WL118 PRESSURE RATING

WL Plastics PE4710 Pipe Pressure Ratings

Short-Term and Long-Term Performance

Polyethylene is unique because its strength under load depends on the magnitude and duration of the load. WL Plastics pressure rated HDPE pipe is manufactured from engineered polyethylene compounds (WL106) that provide a unique balance of short-term and long-term properties for pressure pipe applications.

Ductile pressure pipe materials that provide resilience and toughness resist pressure spikes, handling and installation, soil subsidence, frost heave, and seismic displacement. WL Plastics HDPE pipe provides exceptional toughness and independent co-resident short-term and long-term strengths for many decades of service. Short-term and long-term characteristics are different. Short-term properties cannot be used to predict long-term performance.

Hydrostatic Design Stress, HDS, ratings for long-term internal pressure service up to 140°F (60°C) are determined in accordance with ASTM and PPI standards[1]. (Non-pressure service to 180°F (82°C) is acceptable.)

The HDS is a maximum long-term design stress at an operating temperature for the PE compound. HDS ratings at 73°F (23°C) and 140°F (60°C) incorporate a design factor, DF, of 0.63 for PE4710. Safety factors that are applied to reduce a short-term strength property are not the same as design factors. See WL123 for a design factor explanation.

Table 1 HDS – WL Plastics PE Pipe Compound

Compound	Data Sheet	HDS at 73°F	HDS at 140°F
PE4710	WL106	1000 psi	630 psi

Internal Pressure Rating

Pressure rating is for a combination of PE compound, gas or liquid internal media, external environment, temperature, and pipe size. Pressure rating will vary for different conditions. Equations 1 and 2 are used to determine a long-term internal pressure rating.

$$PR = \frac{2\,HDS\,f_E\,f_T}{(DR-1)} \qquad (1)$$

PR = pressure rating, psi.
HDS = hydrostatic design stress at 73°F, psi
f_E = environmental design factor (Table 2)
f_T = operating temperature multiplier (Tables 3,4)
DR = pipe dimension ratio

$$DR = \frac{D}{t} \qquad (2)$$

D = pipe outside diameter, in (WL102, WL104)
t = pipe min. wall thickness, in (WL102, WL104)

For a pressurized gas or liquid media inside the pipe or for a chemically significant environment outside the pipe, an environmental factor, f_E is applied. See Table 2.

Pipe DR, dimension ratio, is average OD divided by minimum wall thickness. For a given DR, wall thickness increases or decreases in direct proportion to the outside diameter. DR is convenient because it remains constant as pipe size varies. For the same conditions, different OD pipes having the same DR, have the same pressure rating.

Table 2 Environmental Factor, f_E

f_E	Media and Environment Conditions
1.00	Internal liquids, gases and external soils or liquids that are chemically benign to polyethylene such as water (potable, raw, grey, waste, reclaimed), sewage, salt/brine solutions, glycol/antifreeze solutions, alcohol; dry natural gas[A], landfill gas, nitrogen, air, oxygen, carbon dioxide, hydrogen sulfide
0.64	US − Buried distribution, gathering or transmission systems for US Federal and State regulated dry fuel gases such as natural gas, LP gas, propane, butane, landfill gas (use an HDS value of 800 psi per CFR Title 49 Part 192 for pressure calculations using equation 1)
0.80	Canada Only – Buried distribution, transmission or gathering systems for Canadian Federal and Provincial regulated fuel gases such as natural gas, LP gas, propane, butane, landfill gas
0.50	multi-phase fluids, wet natural gas, liquids or groundwater in or around the pipe having a 2% or greater concentration of permeating or solvating chemicals such as hydrocarbon liquids (gasoline, fuel oil, kerosene, crude oil, diesel fuel, jet fuel)

[A] Where US regulations per 49 CFR Part 192 or Canadian regulations per CSA Z662 do not impose regulatory limitations.

Operating Temperature Multiplier, f_T, Tables. Use Tables 3 and 4 for WL106 **PE4710**. See WL106 for material compound code information.

The maximum recommended operating temperature for sustained internal pressure is 140°F (60°C). (Up to 180°F (82°C) is acceptable for non-pressure service.)

[1] ASTM D1598 Time-to-Failure of Plastic Pipe Under Constant Internal Pressure; ASTM D2837 Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials; PPI TR-3 Policies and Procedures for Developing Hydrostatic Design Basis (HDB), Pressure Design Basis (PDB), Strength Design Basis (SDB), and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe

Table 3 PE4710 Operating Temperature Multiplier, f_T, for operating Temperature in °F

°F	f_T	°F	f_T	°F	f_T	°F	f_T	°F	f_T
32	1.28	54	1.12	76	0.98	98	0.85	120	0.73
33	1.27	55	1.12	77	0.97	99	0.84	121	0.72
34	1.27	56	1.11	78	0.97	100	0.84	122	0.72
35	1.26	57	1.10	79	0.96	101	0.83	123	0.71
36	1.25	58	1.10	80	0.96	102	0.83	124	0.71
37	1.24	59	1.09	81	0.95	103	0.82	125	0.70
38	1.24	60	1.08	82	0.94	104	0.82	126	0.70
39	1.23	61	1.08	83	0.94	105	0.81	127	0.69
40	1.22	62	1.07	84	0.93	106	0.80	128	0.69
41	1.21	63	1.06	85	0.93	107	0.80	129	0.68
42	1.21	64	1.06	86	0.92	108	0.79	130	0.68
43	1.20	65	1.05	87	0.91	109	0.79	131	0.67
44	1.19	66	1.04	88	0.91	110	0.78	132	0.67
45	1.19	67	1.04	89	0.90	111	0.78	133	0.66
46	1.18	68	1.03	90	0.90	112	0.77	134	0.66
47	1.17	69	1.03	91	0.89	113	0.77	135	0.65
48	1.17	70	1.02	92	0.88	114	0.76	136	0.65
49	1.16	71	1.01	93	0.88	115	0.75	137	0.64
50	1.15	72	1.01	94	0.87	116	0.75	138	0.63
51	1.14	73	1.00	95	0.87	117	0.74	139	0.63
52	1.14	74	0.99	96	0.86	118	0.74	140	0.63
53	1.13	75	0.99	97	0.86	119	0.73		

Table 4 PE4710 Operating Temperature Multiplier, f_T, for Operating Temperature in °C

°C	f_T	°C	f_T	°C	f_T	°C	f_T	°C	f_T
0	1.28	13	1.12	26	0.97	39	0.83	52	0.71
1	1.27	14	1.10	27	0.96	40	0.82	53	0.70
2	1.25	15	1.09	28	0.95	41	0.81	54	0.69
3	1.24	16	1.08	29	0.94	42	0.80	55	0.68
4	1.23	17	1.07	30	0.93	43	0.79	56	0.67
5	1.22	18	1.06	31	0.91	44	0.79	57	0.67
6	1.20	19	1.05	32	0.90	45	0.78	58	0.66
7	1.19	20	1.03	33	0.89	46	0.77	59	0.65
8	1.18	21	1.02	34	0.88	47	0.76	60	0.64
9	1.17	22	1.01	35	0.87	48	0.75		
10	1.15	23	1.00	36	0.86	49	0.74		
11	1.14	24	0.99	37	0.85	50	0.73		
12	1.13	25	0.98	38	0.84	51	0.72		

Internal Pressure Rating Examples

1. Determine the long-term pressure rating for DR 11 WL Plastics PE4710 pipe transporting brine water at 125°F.

$$PR = \frac{2(1000)(0.70)(1.00)}{(11-1)} = 140\ psi$$

2. Determine the long-term pressure rating for DR 17 WL Plastics PE4710 pipe transporting crude oil at 45°C.

$$PR = \frac{2(1000)(0.78)(0.50)}{(17-1)} = 48.8\ psi$$

3. Determine the long-term pressure rating for 2" IPS DR 11 WL Plastics PE4710 pipe on the surface transporting compressed air at 120°F.

$$PR = \frac{2(1000)(0.73)(1.00)}{(11-1)} = 146\ psi$$

CAUTION – Compressed gas pressure piping is installed so that pipe is restrained against movement from failure or separation from external mechanical damage or faulty joining. Restraint is provided by burial, mechanical restraint or encasement in shatter resistant materials. Mechanically restrained exposed pipes are installed at heights or in areas where the pipe is protected against external damage from moving equipment, third parties, etc. Correctly made, fully restrained joints are required.

Liquid Flows

Short term internal pressure surges such as water hammer result from instantaneous liquid flow velocity change. These conditions are accommodated above the long-term internal pressure rating by short-term physical capabilities.

For distribution and transmission of liquids such as water or water-borne slurries, surge pressure allowances are applied above the pipe pressure rating. That is, during a pressure surge event, the momentary pressure in the pipe can rise to a maximum of PR plus a surge pressure allowance.

Pressure surge allowance is provided for occasional or recurring pressure surges:

$$P_{OS} = 1.00 \times PR \qquad (3)$$

$$P_{RS} = 0.50 \times PR \qquad (4)$$

P_{OS} = surge pressure allowance for occasional surge, psi
P_{RS} = surge pressure allowance for recurring surge, psi

Occasional pressure surges typically result from instantaneous liquid velocity changes from conditions such as firefighting or component failure. Recurring pressure surges typically result from cyclical events such as pump or system control operation or regularly occurring system draws.

Liquid flow velocity is determined using

$$V = \frac{1.283\,Q}{\pi D_i^{\,2}} \qquad (5)$$

V = velocity, ft/sec.
Q = flow quantity, U.S. gal/min
D_i = pipe average inside diameter, in

$$D_i = D - 2.12\frac{D}{DR} \qquad (6)$$

(Note – D_i is an average pipe ID for flow estimation purposes only. Actual pipe ID will vary depending on specification dimensions and tolerances. Consult specifications or measure actual pipe ID for devices such as stiffeners that install in the pipe bore.)

When a surge pressure event such as water hammer occurs in a pipe, the velocity of the pressure surge is dependent on the instantaneous elastic modulus of the pipe material and pipe dimensions.

$$a = \frac{4660}{\sqrt{1 + \frac{k\,D_i}{E\,t}}} \qquad (7)$$

a = pressure wave velocity, ft/sec
k = fluid bulk modulus, psi
= 300,000 psi for water
E = instantaneous dynamic elastic modulus of pipe material, psi
= 150,000 psi for HDPE per AWWA M55

The surge pressure, P_S, caused by a sudden change in liquid flow velocity is:

$$P_S = \frac{a(\Delta v)}{2.31g} \quad (8)$$

P_S = surge pressure, psi
Δv = sudden velocity change, ft/sec
g = gravitational acceleration. ft/sec^2
= 32.2 ft/sec^2

(Note – The sudden velocity change, *Δ*v, must occur within the critical time, 2L/a*, where 'L' is the pipe length in feet* and *'a' is* the pressure wave velocity per Eq. 7. A surge pressure does not occur if the time required for the velocity change exceeds the critical time.)

During steady pressure operation, the maximum operating pressure, MOP, should not exceed the long-term pressure rating, and during a pressure surge event, the total internal pressure should not exceed the long-term pressure rating plus the pressure surge allowance. Table 5 shows the approximate instantaneous water velocity change to produce a surge pressure equal to the surge pressure allowance. If the potential velocity change results in a surge pressure that is higher than the pressure surge allowance, the MOP is reduced or pipe having a higher pressure rating is used (Eq. 10), with the difference between PR and MOP added to P_{SA}.

During steady pressure operation,

$$PR \geq MOP \quad (9)$$

And during a surge pressure event,

$$PR + P_{SA} \geq MOP + P_S \quad (10)$$

Table 5 Pressure Rating, Surge Allowance and Corresponding Velocity Change for Water

DR	*PC, psi*	*P_{SA}, psi*	*Δv, ft/sec*
	PE4710	***PE4710***	***PE4710***
7	333	333	17.6
7.3	317	317	17.3
9	250	250	15.5
11	200	200	13.9
13.5	160	160	12.5
15.5	139	139	11.6
17	125	125	11.1
21	100	100	10.0
26	80	80	8.9
32.5	63	63	8.0

(kPa = psi x 6.895; m/sec = ft/sec x 0.305)

External Pressure/Vacuum Resistance

Circumferentially applied external pressure or internal vacuum or a combination of external pressure and internal vacuum will attempt to flatten the pipe. Freestanding non-pressure pipe in surface, sliplining, submerged and like applications is not supported by embedment or other external confinement that can significantly enhance resistance to flattening from external pressure. The resistance of freestanding pipe to flattening from external pressure depends on wall thickness (pipe DR), elastic properties (time and temperature dependent elastic modulus and Poisson's ratio), and roundness.

$$P_{CR} = \frac{2\,E\,f_O}{\left(1-\mu^2\right)}\left(\frac{1}{DR-1}\right)^3 \quad (11)$$

P_{CR}=flattening resistance limit, psi
E = modulus of elasticity, psi
μ = Poisson's Ratio
= 0.45
f_O = roundness factor
DR = pipe dimension ratio, (Eq. 2)

$$P_{AL} = \frac{P_{CR}}{N} \quad (10)$$

P_{AL} = safe external pressure, psi
N = safety factor (typically $\geq$ 1.5)

Table 6 Roundness Factor, f_O

% Deflection	f_O	% Deflection	f_O
0	1.00	6	0.52
1	0.92	7	0.48
2	0.88	8	0.42
3	0.78	9	0.39
4	0.70	≤10	0.36
5	0.62		

Table 7 Apparent Elastic Modulus for PE4710, kpsi

Temp, °F	Sustained Load Duration – Hours				Sustained Load Duration – Years			
	1	10	100	1000	1	10	50	100
-20	198.1	165.1	139.7	116.8	101.6	86.4	73.7	71.1
-10	184.1	153.4	129.8	108.6	94.4	80.2	68.4	66.1
0	170.0	141.7	119.9	100.3	87.2	74.1	63.2	61.0
10	156.0	130.0	110.0	92.0	80.0	68.0	58.0	56.0
20	141.2	117.7	99.6	83.3	72.4	61.5	52.5	50.7
30	128.7	107.3	90.8	75.9	66.0	56.1	47.9	46.2
40	116.2	96.9	82.0	68.5	59.6	50.7	43.2	41.7
50	103.0	85.8	72.6	60.7	52.8	44.9	38.3	37.0
60	92.0	76.7	64.9	54.3	47.2	40.1	34.2	33.0
73	78.0	65.0	55.0	46.0	40.0	34.0	29.0	28.0
80	72.5	60.5	51.2	42.8	37.2	31.6	27.0	26.0
90	64.0	53.3	45.1	37.7	32.8	27.9	23.8	23.0
100	56.9	47.5	40.2	33.6	29.2	24.8	21.2	20.4
110	49.9	41.6	35.2	29.4	25.6	21.8	18.6	17.9
120	45.2	37.7	31.9	26.7	23.2	19.7	16.8	16.2
130	39.0	32.5	27.5	23.0	20.0	17.0	14.5	14.0
140	33.5	28.0	23.7	19.8	17.2	14.6	12.5	12.0

Table 8 PE4710 External Pressure Rating at 73°F (23°C), P_{AL}, psi, by Load Duration[A]

Load Duration	DR									
	7	7.3	9	11	13.5	15.5	17	21	26	32.5
½ Day	249.1	215.2	105.1	53.8	27.6	18.6	13.2	6.7	3.5	1.7
42 Days	208.4	180.0	87.9	45.0	23.1	14.7	11.0	5.6	2.8	1.5
1 Year	181.2	156.5	76.4	39.2	20.0	12.8	9.6	4.8	2.5	1.3
50 Years	134.5	116.1	56.8	29.1	14.8	9.5	7.1	3.6	1.9	0.9

[A] Values are for free-standing non-pressurized pipe with 3% ovality and using a safety factor of 2. For temperatures other than 73°F (23°C), multiply value by Table 3 or 4 temperature multiplier. Short-term Poisson ratio, 0.35, used for ½ day load duration; long-term Poisson ratio, 0.45, used for all other load durations. Values will vary for greater or lesser ovality, safety factor and load duration. Shading indicates full vacuum resistance. Internal pressure will increase external load resistance by rounding the pipe and counteracting external load. Burial in suitable, properly installed embedment soils can more than triple external load resistance.