Summary of Important Flow-Induced Vibration Relations

Moment of Inertia for a Cylinder	$I_x = \dfrac{\pi\left(d_o^2 - d_i^2\right)}{64}$

Natural Frequency:

No Load (rads/sec)	$\omega_n = \dfrac{n^2\pi^2}{l^2}\sqrt{\dfrac{EI}{m}}$
Load F (rads/sec)	$\omega_n = \dfrac{n^2\pi^2}{l^2}\sqrt{\dfrac{EI}{m}}\sqrt{1+\dfrac{Fl^2}{EI\pi^2 n^2}}$
Natural Frequency in Hertz (sec^{-1})	$f = \omega/2\pi$

Cross Flow: Single Tube

Vortex Shedding	$S = \dfrac{f_{vs} d_o}{v}$
Turbulent Buffeting	$f_{tb} = \dfrac{v}{d_o x_l x_t}\left[3.05\left(1-\dfrac{1}{x_t}\right)^2 + 0.28\right]$

Cross Flow: Tube Bundle

Jet Switching	$\dfrac{v}{f_{js} d_o} = 75$
Fluid-Elastic Instability	$\dfrac{v}{f_{fei} d_o} = K\sqrt{\dfrac{m\delta}{\rho d_o}}$
Acoustic Coupling	$f_{ac} = \dfrac{cn}{2w}$

Axial/Parallel Flow: Internal Flow

Mean Flow	Lowers natural frequency
Upstream Variations	Both near-field and far-field; These must be treated stochastically
Internal Pendulum Motion	Creates low frequency vibration of control rods; Both static and dynamic instability exists

Axial/Parallel Flow: Ex~~In~~ternal Flow

Same mechanisms as internal flow, minus pendulum motion

Fluid Damping

General Equation	$m_o \dfrac{d^2x}{dt^2} + C\dfrac{dx}{dt} + Kx = 0$
Critical Damping (K is the damping constant)	$C^* = 2\sqrt{Km}$

Critical Velocity Correlations for Major Vibration Mechanisms

Fluid-Elastic Instability	$\dfrac{v}{fd_o} = 3.3\sqrt{\chi}$
Turbulent Buffeting	$v = f_n d_o x_t x_l \left[3.05\left(1-\dfrac{1}{x_t}\right)^2 + 0.28\right]^{-1}$
Vortex Shedding	$v = \dfrac{1}{C_L \rho}\pi\sqrt{0.04 C_L \rho\delta m}\, f_n$
Equation Constant	$\chi = \dfrac{m\delta}{\rho d_o^2}$
Logarithmic Damping Constant	$\delta = 2\pi\zeta$