,0	11,4	5,7	105	123
710	712,3	12,9	6,5	109	136