uPVC PENSTOCK LOSSES & THICKNESS CALCULATION

SITE NAME	**Sample**		
Quantity	*Symbol*	*Unit*	
PENSTOCK LOSS CALCULATIONS			
Input Data			
Flow	Q	70 l/s	
Gross head	H_g	22 m	
Penstock length	L	60 m	
Penstock internal diameter	d	190 mm	
Calculations			
Velocity in penstock	$V = 1{,}273 \cdot \left(\frac{Q}{d^2}\right) =$		2.47 m/s
Friction head loss in penstock	$H_f = 12 \cdot 8 \times \left(\frac{V^2.L}{d}\right) \times \frac{1}{\left(\log\left[\frac{1}{370d} + \frac{1}{(93 \cdot 8\, V.d)^{0 \cdot 9}}\right]\right)^2} =$		1.46 m
Net head at end of penstock	$H_n = H_g - H_f =$		20.5 m
Penstock efficiency	$\eta_{pen} = \frac{H_n}{H_g} \times 100 =$		93.3 %
PENSTOCK THICKNESS CALCULATIONS			
Input Data			
Penstock thickness	t	4.7 mm	
% of flow stopped	z	50 %	
Valve closure time	T_{close}	0.1 s	
Overall safety factor	SF_{tot}	3	
Calculations			
Wave velocity in penstock	$V_{wave} = \sqrt{\frac{2 \cdot 8 \times 10^6 .t}{(1 \cdot 33t + d)}} =$		259 m/s
Penstock critical time	$T_{crit} = \frac{2L}{V_{wave}} =$		0.46 s
Surge head for $T_{close} \le T_{crit}$	$H_{surge} = \frac{V_{wave}.z.V}{980} =$		32.6 m
OR			
For $T_{close} \ge T_{crit}$	$K_c = \left(\frac{L.z.V}{980 H_g . T_{close}}\right)^2 =$		11.8
Surge head for $T_{close} \ge T_{crit}$	$H_{surge} = H_g . \left(\frac{K_c}{2} + \sqrt{K_c + \frac{K_c^2}{4}}\right) =$		- m
Total head at surge	$H_{tot} = H_{surge} + H_g =$		54.6 m
Required penstock thickness	$t_{req} = \frac{H_{tot}.d.SF_{tot}}{5{,}710} =$		5.45 mm

Values of Constants Used

Gravity	g	9.8	m/s
Bulk modulus of water	K_w	2.1	kN/mm^2
Density of water	ro	1000	kg/m^3
Kinematic viscosity of water (5°C)	nu	1.53	cSt
Penstock roughness coefficient	k	0.01	mm
Penstock Young's Modulus	E_p	2.8	kN/mm^2
Penstock UTS	σ_{ult}	28	N/mm^2