MPR ASSOCIATES, INC.
1050 Connecticut Ave., NW-Washington, DC 20036

CALCULATION TITLE PAGE

CLIENT CONSUMERS POWER	PAGE 1 OF 8
PROJECT BIG ROCK POINT PLANT	TASK NO. 98-114
CALCULATION TITLE AMPLIFICATION FACTOR FOR SINUSOIDAL FORCING FUNCTION FOR A SECOND-ORDER MECHANICAL SYSTEM	CALCULATION NO. (OPTIONAL) 98-114-HWM 1

PREPARER(S)/DATE	CHECKER(S)/DATE	REVIEWER(S)/DATE	REV. NO.
HWMcCURDY 2-17-92	Michael Francis 2-17-92	John W. [illegible] 2-17-92	0

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE 2
98-114-HWM1	HW McCURDY	M Francis	

FOLLOWING IS A CALCULATION OF THE AMPLIFICATION FACTOR RESULTING FROM A SINUSOIDAL FORCING FUNCTION FOR A SECOND-ORDER MECHANICAL SYSTEM (SEE FIGURE 1).

THE SYSTEM EQUATION IS,

$$\frac{M}{g_c}\ddot{x} + C\dot{x} + Kx = F(t)$$

WHERE,

M = SYSTEM MASS, LB

g_c = GRAVITATIONAL CONSTANT, FT-LB/LB-SEC^2

$x, \dot{x}, \ddot{x}$ = POSITION (FT), VELOCITY (FT/SEC) AND ACCELERATION (FT/SEC^2)

C = SYSTEM DAMPING, LB-SEC/FT

K = SYSTEM SPRING CONSTANT, LB/FT

F = APPLIED FORCE, LB

DIVIDE THE SYSTEM EQUATION BY K,

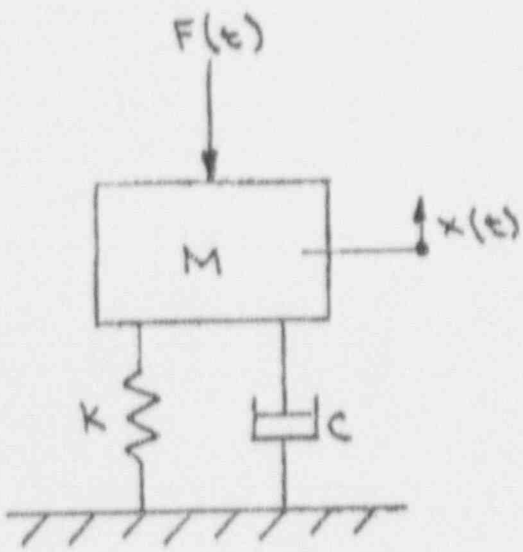
$$\frac{M\ddot{x}}{g_c K} + \frac{C}{K}\dot{x} + x = \frac{F(t)}{K}$$

MPR ASSOCIATES, INC.
1050 Connecticut Ave., NW-Washington, DC 20036

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE 3
98-114-HWM1	HWMcCURDY	M Francis	

FIGURE 1

SECOND-ORDER MECHANICAL SYSTEM



MPR ASSOCIATES, INC.
1050 Connecticut Ave., NW-Washington, DC 20036

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE 4
98-114-HWM1	HWMcCURDY	M Francis	

DEFINE THE FOLLOWING TERMS,

$$\omega_n^2 = \frac{K g_c}{M}$$

$$\frac{2\varphi}{\omega_n} = \frac{C}{K}$$

WHERE,

ω_n = SYSTEM NATURAL FREQUENCY, RAD/SEC

φ = SYSTEM DAMPING COEFFICIENT

SUBSTITUTE IN THE SYSTEM EQUATION,

$$\frac{\ddot{x}}{\omega_n^2} + \frac{2\varphi}{\omega_n}\dot{x} + x = \frac{F(t)}{K}$$

TAKE LAPLACE TRANSFORM AND ASSUME INITIAL CONDITIONS ARE ZERO (SEE REFERENCE 1),

$$\left[\frac{s^2}{\omega_n^2} + \frac{2\varphi s}{\omega_n} + 1\right] x(s) = \frac{F(s)}{K}$$

OR,

$$\frac{K\,x(s)}{F(s)} = \frac{\omega_n^2}{s^2 + 2\varphi\omega_n s + \omega_n^2}$$

MPR ASSOCIATES, INC.
1050 Connecticut Ave., NW - Washington, DC 20036

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE 5
98-114-HWM1	HW McCURDY	M Francis	

ASSUME THAT $F(t) = F_0 \cos \omega_n t$,

$$F(s) = F_0 \frac{s}{s^2 + \omega_n^2}$$

THE SYSTEM EQUATION IS,

$$\frac{Kx(s)}{F_0} = \frac{\omega_n^2 s}{(s^2 + 2\zeta\omega_n s + \omega_n^2)(s^2 + \omega_n^2)}$$

$$\frac{Kx(s)}{F_0} = \frac{\omega_n^2}{2\zeta\omega_n} \times \frac{2\zeta\omega_n s}{(s^2 + 2\zeta\omega_n s + \omega_n^2)(s^2 + \omega_n^2)}$$

$$\frac{Kx(s)}{F_0} = \frac{\omega_n}{2\zeta} \cdot \left[\frac{1}{s^2 + \omega_n^2} - \frac{1}{s^2 + 2\zeta\omega_n s + \omega_n^2} \right]$$

$$\frac{Kx(s)}{F_0} = \frac{1}{2\zeta} \left[\frac{\omega_n}{s^2 + \omega_n^2} - \frac{\omega_n}{(s + \zeta\omega_n)^2 + \omega_n^2(1 - \zeta^2)} \right]$$

TAKE THE INVERSE TRANSFORMS,

$$\frac{Kx(t)}{F_0} = \frac{1}{2\zeta} \left[\sin \omega_n t - \frac{e^{-\zeta\omega t}}{(1 - \zeta^2)^{1/2}} \sin \omega_n (1 - \zeta^2)^{1/2} t \right]$$

ASSUME THAT $\zeta^2 \ll 1$, THE AMPLIFICATION FACTOR IS

GIVEN BY,

$$\frac{Kx_{max}}{F_0} = \frac{F_{max}}{F_0} = \frac{1}{2\zeta}$$

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE 6
98-114-HWM1	H W McCURDY	M Francis	

FROM REFERENCE 2, A TYPICAL DAMPING VALUE FOR A BOLTED STEEL STRUCTURE (LIKE THE BIG ROCK POINT BAFFLE PLATE/CORE PLATE STRUCTURE) IS 4 PERCENT. THE AMPLIFICATION FACTOR IS,

$$\frac{F_{max}}{F_0} = \frac{1}{2 \cdot .04} = 12.5$$ (NOTE THAT THE 4 PERCENT COEFFICIENT IS CONSERVATIVELY LOW AND THEREFORE THE AMPLIFICATION FACTOR IS HIGH.)

FOR THE BIG ROCK POINT INLET NOZZLE/BAFFLE PLATE ARRANGEMENT, THE APPROPRIATE FORCE IS THE MOMENTUM FORCE EXERTED BY THE FLOW ENTERING THE NOZZLE. THE FORCE ON THE BAFFLE IS,

$$F(t) = f \cdot \frac{V\dot{M}}{g_c} \cos \omega_n t = F_0 \cos \omega_n t$$

WHERE,

f = FRACTION OF TOTAL MOMENTUM FORCE WHICH CAUSES LOADING OF BAFFLE

V = FLUID VELOCITY EXITING THE NOZZLE, FT/SEC

$\dot{M}$ = MASS FLOW RATE ENTERING NOZZLE, LB/SEC

MPR ASSOCIATES, INC.
1050 Connecticut Ave., NW-Washington, DC 20036

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE 7
98-114-HWM1	HW McCURDY	M Franco	

THE AMPLIFIED FORCE IS,

$$F_{MAX} = 12.5 \cdot \frac{f v \dot{M}}{g_c}$$

AS AN EXAMPLE, IF $f = \frac{1}{12.5}$,

$$F_{MAX} = \frac{v \dot{M}}{g_c}$$

MPR ASSOCIATES, INC.
1050 Connecticut Ave., NW-Washington, DC 20036

CALCULATION NO.	PREPARED BY	CHECKED BY	PAGE 8
98-114-HWM1	HWMcCURDY	M Francis	

REFERENCES:

(1). CONTROL OF NUCLEAR REACTORS AND POWER PLANTS, M.A. SCHULTZ, McGRAW-HILL BOOK COMPANY, SECOND EDITION, 1961, SEE TABLE 3-3.

(2) USNRC REGULATORY GUIDE 1.61, "DAMPING VALUES FOR SEISMIC DESIGN OF NUCLEAR POWER PLANTS", OCTOBER 1973.