Aquatherm Technical Bulletin

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Underground Thermal Expansion in Aquatherm Pipe

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The need for thermal expansion joints in piping systems arises from the tendency of the pipe to expand or contract due to changes in temperature of the pipe material. This expansion can either be directed to a specific location (i.e. expansion joint) by anchoring the pipe away from the joint and allowing it to expand/move in the direction of the joint, or by allowing the pipe to move throughout its length in both directions.

For polypropylene (PP-R and RP (RCT)) piping systems, an alternative to this approach is to restrain the pipe along the length such that it is not allowed to expand or contract. This is typically not an option for steel pipe because the forces developed in steel pipe are much higher (approximately 300 times) than PP-R or RP (RCT). For example, given a 100^{o}F temperature change, a 100 ft. piece of Aquatherm SDR 11 faser pipe will expand 2.3 inches, whereas schedule 40 steel pipe would expand 1.0 inch. For an 8-inch nominal size pipe this equates to an axial force of approximately 201,600 lbf for the steel pipe, while the Aquatherm pipe exerts an axial force of only 4,800 lbf for SDR 7.4; 3,400 lbf for SDR 11 and 2,180 lbf for SDR 17.6.

For buried pipe, the frictional force at the interface between the soil and the pipe surface will restrain the pipe until the axial force created by thermal expansion is sufficient to overcome the frictional force. Once this occurs the pipe will begin to move in the soil. The friction force can be calculated from the modified Coulomb equation based on the work of Potyondy (1961)[1].

Eq. 1: $F = A_p C\, f_c + L_p W \tan(f_{Ø}\, Ø)$

Where: $A_p = \pi\, ODp/2\ \ Lp$, ft2 ; area of pipe surface bearing against the soil
C = Cohesion of the soil, lb/ft2
f_c = proportionality constant based on shear tests of surface to soil interface
L_p = Length of pipe, ft.
OD_p = Outside diameter of pipe, ft.
$W = 2We + W_p + W_w$, lb/ft.; normal force per unit length
W_e = Vertical load on top and bottom surfaces (prism load), lb/ft
W_p = Weight of pipe, lb/ft
W_w = weight of water in pipe, lb/ft

The values for f_c, $f_Ø$ and Ø are given in the table below, as taken from AWWA M23, Table 4-12[2].

[1]Table 1 – Properties of Soils used for Bedding

Soil Group*	**f_c**	**C, lb/ft^2**	**$f_Ø$**	**Ø, deg**
GW & SW	0	0	0.7	35
GP & SP	0	0	0.7	31
GM & SM	0	0	0.6	30
GC & SC	0.2	225	0.6	25
CL	0.3	250	0.5	20
ML	0	0	0.5	29

*Soil Group per ASTM D2487 (Table 4-6)

The minimum frictional force per Equation (1) will occur when there is little or no soil cohesion (C~0), low soil density (W~100 ib/ft^3) and ($f_Ø$ Ø) is at a minimum. As seen in Table 1, the least frictional force criteria are met for silty gravel (GM) or silty sand (SM).

Using this worst-case soil loading for a 13-ft (4 m) section of Aquatherm SDR 7.4 PP-R piping results in a frictional force of 5,634 lbf at a burial depth of 1 ft. This is well above the axial force imposed by the thermal expansion (4,800 lb_f for SDR 7.4; 3,400 lb_f for SDR 11 and 2,180 lb_f for SDR 17.6) and will readily restrain the pipe from movement. Note that at a burial depth of 3 ft., this frictional force increases to 16,350 lb_f over this same section of piping.

At either burial depth, the frictional force is significantly below the axial force developed in the steel pipe (201,600 lb_f) and as such, the steel pipe would expand and require the use of expansion joints to compensate for the expansion.

The final question is whether this restraint of the Aquatherm piping will cause any damage to the pipe material itself. The axial stress in the pipe wall due to the restraint would be 210 psi. The long term extrapolated strength of the pipe material is 575 psi at 180^oF[3].

It is also worth noting that in work done by Alam and Allouche[4] the actual frictional force restraining the pipe movement was found in laboratory testing to be in good agreement with Potyondy for cohesive and fine grain soils and higher than predicted for coarse granular material and pea gravel (i.e. more conservative).

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[1] Potyondy, J.G, 1961. Skin Friction Between Various Soil and Construction Materials, Geotechnique, Vol. XI, No. 4, pp 339-353

[2] PVC Pipe – Design and Installation, AWWA Manual M23, 2nd Ed., American Water Works Association

[3] ISO 15874-2003, Plastics Piping Systems for hot and cold water installations – Polypropylene (PP)

[4] Alam, S., Allouche, E N., 2010, Experimental investigation of Pipe Soil Friction Coefficients for Direct Buried PVC Pipes, Pipelines 2010: Climbing New Peaks to Infrastructure Reliability – Rnew, Rehab, and Reinvest, 2010 ASCE

Revisions:

1. 9 Sept 2021 – Added RP (RCT)

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