Table−２　Comparison of strength calculation method for vortex excitation of protecting tube

<table>
<tr><th>No.</th><th>Applicable Standard</th><th>ASME PTC 19.3-1974
Include our proprietary method</th><th>JSME S012-1998</th><th>ASME PTC 19.3 TW-2010</th></tr>
<tr><td>1</td><td>Natural frequency fn calculation</td><td colspan="2">Power Test Code Thermometer Wells　/ J.W.Murdock Published Calculation formula (taper type) $fn = f$

$$f = \frac{1}{2\pi}\sqrt{\frac{g}{y}}$$

$$\frac{3E}{4\rho_s g}\left(\frac{A-B}{L}\right)^4 y = \frac{1}{2}(A-B)^2 + \frac{1}{4}\left[\frac{3B^4}{d^2} - 5d^2 - 6\left\{B + t\left(\frac{A-B}{L}\right)\right\}^2\right]\left\{\frac{B}{d}\log_e\frac{(B-d)(A+d)}{(B+d)(A-d)} + \log_e\frac{A^2-d^2}{B^2-d^2}\right\}$$

$$+\frac{1}{2}\left[6\left\{B + t\left(\frac{A-B}{L}\right)\right\}^2 - 7d^2 - \frac{3B^4}{d^2}\right]\left[\left\{\frac{B}{d}\tan^{-1}\frac{d(B-A)}{d^2+AB}\right\} + \frac{1}{2}\log_e\frac{A^2+d^2}{B^2+d^2}\right]$$

$$+2\left[\frac{B^3}{d^2} - 3\left\{B + t\left(\frac{A-B}{L}\right)\right\}\right]\left\{\frac{B}{2}\log_e\frac{(B^2+d^2)(A^2-d^2)}{(B^2-d^2)(A^2+d^2)} + d\tan^{-1}\frac{d(B-A)}{d^2+AB} + \frac{d}{2}\log_e\frac{(B-d)(A+d)}{(B+d)(A-d)}\right\}$$

However, the publication JSME S012, comes with a CD-ROM and includes a program that can perform calculation of natural frequency by finite element method using EXCEL besides PDF of contents of publication There.</td><td>Calculation formula on TW-2010
Multiply the approximate natural frequency by the correction factor

$$f_a = \frac{1.875^2}{2\pi}\left(\frac{EI}{m}\right)^{1/2}\frac{1}{L^2}$$

$$f_n = H_f H_{af} H_{as} f_a$$

H : Correction factor

$$H_f = \frac{0.99\left[1+(1-B/A)+(1-B/A)^2\right]}{1+1.1(D_a/L)^{3[1-0.8(d/D_a)]}}$$

$$H_{af} = 1 - \frac{\rho}{2\rho_m}$$

$$H_{as} = 1 - \frac{\rho_s}{2\rho_m}\left[\frac{1}{(D_a/d)^2 - 1}\right]$$

$f_n^c = H_c f_n$

$$H_c = 1 - (0.61)\frac{(A/L)}{\left[1+1.5(b/A)\right]^2}$$</td></tr>
<tr><td>2</td><td>Forced frequency fs calculation
Or
Calculation of converted fluid velocity Vr and Attenuation rate Cn</td><td>$$f_s = St \times \frac{V}{D_A} \times 10^3$$
St : Strouhal number
V : Fluid velocity
In ASME, D_A has a tip outside diameter, but our company calculates with actual insertion length average outside diameter</td><td>Converted fluid velocity : $Vr=V/(fn \cdot D_A)$
D_A : Actual insertion length average outside diameter
Attenuation rate : $Cn=2 \cdot m \cdot \delta/(\rho \cdot D_{AV}^2)$
D_{AV} : Termowell average outside diameter
m : Termowell quantity

δ : logarithmic decrement rate</td><td>$$f_s = N_s \frac{V}{B}$$
$N_s = 0.22(1-22/Re)$　for $22 \le Re < 1{,}300$
$N_s = 0.213 - 0.0248[\log_{10}(Re/1{,}300)]^2$
$+0.0095[\log_{10}(Re/1{,}300)]^2$　for $1{,}300 \le Re < 5\times10^5$
$N_s = 0.22$　for $5\times10^5 \le Re < 5\times10^7$</td></tr>
</table>

3	Avoid resonance Or Avoidance or suppression of synchronous frequency generation	1）Allowed：$fs/fn<0.8$ （ASME） 2）Not allowed：$0.8 \leqq fs/fn \leqq 1.4$ 3）Can be used with user's permission : $1.4< fs/fn$ （$\sigma r < \sigma ra$） σr : Resonant bending stress σra：Allowable fatigue limit stress Remarks：3） Applied in the case of a light fluid 2）、3） are our proprietary methods	Must be satisfied one of the following 1）$Vr<1$ 2）$Cn>64$ 3）$Vr<3.3$ and $Cn>2.5$	Any of the following $Nsc>2.5$ and $Re<10^5$ $fs/fn<0.8$ $Nsc \leqq 2.5$ and $Re \geqq 10^5$ $S_{o,max} < F_T \cdot F_E \cdot S_f$ $fs/fn<0.8$ However, $0.4<fs/fn<0.6$ is not recommended $Nsc \leqq 2.5$ and $Re \geqq 10^5$ $S_{o,max} \geqq F_T \cdot F_E \cdot S_f$ $fs/fn<0.4$ $N_{Sc} = \pi^2 \zeta (\rho_m / \rho) \left[1-(d/B)^2\right]$：Scruton number