PTC INQ. #04-09

TECHNICAL INQUIRY
PTC 19.3

SUBJECT: **Units for the constant K_f in Table 1.4, for the stress constants in Table 1.5, and for *V*, the fluid velocity, in Equation 2**

Question 1: Is the constant K_f, per Table 1.4, dimensionless or in units of inches?

Answer 1: Refer to the answer to Question 2 below, where the units of K_f are derived explicitly.

Question 2: Is 1461 cps the correct answer for f_n in the example problem, Chapter 1, section 18, or should it be 28699

Answer 2: The dimensions of K_f depend on the dimensions of the specific weight γ in Eq. 1 of Section 15. Following the original paper in which Eq. 1 was derived (J. W. Murdock, "Power Test Code Thermometer Wells", *Trans. ASME: J. Engin. Power*, October, 1959, p. 403), the quantity γ is the specific *weight* of the thermowell material, and not the specific *mass* ρ, which has dimensions of mass per unit volume. The relationship between γ and ρ is $\gamma = \rho g_c$, where g_c is the proportionality constant in Newton's second law, approximately equal to the local acceleration of gravity. Thus the units of γ are in pounds-force per cubic inch, when working in English units.

With the units of γ clarified, we can do a dimensional analysis of Eq. 1, rearranged to solve for K_f. It is useful to use a particular system of units so that any hidden unit conversions (a factor of 12 between feet and inches, for example) will appear.

$$K_f = L^2 f_n (\gamma / E)^{1/2}$$

$$[K_f] = \left(\frac{\text{in.}^2}{\text{sec.}}\right)\left(\frac{\text{lbf/in.}^3}{\text{lbf/in.}^2}\right)^{1/2} = \text{in.}\left(\frac{\text{in.}}{\text{sec.}^2}\right)^{1/2}$$

From this result, we see that K_f has the dimensions of length times the square root of acceleration.

We can evaluate Example 1a of Section 18 with the units now explicitly included:

$$f_{n(70\,^\circ\mathrm{F})} = \frac{\left(3.01\,\text{in.}^{3/2}/\text{sec.}\right)}{\left(4.5\,\text{in.}\right)^2}\left(\frac{28\times10^6\ \text{lbf/in.}^2}{0.290\,\text{lbf/in.}^3}\right)^{1/2}$$

$$= \frac{\left(3.01\right)}{\left(4.5\right)^2}\left(\frac{28\times10^6}{0.290}\right)^{1/2}\ \text{sec.}^{-1}$$

$$= 1461\,\text{cps}$$

If we had interpreted γ as the specific mass, an analysis similar to the above shows that K_f would have dimensions of inches, but with a units conversion factor:

$$\left[K_f\right] = \text{in.}\left(\frac{\text{in.}}{\text{sec.}^2}\frac{1}{g_c}\right)^{1/2} = \left(32.17\cdot12\right)^{-1/2}\ \text{in.}$$

Throughout PTC 19.3, including Table 1.4, any conversion factors for non-SI or other incompatible units, such as the mixed inch and feet units in Eq. 1, or the proportionality constant, g_c, in Newton's second law, are built into the tabulated values of K_f. No additional units conversions are required. Therefore, E, γ, and L should be entered directly into the equation in the units specified in the text below Eq. 1, the value of K_f should be entered as indicated in Table 1.4, and the resulting value of f_n will be in units of cycles per second.

The PTC 19.3 subcommittee members are aware of the ambiguity of the units in PTC 19.3, and these problems will be corrected when PTC 19.3 is next revised.

Question 3: Are the units for ***V***, the fluid velocity [in Eq. 2], fps or should they be in inches/sec?

Answer 3: Eq. 2 of Section 15 was written such that the equation will give the correct answer if values of V and B are entered in units as specified below Eq. 2. As a result, the constant 2.64 in Eq. 2 carries hidden units of inches per feet. A version of Eq. 2 that conforms to modern engineering practice is:

$$f_w = \left(2.64\ \text{in/ft}\right)\frac{V}{B} = 0.220\frac{V}{B} \quad .$$

As in Question 2, if V and B are entered directly into the equation in the units specified in the text below Eq. 2, the resulting f_w will be in units of cycles per second.

Question 4: Are the values of the stress constants in Table 1.5 dimensionless or should they be in inch units?

Answer 4: The stress constants K_1 and K_3 relate operating pressures to material stress. The units of pressure and material stress for the PTC 19.3 calculations are both in psi, so consequently K_1 and K_3 are dimensionless. For K_2, we can perform an analysis of the units similar to that done for Question 2 above. Rearranging Eq. 5 in Section 17 to solve for K_2, we find the dimensions and unit conversion factor of K_2 by inserting the units for the other parameters specified in the text below Eq. 5:

$$[K_2] = [VL]\left[\left(\frac{(1+F_M)}{v(S-K_3P_0)}\right)^{1/2}\right]$$

$$= \left(\frac{\text{ft. in.}}{\text{sec.}}\right)\left(\frac{\text{lbm}}{\text{ft.}^3}\frac{\text{in.}^2}{\text{lbf}}\right)^{1/2}$$

$$= \left(\frac{\text{in.}^2}{\text{sec.}}\right)\left(\frac{\text{lbm}}{\text{ft.}}\frac{1}{g_c\ \text{lbm}}\right)^{1/2}$$

$$= \left(\frac{\text{in.}^2}{\text{sec.}}\right)\left(\frac{\text{sec.}^2}{32.17\ \text{ft.}^2}\right)^{1/2}$$

$$= (32.17)^{-1/2}\ \frac{\text{in.}^2}{\text{ft.}}$$

$$= \frac{1}{12(32.17)^{1/2}}\ \text{in.}$$

As in Question 2, it is easiest to enter the parameters directly into Eq. 5 in the units specified in the text below Eq. 5, and the resulting L_{max} will be in units of inches.