



*GLASS FIBER REINFORCED POLYESTER (GRP)
PIPELINES*
TECHNICAL INFORMATION



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PRESSURE LOSS (HEAD LOSS) CALCULATIONS

At all types of pipelines, head loss occurs due to the nature of fluid flow mechanics. Various facts may cause reduction of head loss such as the friction between fluid and pipe walls, change of flow direction, elevation change, change in fluid temperature etc. The level of head loss may be reduced with precautions, but can never be completely dispelled.

Therefore, while designing a pipeline, head loss calculations are very important. Calculations presented in this manual are performed according to and in compliance with the guidelines presented in AWWA M-45, Fiberglass Pipe Design, Manual of Water Supply Practices, prepared by American Water Works Association.

Purpose of this manual is to create a general overview and information presented on this manual should be used only as a guideline. For actual applications, please consult SUPERLIT Project Design and Site Support Department.

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HAZEN – WILLIAMS (Pressured Pipelines)

Hazen Williams equation is an empirical equation widely used for pressured water pipelines. Accuracy of the equation is dependent on the temperature and flow velocity of water. If the water temperature is high, error level of the equation increases. Even though accuracy of the equation also changes with the flow velocity, Hazen Williams equation is widely used for pressured water pipelines due to its practicality. For fluids other than water, for cases where water temperature is high, or if more accurate calculations are required, other empirical equations should be used for head loss calculations.

$$V = 0,345 \times C \times D^{0.63} \times S^{0.54} \quad Q = A \times V$$

$$Q = \frac{\pi \times D^2}{4} \times 0,345 \times C \times D^{0.63} \times S^{0.54}$$

$$Q = 0,2709 \times C \times D^{2.63} \times S^{0.54}$$

$$S^{0.54} = \frac{Q}{0,2709 \times C \times D^{2.63}}$$

$$S = \frac{Q^{1.85}}{0,08905 \times C^{1.85} \times D^{4.87}}$$

V : Fluid velocity (m/s)

Q : Flow rate (m³/s)

D : Pipe internal diameter (m)

A : Cross sectional area of pipe (m²)

S : Hydraulic slope (m/m)

C : Hazen-Williams roughness coefficient (C=150 for Superlit GRP pipes)

L : Length of pipeline (m)

$$S = 0,001 \times \frac{Q^{1.85}}{D^{4.87}}$$

$$\text{Head Loss} = H_f = L \times S$$



MANNING

Manning empirical equation is more preferable for pipelines with gravity flow, and for pipelines with semi-full flows.

$$V = \frac{1}{n} \times R^{2/3} \times S^{1/2}$$

$$R = \frac{D}{4} \text{ (For pressured pipelines)}$$

$$Q = A \times V$$

$$Q = \pi \times \frac{D^2}{4} \times \frac{1}{n} \times R^{2/3} \times S^{1/2}$$

$$Q = 0,312 \times \frac{1}{n} \times D^{8/3} \times S^{1/2}$$

$$S^{1/2} = \frac{Q \times n}{0,312 \times D^{8/3}}$$

$$S = \frac{Q^2 \times n^2}{0,0973 \times D^{16/3}}$$

V : Fluid velocity (m/s)

Q : Flow rate (m³/s)

D : Pipe internal diameter (m)

A : Cross sectional area of pipe (m²)

S : Hydraulic slope (m/m)

W : Wetted perimeter of pipe (m)

R : Hydraulic radius (m)

n : Manning roughness coefficient (n=0,009 for SUPERLIT GRP pipes)

L : Length of pipeline (m)

$$S = 8,325 \times 10^{-4} \times \frac{Q^2}{D^{16/3}}$$

$$\text{Head Loss} = H_f = L \times S$$



CALCULATION FOR SEMI-FULL FLOWING PIPELINES

For calculation of semi-full flowing pipelines, engineers generally refer to hydraulic loss tables or diagrams due to the relationship between flow velocity and the height of the flowing water. Change of flowing water height effects the hydraulic radius, thus changing the flow velocity.

For all heights of flowing water, SUPERLIT engineers present below formula for hydraulic radius calculation, which is proved to have a very high level of accuracy.

After calculation of the hydraulic radius, Manning equation can be used.

$$R = \frac{A}{W} \text{ (For semi-full flowing pipelines)}$$

$$R = \frac{DN}{1000} \times (-8 \times 10^{-6} \times h_{\text{water}}^3 + 0,0002 \times h_{\text{water}}^2 + 0,317 \times h_{\text{water}} + 0,0898) = \text{cm}$$

$$A = \left(\frac{DN}{1000}\right)^2 \times (-0,0087 \times h_{\text{water}}^3 + 1,3015 \times h_{\text{water}}^2 + 36,261 \times h_{\text{water}} - 55,22) = \text{cm}^2$$

- DN** : Nominal diameter (mm)
A : Cross sectional area of pipe (m²)
W : Wetted perimeter of pipe (m)
R : Hydraulic radius (cm)
H_{water} : Height of flowing water (cm)

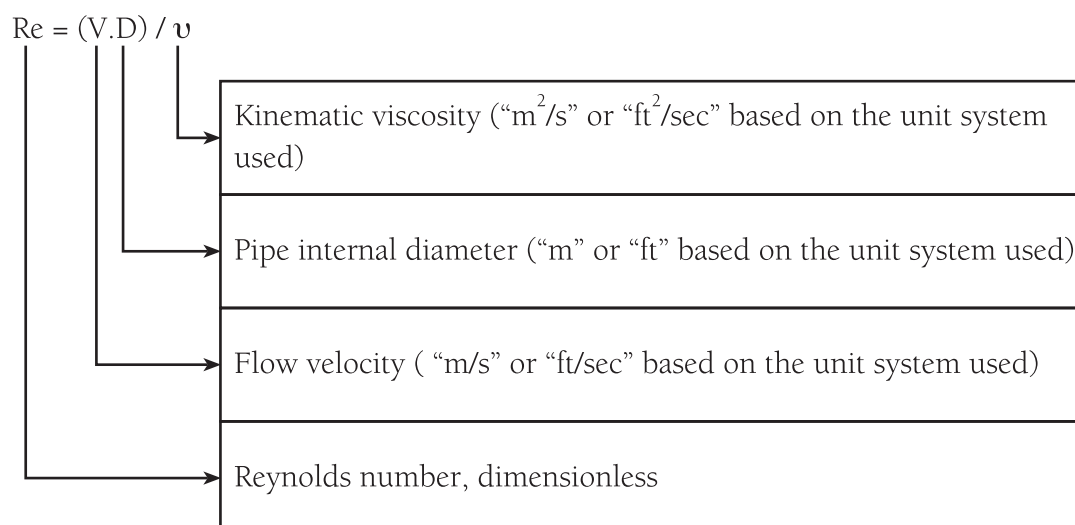


DARCY-WEISBACH

Darcy-Weisbach equation refers 3 basic essentials.

- 1) Head loss is proportional to the square of flow velocity.
- 2) Head loss is proportional to the pipeline length.
- 3) Head loss is inversely proportional to pipe diameter.

This equation is valid for both laminar and turbulent fluid flows, however, Darcy-Weisbach friction coefficient is variable. Therefore, after determination of pipe diameter, the flow characteristic should also be identified as whether laminar or turbulent. Reynolds number can be used for determination of flow characteristic.



TEMPERATURE	SPECIFIC GRAVITY	KINEMATIC VISCOSITY	VAPOR PRESSURE
C	kg/m ³	m ² /sn	m
0	1000	0,000001788	0,06
10	1000	0,000001307	0,12
20	998	0,000001005	0,24
30	996	0,000000802	0,43
40	992	0,000000662	0,77
50	988	0,000000555	1,26
60	983	0,000000475	2,03
70	978	0,000000414	3,18
80	972	0,000000365	4,83
90	965	0,000000327	7,15
100	958	0,000000295	10,33



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According to the Reynold's number, flow characteristic can be determined from the below table.

<u>Reynolds number</u>	<u>Type of flow</u>
$Re \leq 2000$	Laminar
$2000 < Re \leq 4000$	Transition zone
$Re \geq 4000$	urbulent

Darcy-Weisbach equation:

$$h_f = (f/D) \cdot (V^2/2g) \cdot L$$

Pipe length ("m" or "ft" based on the unit system used)
Earth's gravity ("m/s ² " or "ft/sec ² " based on the unit system used)
Flow velocity ("m/s" or "ft/sec" based on the unit system used)
Pipe internal diameter ("m" or "ft" based on the unit system used)
Darcy-Weisbach friction coefficient (dimensionless) (expressed as f_l for laminar flow and f_t for turbulent flow)
Head loss ("m" or "ft" based on the unit system used)

Laminar flow ($Re \leq 2000$) : " f_l " friction factor can be calculated with the formula
" $f_l = 64/Re$ "

Turbulent flow ($Re \geq 4000$) : " f_t " friction factor can be calculated with
Colebrook-White equation:

$$1 / f_t = - 2 \cdot \text{Log} [(e/D)/3,7] + (2,51 / [(Re)(\sqrt{f_t})])$$

As seen from the above equation, f_t is present on both sides of the equation, which makes the equation quite complex to solve. For solution, various values for f_t should be placed in the equation for trial. Since this condition is not practical to apply, Moddy diagram can be referred instead.

("e" factor in the equation represents surface roughness factor and this value is very small for GRP pipes ($e = 1,7 \times 10^{-5}$ $f_t = 5,18 \times 10^{-6}$ m). Therefore, "e" factor is accepted as almost negligible.)

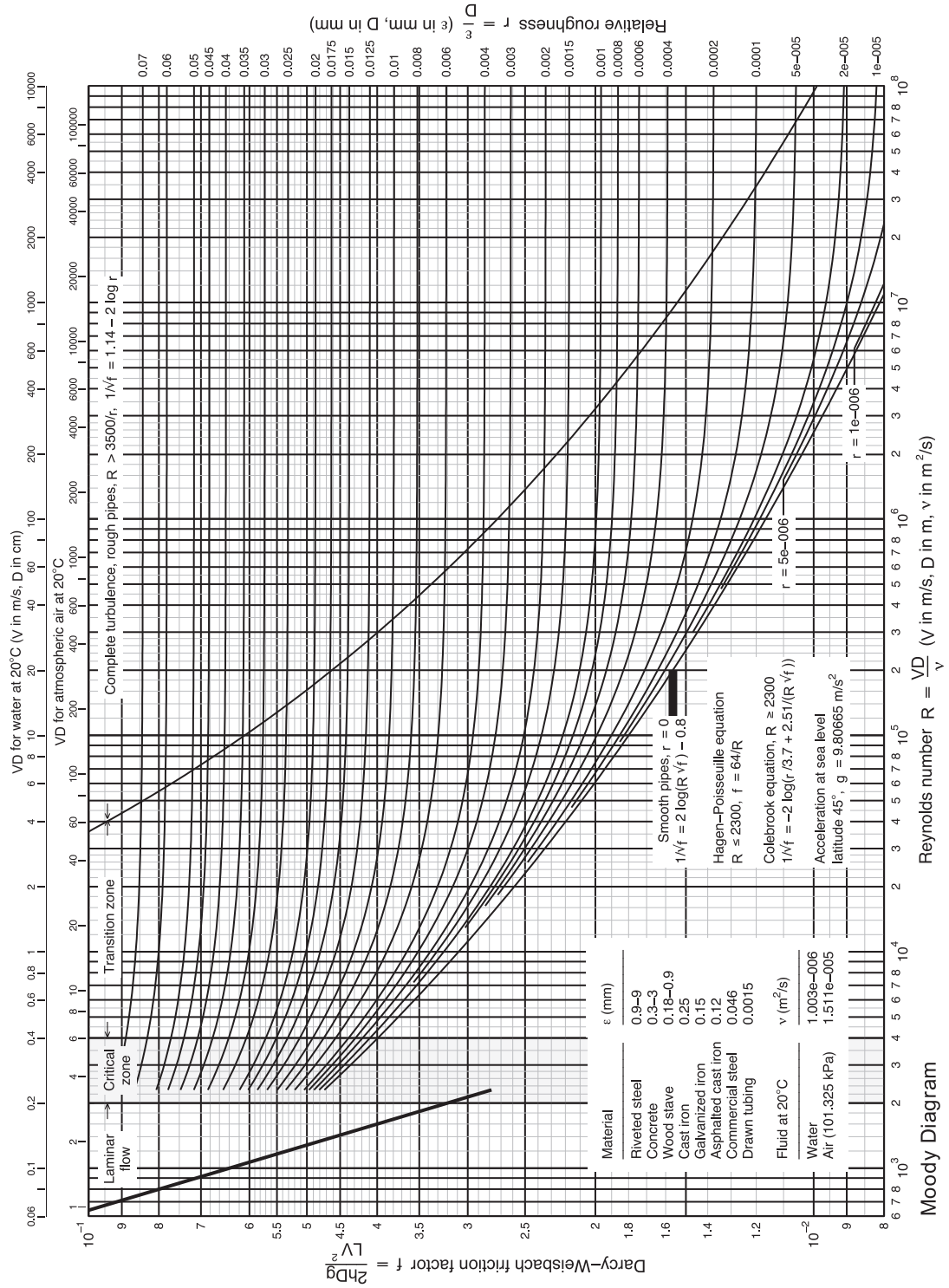
Due to the difficulties mentioned above, AWWA M-45 Fiberglass Pipe Design Manual recommends below equation:

$$\text{Within } \% 1 \text{ accuracy } f_t = [1,8 \times \text{Log} (Re/7)]^{-2} \text{ (AWWA M-45 Manual, 2005)}$$



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MOODY DIAGRAM





CALCULATION OF PRESSURE LOSS (HEAD LOSS) FOR FITTINGS

2 basic approaches to characterize head loss for fittings are as follows:

1) According to this approach which is valid for Hazen-Williams and Manning equations, fitting length is added on the pipe length and pipe-fitting structure is accepted as a single pipe for head loss calculation purposes. This approach has an acceptable accuracy level for several applications.

2) Above mentioned approach ignores turbulent losses. For cases where more detailed calculations are required, Darcy Weisbach equation (or similar) can be used. Fitting loss coefficient “K” values are presented in many fluid hydraulic technical manuals and booklets. For reference purposes, some of “K” coefficients for fittings presented on AWWA M-45 Fiberglass Pipe Design Manual are as follows:

Fitting Type	“K” Coefficient
90° elbow, standard	0.5
90° elbow, single miter	1.4
90° elbow, double miter	0.8
90° elbow, triple miter	0.6
180° return bend	1.3
Tee, straight flow	0.4
Tee, flow to branch	1.4
Tee, flow from branch	1.7
Reducer (single size)	0.7
Reducer (double size)	3.3

$$h_k = K \cdot (V^2/2g)$$

→	Earth's gravity (“ m/s ² ” or “ft/sec ² ” based on the unit system used)
→	Flow velocity (“m/s” or “ft/sec” based on the unit system used)
→	Fitting loss coefficient
→	Fitting head loss (m)



RUNNING COST AND ENERGY CONSUMPTION EVALUATION

While designing a pipeline, initial investment costs are taken into consideration and generally running costs are not duly evaluated. However, a big portion of pipeline running costs comes from the energy consumption of pumps compensating the head loss due to the friction of the fluid with pipe walls. In metal based pipes, corrosion (which is dependent on the flowing fluid structure such as pH value, Langelier carbonate-calcium index, etc) and aging effects of the pipe material further complex the running cost issue. In other words, friction of fluid and pipe walls are increased by corrosion and aging, which leads to increased pump energy consumptions, as well as partial, sectional pipe replacements or repairs.

The easiest way to approach running cost economics is the calculation of pump horsepower demand.

For a determined pipe diameter, total head loss can be calculated and can be converted into pump horsepower demand as follows:

$$N = \gamma \cdot Q \cdot h_f / \eta$$

→	Pump efficiency (generally between %75 and %85).
→	Total headloss of pipeline (m).
→	Flow rate (m ³ /s).
→	Specific gravity of water (1000kgf/m ³).

If total working hours of pumps per year is “T”, total energy consumption is

$$W = N.T \text{ (kw-h)}$$

Total cost of pump energy consumption cost can be calculate with multiplication of the total energy consumption (result of the above formula) with the energy unit price.



WATER HAMMER

Pressure surge named as “Water hammer” is generally caused by rapid changes of flow velocity. Depending on the direction and origin of the surge, water hammer may increase or decrease the flow pressure. Increase of flow pressure due to water hammer is defined as Suppression Condition and decrease of flow pressure due to water hammer is defined as Depression Condition.

Water Hammer is a critical issue for all types of pipelines. Strong water hammers cause serious structural damages on pipelines such as cracks and torn.

CAUSES OF WATER HAMMER

1. Rapid pump stopping and running.
2. Pump energy cut-off.
3. Rapid valve closure and openings.
4. Rapid air expelling from pipeline.
5. Rapid discharge of water from the pipeline where the water was remaining without flow.

Water Hammer can also be described as the transformation tendency of fluid's kinetic energy to potential energy. During this transformation tendency, shock waves can be formed. These shock waves, running through the pipeline, may damage a section far away from the origin of the waves.

Pressure changes caused by water hammer can not be detected by Bourden tube or similar gauges, since these tools have high level of inertia which can not detect rapid changes.

As a result of water hammer, high pressures or very low pressures which may cause cavitation may be also be experienced.

Cavitation: When the pressure of the fluid falls below its vapor pressure during the flow, vapor bubbles are formed. Flowing fluid tends to fill these vapor bubbles which generates heavy shock waves, temperature increase and micro-jets. This formation, called cavitation, may cause serious pipe deformations.



Magnitude of water hammer is dependent on below parameters.

1. Bulk modulus of the fluid.
2. Fluid flow velocity.
3. Pipe material modulus of elasticity.
4. Pipe wall thickness.

CALCULATION OF WATER HAMMER

There are several studies on calculation of water hammer and all of these studies state empirical equations. Some of these studies are:

- ⑤ Joukosky method.
- ⑤ Allieve method.
- ⑤ Vensano method.
- ⑤ Warren method.
- ⑤ Johnson method.
- ⑤ Gibson method.
- ⑤ Fanning method.
- ⑤ De Sparre method.
- ⑤ Quick method.
- ⑤ Talbot method.

AWWA M-45, Fiberglass Pipe Design, Manual of Water Supply Practices, prepared by American Water Works Association recommends Talbot Method for calculation of water hammer. AWWA M-45 is the only detailed manual prepared by an official association and most GRP pipe manufacturers, including SUPERLIT Pipe, follow this manual and prefers Talbot Method for water hammer calculation.



$$P_s = (a)(SG)(\Delta V) \quad (\text{Equation 4-21 from AWWA M-45})$$

$$a = 1 / [(\rho \cdot g / g)(1/10^9 k + d/10^9 E(t))]^{0.5} \quad (\text{Equation 4-22 from AWWA M-45})$$

P_s = Pressure surge deviation, kPa

SG = Fluid specific gravity, (for water=1) dimensionless

V = Change in flow velocity, m/s

a = Wave velocity, m/s

g = Earth gravity constant, 9,81 m/s²

ρ = Fluid density, kg/m³

k = Fluid bulk modulus of compressibility (for water = 2GPa)

d = Internal pipe diameter, mm

E = Pipe wall modulus of elasticity, GPa

T = Pipe wall thickness, mm

HOW TO AVOID WATER HAMMER

Following items should be considered to avoid water hammer:

1. Avoid rapid pump stopping and running.
2. Avoid pump energy cut-offs.
3. Assure that pump and valve automation systems operate properly.
4. Supply pressure reducing air tanks.
5. Assure to supply appropriate valves.
6. Supply compensation chambers.
7. Supply pressure relief valves.
8. Supply feeder tanks.
9. Increase number of air release valves. (When the number of air release valves is increased, air volume to be released per valve will be less which would also decrease the possibility of rapid air expelling.)
10. Fill pipe line with a low flow rate. (At 5 – 15% of operation flow rate)
11. Decrease fluid flow velocity.
12. Prefer pipes with lower wall thickness and lower elasticity modulus.



DESIGN EXAMPLE FOR BURIED PIPES

Below example follows calculation method of AWWA M-45.

Conditions and parameters for design

Parameter		Value, SI	Units
Nominal diameter	DN 1400	1400	mm
Working pressure	4 bar	400	kPa
Surge pressure	4 bar	400	kPa
Vacuum	1 bar	100	kPa
Cover Depth			
Maximum		4	m
Minimum		1,5	m
Wheel load		90000	N
Service temperature		1 - 35	°C
Pipe Characteristics			
Pressure Class		600	kPa
Nominal Stiffness		250	kPa
Internal diameter		-	-
External diameter		1433,6	mm
Wall thickness		21,36	mm
Liner thickness		1,2	mm
Reinforced wall thickness		20,16	mm
Mean diameter		1413,04	mm
Hoop tensile modulus		10,13	GPa
HDB		0.0066	mm/mm
Sb		0,012	mm/mm
Maximum allowed deflection		5	%
Installation parameters			
Native soil			
Description	Granuler/Moderately compacted		
Soil modulus		20,7	MPa
Backfill soil			
Description	Moderately compacted sand-SC2 - SPD 95 %		
Soil modulus maximum depth		9,98	MPa
Soil modulus minimum depth		11.3	MPa
Specific weight		18800	N/m ³
Groundwater effects			
Groundwater depth (min.)		1.5	m
Groundwater depth (max.)		4	
Shape factor		3,8	-
Deflection lag factor		1,05	-
Deflection coefficient		0,1	-
Trench width		2300	mm



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Above given values are given for illustration purposes only and should not be used as design values. For design parameters, please contact SUPERLIT Pipe.

Step 1, Confirm pressure class (Equation 5-2, AWWA M-45).

$$P_c < \left(\frac{HDB}{FS} \right) \left(\frac{2tE_H}{D} \right) \times 10^6 \quad P_c = 600 \text{ kPa} < 953,87 \text{ kPa}, \quad \text{OK}$$

Step 2, Check working pressure (Equation 5-3, AWWA M-45).

$$P_c \geq P_w \quad 600 \text{ kPa} \geq 400 \text{ kPa}, \quad \text{OK}$$

Step 3, Check water hammer (Equation 5-4, AWWA M-45).

$$P_c \geq \frac{(P_w + P_s)}{1,4} \quad P_c = 600 \text{ kPa} \geq (400 + 400) / 1,4$$

$$600 \text{ kPa} \geq 571,43 \text{ kPa}, \quad \text{OK}$$

Step 4, Calculate maximum allowable deflection (Equation 5-6, AWWA M-45).

$$\epsilon_b = D_f \left(\frac{\Delta y_a}{D} \right) \left(\frac{t_L}{D} \right) \leq \frac{S_b}{FS}$$

$$\Delta y_a = 196,79 \text{ mm}, \quad \text{Maximum allowable deflection} = 13,9 \%$$

$$\text{Maximum allowable deflection} = 5 \% \leq 13,9 \% \quad \text{OK}$$

Step 5, Calculate soil loads (Equation 5-9, AWWA M-45).

$$\text{Minimum depth of } 1,5 \text{ m} \quad W_c = 28200 \text{ N/m}^2$$

$$\text{Maximum depth of } 4,0 \text{ m} \quad W_c = 75200 \text{ N/m}^2$$



Step 6, Calculate live loads (Equation 5-10, AWWA M-45).

$$W_L = \frac{M_p P I_f}{(L_1)(L_2)}$$

Minimum depth of 1,5 m $W_L = 30338,32 \text{ N/m}^2$

Maximum depth of 4,0 m $W_L = 6421,27 \text{ N/m}^2$

Step 7, Calculate the composite constrained soil modulus (Equation 5-19, AWWA M-45).

$$M_S = S_C M_{sb}$$

Refer to Table 5-5 for S_C value.

For $h=1,5\text{m}$ $M_S = 18,92 \text{ Mpa}$

For $h=4,0\text{m}$ $M_S = 20,81 \text{ Mpa}$

Step 8, Calculate the predicted deflection (Equation 5-8, AWWA M-45).

$$\frac{\Delta y}{D} = \frac{(D_L W_C + W_L) K}{149 P S + 61000 M_S}$$

For $h=1,5\text{m}$ $0,5 \% < 5 \%$ For $h=4,0\text{m}$ $0,7 \% < 5 \%$

Predicted deflection is less than the maximum permitted deflection. **OK**

Step 9, Check combined loading (Equation 5-22 & 5-23, AWWA M-45).

$$\frac{\epsilon_{pr}}{HDB} \leq \frac{1 - \left(\frac{\epsilon_b r_c}{S_b} \right)}{FS_{pr}} \quad 0,210 \leq 0,396 \quad \text{OK}$$



Step 10, Check buckling (Equation 5-24a, AWWA M-45).

$$q_a = \frac{(1,2C_n)(EI)^{0,33}(\varphi_s 10^6 M_S k_v)^{0,67} R_h}{(FS)r}$$

For h=1,5 m $q_a = 489,41$ kPa

For h=4,0 m $q_a = 548,62$ kPa

Check under vacuum effect (Equation 5-25, AWWA M-45).

$$[Y_w h_w + R_w(W_c)] \times 10^{-3} + P_v \leq q_a$$

For h=1,5 m $133,59$ kPa $\leq 489,41$ kPa **OK**

For h=4,0 m $189,58$ kPa $\leq 548,62$ kPa **OK**

Check considering live load (Equation 5-26, AWWA M-45).

$$[Y_w h_w + R_w(W_c) + W_L] \times 10^{-3} \leq q_a$$

For h=1,5 m $63,93$ kPa $\leq 489,41$ kPa **OK**

For h=4,0 m $96,01$ kPa $\leq 548,62$ kPa **OK**

Please refer to Appendix section for design parameter Tables.



HYDROSTATIC THRUST FORCES

At direction changes or at diameter changes, unbalanced thrust forces are formed as shown on below illustrations which might cause serious structural damages on the pipeline if not controlled and balanced. Direction and diameter changes are performed with fittings in most cases. Therefore, we can say that unbalanced thrust forces which occurs on fittings (such as elbow, Tee, reducer, etc) should be restrained with thrust blocks. If not stated otherwise, all SUPERLIT fittings should be encased in concrete.

Thrust force at elbow

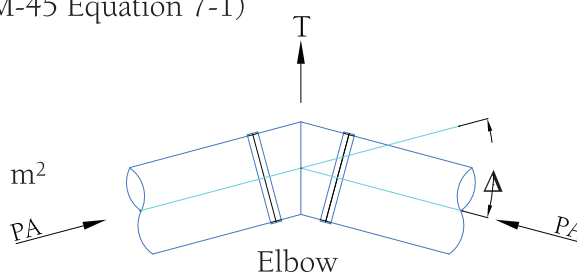
$$T = 2000 PA \sin (\Delta/2) \quad (\text{AWWA M-45 Equation 7-1})$$

T= thrust force, N

P= internal pressure, kPa

A= cross sectional area at pipe joint, m²

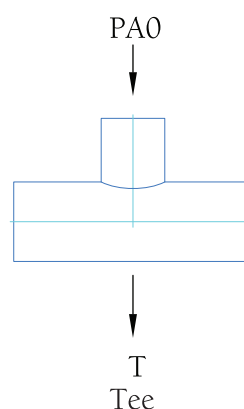
Δ= elbow angle, degrees



Thrust force at Tee

$$T = P \cdot A_0$$

A₀= Branch pipe cross sectional area, m²

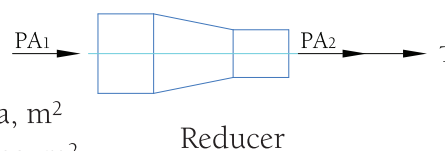


Thrust force at Reducer

$$T = P \cdot (A_1 - A_2)$$

A₁= Bigger diameter pipe cross sectional area, m²

A₂= Smaller diameter pipe cross sectional area, m²



Thrust force at Dead End

$$T = P \cdot A$$





THRUST BLOCK DIMENSIONS

AWWA M-45 takes into consideration the bearing capacity of the soil and ignores the dead weight of the thrust block.

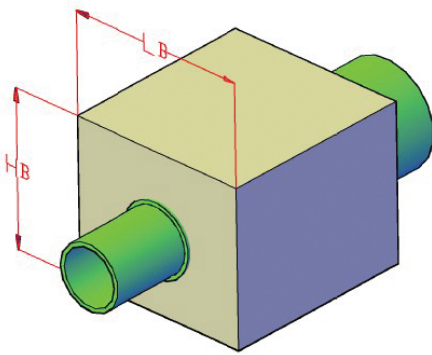
Area of block = $(L_B \times H_B) = (T \times FS) / 1000 \sigma$ (AWWA M-45 Equation 7-2)

T = thrust force, N

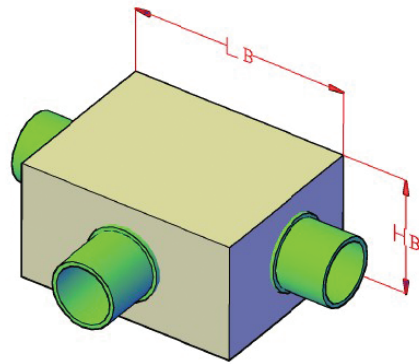
$L_B \times H_B$ = area of thrust block bearing surface, m²

FS = design factor, 1.5

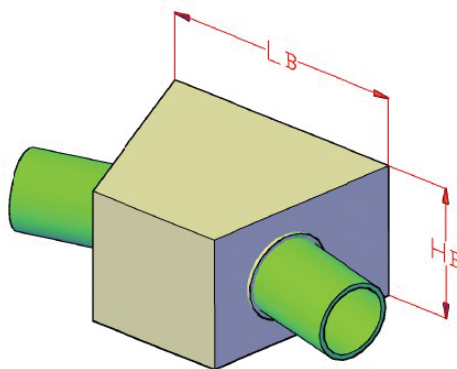
σ = soil bearing strength, kPa



Reducer with thrust block



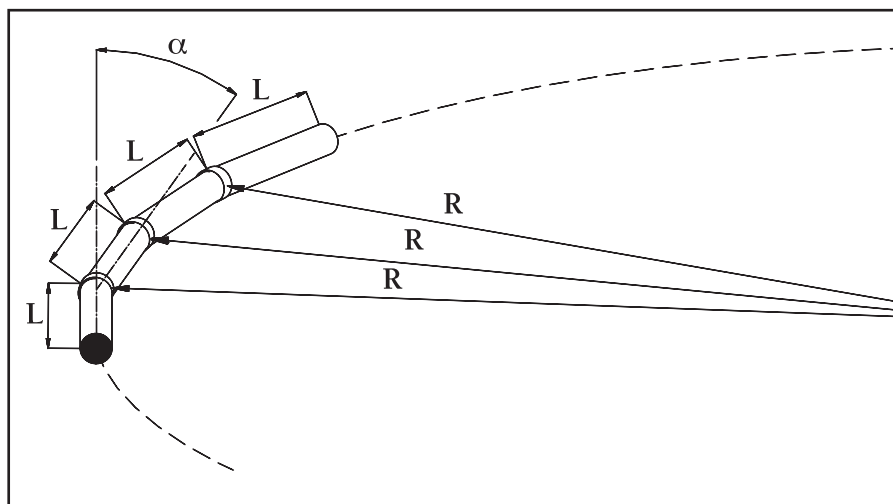
Tee with thrust block



Elbow with thrust block



ANGULAR DEFLECTION OF COUPLINGS AND KURP RADIUS CALCULATION



Kurp Radius (R) can be calculated by the equation $(L/2)/R = \sin(\alpha/2)$ for different angular deflection values at different pipe lengths.

Pipe Length L (m)		3	4	6	8	10	12
DN (mm)	Deflection angle	R (m)	R (m)	R (m)	R (m)	R (m)	R (m)
300 - 500	3°	57,30	76,40	114,60	152,81	191,01	229,21
600 - 900	2°	85,95	114,60	171,90	229,19	286,49	343,79
1000 - 1800	1°	171,89	229,19	343,78	458,37	572,97	687,56
1900 - 3400	0,5°	343,78	458,37	687,55	916,74	1145,92	1375,10



APPENDIX

AWWA M-45 / Table 5-1 Shape factors					
Pipe Stiffness		Pipe zone embedment material and compaction			
		Gravel ⁽¹⁾		Sand ⁽²⁾	
		Dumped to Slight	Moderate to High ⁽⁴⁾	Dumped to Slight ⁽³⁾	Moderate to High ⁽⁴⁾
psi	kpa	Shape factor, Df (dimensionless)			
9	62	5,5	7,0	6,0	8,0
18	124	4,5	5,5	5,0	6,5
36	248	3,8	4,5	4,0	5,5
72	496	3,3	3,8	3,5	4,5

- 1) GW, GP, GW-GC, GW-GM, GP-GC ve GP-GM per ASTM D2487 (includes crushed rock)
- 2) SW, SP, SM, SC, GM and GC or mixtures per ASTM D2487.
- 3) <85Tc Proctor Density (ASTM D698), <40% relative density (ASTM D4253 ve D4254).
- 4) ≥85% Proctor Density (ASTM D698), ≥40% relative density (ASTM D4253 ve D4254).

AWWA M-45 / Table 5-2 AASHTO HS-25, and Cooper E80 live loads (psi)									
AASHTO Live loads		HS-20		HS-25		Cooper E80 Live loads			
Depth		W _L		W _L		Depth		W _L	
fit	m	psi	kPa	psi	kPa	fit	m	psi	kPa
2	0,6	13,4	92	16,8	116	3	0,9	16	110
2,5	0,8	9,7	67	12,2	84	4	1,2	14,1	97
3	0,9	7,4	51	9,2	63	5	1,5	12,2	84
4	1,2	4,7	32	5,9	41	6	1,8	10,5	72
5	1,5	3,4	23	4,2	29	7	2,1	9	62
6	1,8	2,6	18	3,2	22	8	2,4	7,7	33
8	2,4	1,6	11	2	14	10	3,0	5,7	39
10	3,0	1,1	7,6	1,4	10	12	3,7	4,6	32
12	3,7	0,8	5,5	1,1	7,6	15	4,6	3,4	23
15	4,6	0,6	4,1	0,7	4,8	20	6,1	2,2	15
20	6,1	0,4	2,8	0,5	3,4	25	7,6	1,5	10
28	8,5	0,2	1,4	0,25	1,8	30	9,1	1,1	7,6
40	12,2	0,1	0,7	0,1	0,7	40	12,2	0,6	4,1

Note: Cooper E80 as defined by the American Railway Engineers and Maintenance-of-way Association (AREMA) in their Manual of Railway Engineering



GLASS FIBER REINFORCED POLYESTER (GRP) PIPELINES TECHNICAL INFORMATION

AWWA M-45 / Table 5-4 Msb based on soil type and compaction condition					
Inch-Pound Units					
Vertical stress level (see note 5), psi	Depth for $\gamma=120$ pcf. ft	Stiffness Categories 1 and 2 (SCI, SC2)			
		SPD 100, psi	SPD 95, psi	SPD 90, psi	SPD 85, psi
1	1,2	2.350	2.000	1.275	470
5	6	3.450	2.600	1.500	520
10	12	4.200	3.000	1.625	570
20	24	5.500	3.450	1.800	650
40	48	7.500	4.250	2.100	825
60	72	9.300	5.000	2.500	1.000
Stiffness Categories 3 (SC3)					
1	1,2		1.415	670	360
5	6		1.670	740	390
10	12		1.770	750	400
20	24		1.880	790	430
40	48		2.090	900	510
60	72		2.300	1.025	600
Stiffness Categories 4 (SC4)					
1	1,2		530	255	130
5	6		625	320	175
10	12		690	355	200
20	24		740	395	230
40	48		815	460	285
60	72		895	525	345



GLASS FIBER REINFORCED POLYESTER (GRP) PIPELINES TECHNICAL INFORMATION

AWWA M-45 / Table 5-4 Msb based on soil type and compaction condition					
Metric					
Vertical stress level (see note 5), kPa	Depth for soil density = 18.8 kN/m ³ , m	Stiffness Categories 1 and 2 (SC1, SC2)			
		SPD100, MPa	SPD95, MPa	SPD90, MPa	SPD85, MPa
6,9	0,4	16,2	13,8	8,8	3,2
34,5	1,8	23,8	17,9	10,3	3,6
69	3,7	29	20,7	11,2	3,9
138	7,3	37,9	23,8	12,4	4,5
276	14,6	51,7	29,3	14,5	5,7
414	22	64,1	34,5	17,2	6,9
Stiffness Categories 3 (SC3)					
6,9	0,4		9,8	4,6	2,5
34,5	1,8		11,5	5,1	2,7
69	3,7		12,2	5,2	2,8
138	7,3		13,0	5,4	3,0
276	14,6		14,4	6,2	2,5
414	22		15,9	7,1	4,1
Stiffness Categories 4 (SC4)					
6,9	0,4		3,7	1,8	0,9
34,5	1,8		4,3	2,2	1,2
69	3,7		4,8	2,5	1,4
138	7,3		5,1	2,7	1,6
276	14,6		5,6	3,2	2,0
414	22		6,2	3,6	2,4

Notes:

- 1) SC1 soils have the highest stiffness and require the least amount of compactive energy to achieve a given density. SC5 soils which are not recommended for use as backfill, have the lowest stiffness and require substantial effort to achieve a given density.
- 2) SC1 soils have higher stiffness than SC2 soils, but data on specific soil stiffness value is not at the current time. Until such data is available, soil stiffness of dumped SC1 soils can be taken equivalent to SC2 soils compacted to 90% of maximum Standard Proctor Density (SPD90), and the soil stiffness of compacted SC1 soils can be taken equivalent to SC2 soils compacted to 100% of maximum Standard Proctor Density (SPD100). Even if dumped, SC1 materials should always be worked into the haunch zone.
- 3) The numerical suffix to the SPD indicates the compaction level of the soil as a percentage of maximum dry density determined in accordance with ASTM D698 or AASHTO T-99.
- 4) Vertical stress level is the vertical effective soil stress at the springline elevation of the pipe. It is normally computed as the design soil unit weight times the depth of fill. Buoyant unit weight should be used below the groundwater level.
- 5) Engineers may interpolate intermediate values of Msb for vertical stress levels not shown on the table.
- 6) For pipe installation below the water table, the modulus should be corrected for reduced vertical stress due to buoyancy and by an additional factor 1.00 for SC1 and SC2 soils with SPD>95, 0.85 for SC2 soils with SPD of 90, 0.70 for SC2 soils with SPD of 85, 0.5 for SC3 soils and 0.30 for SC4 soils.
- 7) It is recommended to embed pipe with stiffness of 9 psi (62kPa) or less only in SC1 or SC2 soils.



GLASS FIBER REINFORCED POLYESTER (GRP) PIPELINES TECHNICAL INFORMATION

AWWA M-45 / Table 5-5 Values for the soil supporting combining factor S_c								
M_{sn} / M_{sb}	$B_d/D=1,25$	$B_d/D=1,5$	$B_d/D=1,75$	$B_d/D=2$	$B_d/D=2,5$	$B_d/D=3$	$B_d/D=4$	$B_d/D=5$
0.005	0.02	0.05	0.05	0.12	0.23	0.43	0.72	1.00
0.01	0.03	0.07	0.11	0.15	0.27	0.47	0.74	1.00
0.02	0.05	0.10	0.15	0.20	0.32	0.52	0.77	1.00
0.05	0.10	0.15	0.20	0.27	0.38	0.58	0.80	1.00
0.1	0.15	0.20	0.27	0.35	0.46	0.65	0.84	1.00
0.2	0.25	0.30	0.38	0.47	0.58	0.75	0.88	1.00
0.4	0.45	0.50	0.56	0.64	0.75	0.85	0.93	1.00
0.6	0.65	0.70	0.75	0.81	0.87	0.94	0.98	1.00
0.8	0.84	0.87	0.90	0.93	0.96	0.98	1.00	1.00
1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.5	1.40	1.30	1.20	1.12	1.06	1.03	1.00	1.00
2	1.70	1.50	1.40	1.30	1.20	1.10	1.05	1.00
3	2.20	1.80	1.65	1.50	1.35	1.20	1.10	1.00
5	3.00	2.20	1.90	1.70	1.50	1.30	1.15	1.00
Not: In between values of S_c may be determined by straight-line interpolation from adjacent values.								

AWWA M-45 / Table 5-6 Values for the constrained modulus of the native soil at pipe zone elevation.						
Native in situ soils						
Cohesive						
Granular		q_u		M_{sn}		
Esme/fi ⁽²⁾ (0,3m)	Description	ton/sf	kPa	Description	psi	MPa
>0-1	very, very loose	>0-0.125	0-13	very, very soft	50	0.34
1-2	very loose	0.125-0.25	13-25	very soft	200	1.4
2-4		0.25-0.50	25-50	soft	700	4.8
4-8	loose	0.50-1.0	50-100	medium	1.500	10.3
8-15	slightly compact	1.0-2.0	100-200	stiff	3.000	20.7
15-30	compact	2.0-4.0	200-400	very stiff	5000	34.5
30-50	dense	4.0-6.0	400-600	hard	10.000	69.0
>50	very dense	>6.0	>600	very hard	20.000	138.0

(See notes on next page)



GLASS FIBER REINFORCED POLYESTER (GRP) PIPELINES TECHNICAL INFORMATION

- 1) The constrained modulus M_{sn} for rock is $\geq 50,000$ psi (345 Mpa)
- 2) Standard penetration test per ASTM D1586

Notes: For embankment installation $M_{sb} = M_{sn} = M_s$

M_s special cases:

Geotextiles—When a geotextile pipe zone wrap is used, M_{sn} values for poor soils can be greater than those shown in this table.

Solid sheeting – When permanent solid sheeting designed to last the life of the pipeline is used in the pipe zone, M_s , shall be based solely on M_{sb}

Cement stabilized sand—When cement stabilized sand is used as the pipe zone surround, initial deflections shall be based on a sand installation and the long term $M_{sb} = 25,000$ psi (172 Mpa) (Typical mix ratio is 1 sack of cement per ton or 1.5 sacks of cement per cubic yard of mix)

AWWA M-45 / Table 7 -1 Horizontal soil-bearing strengths		
Soil	Bearing Strength (σ)	
	lb / ft ²	kN/ m ²
Muck	0	0
Soft clay	1000	48
Silt	1500	72
Sandy silt	3000	144
Sand	4000	192
Sandy clay	6000	287
Hard clay	9000	431

Although the bearing strength values have been used successfully in the design of thrust blocks and considered to be conservative, their accuracy is dependent on accurate soil identification and evaluation. The design engineer must select the proper bearing strength of a particular soil type.

Reference for the tables above at the Appendix section: AWWA M-45, Fiberglass Pipe Design, Manual of Water Supply Practices, published by American Water Works Association.



GLASS FIBER REINFORCED POLYESTER (GRP) PIPELINES TECHNICAL INFORMATION

GRP COUPLING DIMENSIONS															
Nominal Diameter	Pipe outer diameter	Coupling internal diameter	Coupling width	Coupling outer diameter - Dc (mm)						Coupling weight - Wc (kg)					
DN (mm)	OD (mm)	Di (mm)	L (mm)	PN (1-10)	PN 12	PN 16	PN 20	PN 25	PN 32	PN (1-10)	PN 12	PN 16	PN 20	PN 25	PN 32
250	272,3	273,8	220	305	305	305	307	308	310	5,0	5,0	5,0	5,3	5,6	5,9
300	324,0	325,5	220	356	356	356	357	359	361	5,5	5,5	5,5	5,8	6,2	6,5
350	376,1	377,6	220	408	408	408	409	411	413	6,4	6,4	6,4	6,8	7,2	7,6
400	427,1	429,6	242	460	460	462	464	465	467	8,4	8,4	8,9	9,4	9,9	10,3
450	475,3	477,8	242	509	509	511	512	514	515	9,4	9,4	9,9	10,5	11,0	11,5
500	530,1	532,6	242	564	566	567	569	572	575	10,4	11,0	11,6	12,2	13,4	14,5
600	633,1	635,6	242	668	670	671	674	679	684	12,5	13,1	13,8	15,2	17,3	19,4
700	718,3	720,8	260	757	758	760	763	769	775	17,5	18,3	19,1	20,8	24,0	27,2
800	819,9	822,4	260	859	862	864	867	873	880	20,0	21,9	22,8	24,6	28,3	32,9
900	924,1	926,6	260	963	964	967	971	977	985	23,5	24,6	26,3	29,4	33,5	38,7
1000	1026,1	1028,6	260	1067	1068	1071	1075	1081	1089	27,3	28,4	30,4	33,8	38,4	44,1
1100	1127,3	1129,8	260	1169	1170	1174	1179	1185	1194	30,0	31,3	34,7	38,4	43,5	51,0
1200	1228,8	1231,3	260	1271	1274	1276	1282	1290	1297	32,6	35,4	37,7	43,2	50,0	56,9
1300	1331,5	1334,0	260	1375	1378	1381	1387	1394	1403	36,9	39,9	42,3	48,3	55,7	64,6
1400	1433,6	1436,1	275	1479	1481	1483	1490	1498	1507	47,8	50,5	53,2	60,2	70,0	79,7
1500	1535,6	1538,1	275	1582	1585	1587	1593	1602	1611	52,6	55,5	58,4	66,0	75,8	86,8
1600	1637,6	1640,1	275	1686	1689	1691	1697	1705	1715	58,3	61,4	64,5	72,6	83,1	94,8
1700	1739,4	1741,9	275	1788	1791	1794	1801	1809	1820	61,7	65,0	69,6	78,8	89,9	104,4
1800	1841,7	1844,2	275	1893	1895	1898	1907	1915	1925	67,7	71,1	76,0	87,8	99,6	114,9
1900	1943,5	1946,0	275	1995	1997	2002	2010	2018	2029	71,3	75,0	82,3	94,8	107,2	123,4
2000	2045,8	2048,8	275	2098	2101	2106	2114	2122	2133	75,1	81,3	89,0	102,1	115,2	132,2
2100	2148,0	2151,0	275	2199	2203	2208	2216	2224	2235	80,7	87,2	95,3	109,1	122,8	140,6
2200	2250,0	2253,0	275	2302	2307	2312	2320	2328	2338	84,0	93,4	101,8	116,2	130,6	149,3
2300	2351,4	2354,4	275	2405	2410	2415	2423	2431	2442	90,7	100,4	109,3	124,3	139,4	158,9
2400	2453,0	2456,0	275	2508	2513	2518	2526	2534	2545	97,6	107,8	107,0	132,7	148,4	168,8
2500	2555,0	2558,0	330	2605	2609	2613	2619	2627	2635	117,1	128,3	136,4	152,5	171,8	191,0
2600	2656,0	2659,0	330	2707	2712	2715	2722	2730	2738	124,9	136,5	144,9	161,7	181,7	201,7
2700	2758,0	2761,0	330	2811	2815	2819	2825	2833	2841	133,1	145,2	153,9	171,3	192,1	212,8
2800	2860,0	2863,0	330	2914	2919	2922	2929	2937	2945	141,4	153,9	163,0	181,0	202,6	224,1
2900	2962,0	2965,0	330	3018	3022	3026	3032	3040	3048	150,0	162,9	172,3	191,0	213,3	235,6
3000	3065,0	3068,0	330	3121	3126	3129	3136	3144	3152	158,9	172,3	182,0	201,3	224,4	247,4
3100	3170,0	3173,0	330	3230	3235	3238	3245	3253	3261	171,9	185,8	195,8	215,8	239,7	263,5
3200	3268,0	3271,0	330	3329	3334	3337	3344	3352	3360	181,2	195,5	205,8	226,4	251,0	275,6
3300	3370,0	3373,0	330	3433	3438	3441	3448	3456	3463	191,0	205,7	216,3	237,6	263,0	288,3
3400	3472,0	3475,0	330	3536	3541	3544	3551	3559	3567	200,9	216,0	227,0	248,9	275,0	301,2

Note: Above given values are approximate values. SUPERLIT reserves the right to change any part of the above table or as a whole without prior notification.



GLASS FIBER REINFORCED POLYESTER (GRP) PIPELINES TECHNICAL INFORMATION

		SUPERLIT CFW Pipe Weight			
DN	SN	PN 1 bar	PN 6 bar	PN 10 bar	PN 16 bar
mm	N/m ²	Kg / m	Kg / m	Kg / m	Kg / m
300	2500	8,3	8,3	8,3	8,2
350		11,3	11,3	11,0	11,0
400		14,6	14,6	14,1	14,0
450		18,4	18,4	17,5	17,5
500		22,9	22,9	21,4	21,3
600		30,2	30,2	26,4	24,7
700		40,6	40,6	35,7	33,0
800		52,7	52,7	46,4	42,7
900		66,5	66,5	58,5	53,4
1000		82,2	82,2	71,9	65,8
1100		99,4	99,4	86,4	78,8
1200		117,7	117,7	102,3	93,7
1300		138,1	138,1	119,6	109,6
1400		159,5	159,5	138,8	126,7
1500		181,8	181,8	158,1	144,8
1600		207,4	207,4	179,9	164,3
1700		235,8	235,8	203,2	185,0
1800		263,8	263,8	227,5	206,7
1900		292,9	292,9	252,2	229,9
2000		324,4	324,4	279,6	254,0
2100		357,3	357,3	308,1	280,5
2200		391,5	391,5	337,3	306,5
2300		427,3	427,3	369,1	334,9
2400		464,7	464,7	400,9	364,3
2500		475,4	475,4	411,0	373,6
2600		514,9	514,9	444,1	403,8
2700		554,9	554,9	478,4	434,7
2800		595,2	595,2	514,4	467,7
2900		638,5	638,5	551,2	495,9
3000		684,0	684,0	589,8	525,1
3100		727,9	727,9	628,4	545,7
3200		776,0	776,0	669,6	584,3
3300		825,7	825,7	712,1	615,1
3400		875,3	875,3	755,8	646,8

		SUPERLIT CFW Pipe Weight			
DN	SN	PN 1 bar	PN 6 bar	PN 10 bar	PN 16 bar
mm	N/m ²	Kg / m	Kg / m	Kg / m	Kg / m
300	5000	10,5	10,5	10,5	11,2
350		14,3	14,3	14,0	14,7
400		18,6	18,6	17,6	18,9
450		23,5	23,5	22,3	23,4
500		29,0	29,0	27,3	28,9
600		37,9	37,9	34,6	34,8
700		51,0	51,0	46,9	46,8
800		66,1	66,1	60,7	60,6
900		83,4	83,4	77,5	76,2
1000		102,4	102,4	95,4	93,3
1100		123,7	123,7	115,0	112,7
1200		146,2	146,2	136,5	133,3
1300		172,4	172,4	159,6	156,2
1400		199,4	199,4	184,6	180,6
1500		229,2	229,2	211,6	207,0
1600		259,9	259,9	240,7	235,1
1700		293,1	293,1	271,0	264,9
1800		328,5	328,5	303,4	296,6
1900		365,1	365,1	338,1	329,3
2000		403,8	403,8	374,3	364,6
2100		445,1	445,1	411,8	401,6
2200		488,5	488,5	451,9	440,4
2300		532,5	532,5	494,4	481,0
2400		578,9	578,9	537,4	523,0
2500		594,7	594,7	550,9	487,8
2600		624,6	624,6	595,0	527,4
2700		691,5	691,5	641,5	568,4
2800		774,0	774,0	690,0	610,9
2900		798,3	798,3	739,2	654,4
3000		853,2	853,2	790,5	699,0
3100		910,1	910,1	844,9	739,7
3200		969,3	969,3	899,5	781,7
3300		1031,1	1031,1	956,7	824,7
3400		1094,7	1094,7	1014,1	869,8



GLASS FIBER REINFORCED POLYESTER (GRP) PIPELINES TECHNICAL INFORMATION

		SUPERLIT CFW Pipe Weight			
DN	SN	PN 1 bar	PN 6 bar	PN 10 bar	PN 16 bar
mm	N/m ²	Kg / m	Kg / m	Kg / m	Kg / m
300	10000	12,9	12,9	12,9	12,7
350		17,5	17,5	17,5	16,8
400		22,6	22,6	22,6	21,7
450		28,4	28,4	28,4	26,6
500		35,1	35,1	35,1	32,9
600		46,2	46,2	46,2	41,4
700		63,2	63,2	63,2	55,9
800		82,2	82,2	82,2	72,2
900		103,3	103,3	103,3	91,2
1000		127,8	127,8	127,8	112,0
1100		154,7	154,7	154,7	135,2
1200		183,4	183,4	183,4	160,6
1300		215,1	215,1	215,1	187,6
1400		248,9	248,9	248,9	217,7
1500		284,4	284,4	284,4	249,5
1600		324,2	324,2	324,2	283,5
1700		364,8	364,8	364,8	319,3
1800		409,1	409,1	409,1	357,8
1900		455,2	455,2	455,2	397,8
2000		503,0	503,0	503,0	440,5
2100		554,8	554,8	554,8	484,8
2200		608,5	608,5	608,5	531,6
2300		664,1	664,1	664,1	580,9
2400		722,2	722,2	722,2	632,8
2500		741,0	741,0	741,0	648,3
2600		801,4	801,4	801,4	700,2
2700		863,5	863,5	863,5	755,2
2800		928,7	928,7	928,7	811,2
2900		994,0	994,0	994,0	870,3
3000		1064,4	1064,4	1064,4	930,9
3100		1135,5	1135,5	1135,5	992,7
3200		1210,3	1210,3	1210,3	1058,4
3300		1287,5	1287,5	1287,5	1121,2
3400		1364,5	1364,5	1364,5	1183,5

Note: Above given values are approximate values. SUPERLIT reserves the right to changes any part of the above table or as a whole without prior notification.