1. Wind Load Calcualtions (per SNiP 2.01.07-89, Chap. 6)

$l := 52.8$: Length (or Height) of Equipment

$b := 7.6$ $d := b$: Width of Equipment

1.1 Load Calculations of Average Component

$v_0 := 29.4$: Basic Wind Velocity at EL. 10 m (m/sec)
(region type A, 10 minute averaging time and 5 year recurrence intervals)

$$w_0 := \frac{0.61 \cdot v_0^{2}}{1000} = 0.527$$: Wind Pressure in Wind Region III (kPa)

: Coefficients k for Locality Types (Table 6)

Altitude z, m	Factor k for various types of terrain		
	A	B	C
≤ 5	0,75	0,5	0,4
10	1,0	0,65	0,4
20	1,25	0,85	0,55
40	1,5	1,1	0,8
60	1,7	1,3	1,0
80	1,85	1,45	1,15
100	2,0	1,6	1,25
150	2,25	1,9	1,55
200	2,45	2,1	1,8
250	2,65	2,3	2,0
300	2,75	2,5	2,2
350	2,75	2,75	2,35
≥ 480	2,75	2,75	2,75

$z := [5 \;\; 10 \;\; 20 \;\; 40 \;\; 52.8]$: Height (m)

$k_z := [0.75 \;\; 1.0 \;\; 1.25 \;\; 1.5 \;\; 1.6]$

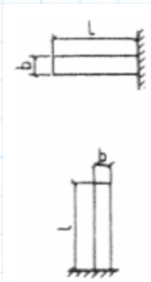
$z := z^{T}$

$k_z := k_z^{T}$

$$\lambda := \frac{l}{b} = 6.947$$

$\lambda_e := 2\ \lambda = 13.895$

$$k := \frac{0.75 - 0.65}{20 - 10} \cdot 5 + 0.65 = 0.7$$

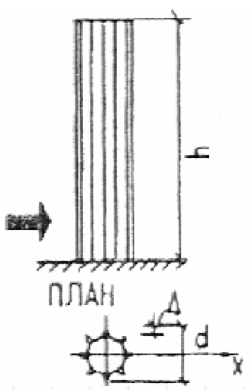


λ_e	5	10	20
k	0,6	0,65	0,75

: Refer to App. 4 - Pattern 13

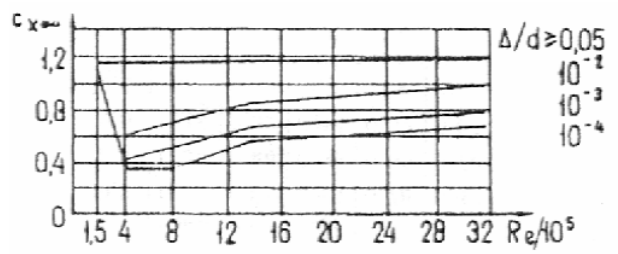
$\gamma := 1.4$: Reliability Coefficient for Wind Load

$$R_e := \overrightarrow{0.88 \cdot d \cdot \sqrt{w_0 \cdot k_z \cdot \gamma} \cdot 10^{5}} = \begin{bmatrix} 4.976 \cdot 10^{5} \\ 5.746 \cdot 10^{5} \\ 6.424 \cdot 10^{5} \\ 7.037 \cdot 10^{5} \\ 7.268 \cdot 10^{5} \end{bmatrix}$$: Reynolds Number



$$c_x = k c_{x\infty},$$

where k is determined by Table 1 of pattern 13;
$c_{x\infty}$ is determined by the chart:



$\Delta := 0.001$ $d = 7.6$: Refer to App. 4 - Pattern 14. $\dfrac{\Delta}{d} = 1.316 \cdot 10^{-4}$

$c_{x\_inf} := [0.38 \ \ 0.38 \ \ 0.38 \ \ 0.38 \ \ 0.38]$

$c_x := \overrightarrow{k \cdot c_{x\_inf}} = [0.266 \ \ 0.266 \ \ 0.266 \ \ 0.266 \ \ 0.266]$: Head Resistance $c_x := c_x^{\mathrm{T}}$

$$w_m := \overrightarrow{w_0 \cdot k_z \cdot c_x} = \begin{bmatrix} 0.105 \\ 0.14 \\ 0.175 \\ 0.21 \\ 0.224 \end{bmatrix}$$

: Average Component of Wind Load

1.2 Load Calculations of Pulsing Component

: Coefficient ζ of Wind Pressure Pulsation at Level z

Altitude z, m	Wind pressure pulsation factor ζ for various types of terrain		
	A	B	C
≤ 5	0,85	1,22	1,78
10	0,76	1,06	1,78
20	0,69	0,92	1,50
40	0,62	0,80	1,26
60	0,58	0,74	1,14
80	0,56	0,70	1,06
100	0,54	0,67	1,00
150	0,51	0,62	0,90
200	0,49	0,58	0,84
250	0,47	0,56	0,80
300	0,46	0,54	0,76
350	0,46	0,52	0,73
≥ 480	0,46	0,50	0,68

$\zeta := [0.85 \;\; 0.76 \;\; 0.69 \;\; 0.62 \;\; 0.60]$

$\zeta := \zeta^{T}$

: Coefficient ν of Wind Pressure Pulsation at Level z

ρ, m	Factor ν at χ, m, equal to						
	5	10	20	40	80	160	350
0,1	0,95	0,92	0,88	0,83	0,76	0,67	0,56
5	0,89	0,87	0,84	0,80	0,73	0,65	0,54
10	0,85	0,84	0,81	0,77	0,71	0,64	0,53
20	0,80	0,78	0,76	0,73	0,68	0,61	0,51
40	0,72	0,72	0,70	0,67	0,63	0,57	0,48
80	0,63	0,63	0,61	0,59	0,56	0,51	0,44
160	0,53	0,53	0,52	0,50	0,47	0,44	0,38

: Refer to Table 9.

$\rho := 0.4 \cdot d = 3.04$

$\nu_1 := 0.95 + (3.04 - 0.1) \cdot \dfrac{0.89 - 0.95}{5 - 0.1} = 0.914$

$\nu_2 := 0.92 + (3.04 - 0.1) \cdot \dfrac{0.87 - 0.92}{5 - 0.1} = 0.89$

$\nu_3 := 0.88 + (3.04 - 0.1) \cdot \dfrac{0.84 - 0.88}{5 - 0.1} = 0.856$

$\nu_4 := 0.83 + (3.04 - 0.1) \cdot \dfrac{0.80 - 0.83}{5 - 0.1} = 0.812$

: at Level 52.83 m

$\rho_{0.1} := 0.83 + (52.83 - 40) \cdot \dfrac{0.76 - 0.83}{80 - 40} = 0.808$

$\rho_5 := 0.80 + (52.83 - 40) \cdot \dfrac{0.73 - 0.80}{80 - 40} = 0.778$

$\nu_5 := 0.83 + (3.04 - 0.1) \cdot \dfrac{0.778 - 0.808}{5 - 0.1} = 0.812$

$$w_p := \overrightarrow{w_m \cdot \zeta \cdot \nu} = \begin{bmatrix} 0.082 \\ 0.095 \\ 0.104 \\ 0.106 \\ 0.109 \end{bmatrix}$$

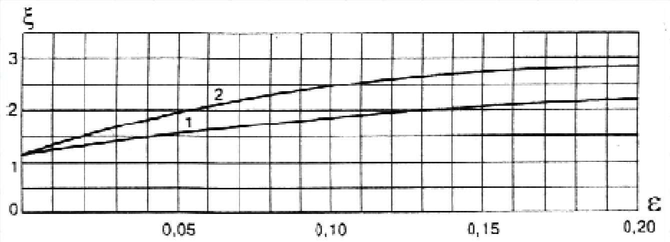
: Pulsing Component of Wind Load

$f_1 := 1.119$: Frequency of 1st Mode (Hz, See Appendix 1 - Case 2)

$f_l := 3.8$: Ultimate value of Natural Frequency

The pulsing component of wind load should be corrected due to the conditon, $f_1 < f_l$. To simplify the procedure the fomula for the most conservative case is selected in this calculation note.

$w_{ph} := w_{p_5} = 0.109$: Pulsing Component of Wind Load at Top Level



Drawing 2. Dynamic amplification factors

$\gamma = 1.4$: Reliability Coefficient for Wind Load

$w_0 = 0.527$: Wind Pressure in Wind Region III (kPa)

$\varepsilon := \dfrac{\sqrt{\gamma \cdot w_0}}{940 \cdot f_1} = 8.168 \cdot 10^{-4}$: Parameter for Dynamic Coefficient (Refer to Sectoin 6.7)

$\xi := 1.0$: Dynamic Coefficient Determined by ε in Figure 2

$h := l = 52.8$: Length (or Height) of Equipment

$w_p := \overrightarrow{1.4 \cdot \left(\dfrac{z}{h}\right) \cdot \xi \cdot w_{ph}} = \begin{bmatrix} 0.014 \\ 0.029 \\ 0.058 \\ 0.116 \\ 0.153 \end{bmatrix}$: Pulsing Component of Wind Load Corrected

1.3 Base Shear and Moment

$$w := w_m + w_p = \begin{bmatrix} 0.12 \\ 0.169 \\ 0.233 \\ 0.326 \\ 0.377 \end{bmatrix}$$: Wind Load, Sum of Average and Pulsing Components

$A_1 := d \cdot z_1 = 38$ $\quad A_2 := d \cdot (z_2 - z_1) = 38$ $\quad A_3 := d \cdot (z_3 - z_2) = 76$: Applied Area at Each Height

$A_4 := d \cdot (z_4 - z_3) = 152$ $\quad A_5 := d \cdot (z_5 - z_4) = 97.28$

$$F := \overrightarrow{w \cdot A} = \begin{bmatrix} 4.548 \\ 6.431 \\ 17.73 \\ 49.602 \\ 36.719 \end{bmatrix}$$

$$\Sigma F := \left(w_1 \cdot A_1 + w_2 \cdot A_2 + w_3 \cdot A_3 + w_4 \cdot A_4 + w_5 \cdot A_5\right) = 115.031 \text{ kN}$$

$$\Sigma M := \left(F_1 \cdot \frac{z_1}{2} + F_2 \cdot \left(z_1 + \frac{z_2 - z_1}{2}\right) + F_3 \cdot \left(z_2 + \frac{z_3 - z_2}{2}\right) + F_4 \cdot \left(z_3 + \frac{z_4 - z_3}{2}\right) + F_5 \cdot \left(z_4 + \frac{z_5 - z_4}{2}\right)\right) = 3.517 \cdot 10^3 \text{ kN·m}$$

$\Sigma F_{SNiP} := \Sigma F = 115.031$ $\quad \Sigma M_{SNiP} := \Sigma M = 3.517 \cdot 10^3$

$\Sigma F_{ASCE} := 191.61$ $\quad \Sigma M_{ASCE} := 5508.48$: Base Shear and Moemnt per ASCE 7-05
Applied V=29.4 m/s (10 min. average)

$Ratio_{\Sigma F} := \dfrac{\Sigma F_{SNiP}}{\Sigma F_{ASCE}} = 0.6$ $\quad Ratio_{\Sigma F} := \dfrac{\Sigma M_{SNiP}}{\Sigma M_{ASCE}} = 0.639$: Ratio of SNiP to ASEC

$Item^{\langle 1 \rangle} :=$ "height" $\quad Item^{\langle 2 \rangle} :=$ "wind pressure"

$File :=$ WRITEEXCEL ("Wind_Pressure_SNiP.xlsx", $Item$, "Sheet1!A1")

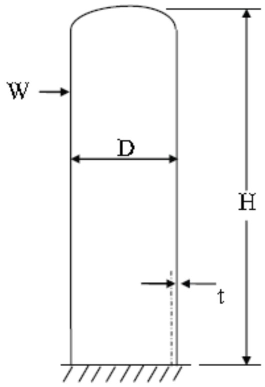
$wind\_p^{\langle 1 \rangle} := z$ $\quad wind\_p^{\langle 2 \rangle} := w$

$File :=$ WRITEEXCEL ("Wind_Pressure_SNiP.xlsx", $wind\_p$, "Sheet1!A2")

$$\frac{w}{w_0} = \begin{bmatrix} 0.227 \\ 0.321 \\ 0.442 \\ 0.619 \\ 0.716 \end{bmatrix}$$: Wind Pressure Coefficient at Each Height

Appendix 1. Natural Frequency Calcualtions (1st Mode Only)

E. Natural Period of Vibration - Uniform Vertical Cylindrical Steel Vessel



$$T = \frac{7.78}{10^6}\left(\frac{H}{D}\right)^2 \sqrt{\frac{12WD}{t}}$$

where: T – Period (sec)
W – Weight (lb/ft)
H – Height (ft)
D – Diameter (ft)
t – Shell Thickness (inch)

$H := l \cdot m = 52.8\ m$: Length of Equipment $D := d \cdot m = 7.6\ m$: Width of Equipment

$t := 25 \cdot mm$: Thickness of Equipment

$W_{erection} := 428 \cdot 10^3 \cdot kgf$: Weight of Equipment Only

$W_{operation} := 1463 \cdot 10^3 \cdot kgf$: Weight of Equipment plus Water

$H = 173.228\ ft$ $H := H \cdot ft^{-1} = 173.228$

$D = 24.934\ ft$ $D := D \cdot ft^{-1} = 24.934$

$t = 0.984\ in$ $t := t \cdot in^{-1} = 0.984$

※ Ultimate value of Natural Frequency (f_l)

of Mandatory Appendix 5)		
	δ = 0,3	δ = 0,15
Ia	0,85	2,6
I	0,95	2,9
II	1,1	3,4
III	1,2	3,8
IV	1,4	4,3
V	1,6	5,0
VI	1,7	5,6
VII	1,9	5,9

Case 1. Erection Condition

$W_{erection} = \left(9.436 \cdot 10^5\right)\ lbf$ $W := \frac{W_{erection} \cdot lbf^{-1}}{H} = 5.447 \cdot 10^3$

$T := \frac{7.78}{10^6} \cdot \left(\frac{H}{D}\right)^2 \cdot \sqrt{\frac{12 \cdot W \cdot D}{t}} = 0.483$: Natural Period (sec)

$f := \frac{1}{T} = 2.069$: Natural Frequency (Hz)

Case 2. Operation Condition

$W_{operation} = (3.225 \cdot 10^{6})\ lbf$

$W := \dfrac{W_{operation} \cdot lbf^{-1}}{H} = 1.862 \cdot 10^{4}$

$T := \dfrac{7.78}{10^{6}} \cdot \left(\dfrac{H}{D}\right)^{2} \cdot \sqrt{\dfrac{12 \cdot W \cdot D}{t}} = 0.893$: Natural Period (sec)

$f := \dfrac{1}{T} = 1.119$: Natural Frequency (Hz)