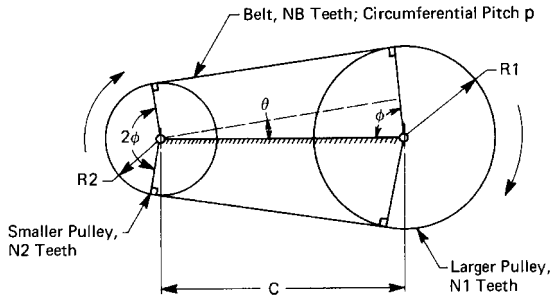


**SECTION 22 CENTER DISTANCE FORMULAS**

**22.1 Nomenclature And Basic Equations**

**Figure 40** illustrates the notation involved. The following nomenclature is used:

- C = Center Distance (in)
- L = Belt Length (in) = p·NB
- p = Pitch of Belt (in)
- NB = Number of Teeth on belt = L/p
- N1 = Number of Teeth (grooves) on larger pulley
- N2 = Number of Teeth (grooves) on smaller pulley
- $\phi$  = One half angle of wrap on smaller pulley (radians)
- $\theta$  =  $\pi/2 - \phi$  = angle between straight portion of belt and line of centers (radians)
- R1 = Pitch Radius of larger pulley (in) = (N1) p/2 $\pi$
- R2 = Pitch Radius of smaller pulley (in) = (N2) p/2 $\pi$
- $\pi$  = 3.14159 (ratio of circumference to diameter of circle)



**Figure 40 Belt Geometry**

The basic equation for the determination of center distance is:

$$2C \sin \phi = L - \pi (R1 + R2) - (\pi - 2\phi) (R1 - R2) \tag{22-1}$$

where  $C \cos \phi = R1 - R2$  (22-2)

These equations can be combined in different ways to yield various equations for the determination of center distance. We have found the formulations, which follow, useful.

**22.2 Exact Center Distance Determination – Unequal Pulleys**

The exact equation is as follows:

$$C = (1/2)p [(NB - N1) + k(N1 - N2)] \tag{22-3}$$

where  $k = \left(\frac{1}{\pi}\right) \left[\tan\left(\frac{\pi}{4} - \frac{\phi}{2}\right) + \phi\right]$  (22-4)

and  $\phi$  is determined from:

$$\left(\frac{1}{\pi}\right) (\tan \phi - \phi) = \frac{(NB - N1)}{(N1 - N2)} = Q \text{ (say)} \tag{22-5}$$

The value,  $C/p$ , is called the center distance factor and is tabulated for various combinations of  $(NB - N1)$  and  $(N1 - N2)$  in Table 42 in the next section.

The value of  $k$  varies within the range  $(1/\pi, 1/2)$  depending on the number of teeth on the belt. All angles in **Equations (22-4)** through **(22-5)** are in radians.

The procedure for center distance determination is as follows:

1. Select values of  $N1, N2$  (in accordance with desired transmission ratio) and  $NB$ .
2. Compute  $Q = (NB - N1)/(N1 - N2)$ .
3. Compute  $\phi$  by solving **Equation (22-5)** numerically.
4. Compute  $k$  from **Equation (22-4)**.
5. Compute  $C$  from **Equation (22-3)**.

### 22.3 Exact Center Distance Determination – Equal Pulleys

For equal pulleys,  $N1 = N2$  and **Equation (22-3)** becomes:

$$C = \frac{p(NB - N1)}{2} \tag{22-6}$$

### 22.4 Approximate Center Distance Determination

Approximate formulas are used when it is desirable to minimize computation time and when an approximate determination of center distance suffices.

An alternative to **Equation (22-1)** for the exact center distance can be shown to be the following:

$$C = \frac{p}{4} \left\{ NB - \frac{(N1 + N2)}{2} + \sqrt{\left[ NB - \frac{(N1 + N2)}{2} \right]^2 - \frac{2(N1 - N2)^2}{\pi^2} (1 + S)} \right\} \tag{22-7}$$

where  $S$  varies between 0 and 0.1416, depending on the angle of wrap of the smaller pulley. The value of  $S$  is given very nearly by the expression:

$$S = \frac{(\cos^2 \phi)}{12} \tag{22-8}$$

In the approximate formulas for center distance, it is customary to neglect  $S$  and thus to obtain following approximation for  $C$ :

$$C = \frac{p}{4} \left\{ NB - \frac{(N1 + N2)}{2} + \sqrt{\left[ NB - \frac{(N1 + N2)}{2} \right]^2 - \frac{2(N1 - N2)^2}{\pi^2}} \right\} \tag{22-9}$$

The error in **Equation (22-9)** depends on the speed ratio and the center distance. The accuracy is greatest for speed ratios close to unity and for large center distances. The accuracy is least at minimum center distance and high transmission ratios. In many cases, the accuracy of the approximate formula is acceptable.

Alternatively, center distance can be obtained to sufficient accuracy using the center distance factor table (See Section 23).

### 22.5 Number Of Teeth In Mesh (TIM)

It is generally recommended that the number of teeth in mesh be not less than 6. The number, TIM, teeth in mesh is given by:

$$TIM = \lambda \cdot N2 \tag{22-10}$$

where  $\lambda = \frac{\phi}{\pi}$  when  $\phi$  (see **Equation (22-5)**) is given in radians (see also the derivation given for TIM in this Handbook).

## 22.6 Determination Of Belt Size For Given Pulleys And Center Distance

Occasionally, the center distance of a given installation is prescribed and the belt length is to be determined. For given pitch, number of teeth on pulleys and center distance, the number of teeth of the belt can be found from the equation:

$$NB = \frac{(N1 + N2)}{2} + \frac{(N1 - N2)}{\pi} \sin^{-1} \left[ \frac{(N1 - N2)p}{2 \pi C} \right] + \sqrt{\left(\frac{2C}{p}\right)^2 - \left(\frac{N1 - N2}{\pi}\right)^2} \tag{22-11}$$

where the arcsin is given in radians and lies between 0 and  $\pi/2$ . Since NB, in general, will not be a whole number, the nearest whole number less than NB can be used, assuming a slight increase in belt tension is not objectionable.

An approximate formula can be used to obtain the belt length:

$$L = 2C + \frac{(D1 - D2)^2}{4C} + 1.57 \times (D1 + D2) \tag{22-12}$$

## SECTION 23 CENTER DISTANCE FACTOR TABLES (TABLE 42)

TABLE 42

<b>Definition:</b> The center distance factor is the center distance between two pulleys expressed in a dimensionless unit, which corresponds to the pitch of the pulley and the belt used.
<b>How To Use:</b> Multiply the center distance factor by the pitch of the belt expressed in inch or metric unit. The number obtained will be the center distance expressed in the same (inch or metric) unit.
<b>Nomenclature Used:</b> N1 = Number of teeth of larger pulley N2 = Number of teeth of smaller pulley NB = Number of teeth of belt used
<b>Example:</b> From the Transmission Ratio Table, for N1/N2 = 1.750, N1 = 28 and N2 = 16 are chosen. From the same table we also note that N1 - N2 = 12 and C MIN = 7.003. Assume that NB = 80. Then, NB - N1 = 52. Refer to the Center Distance Factor Table for N1 - N2 = 12 and NB - N1 = 52 and obtain the center distance factor of 28.937 which is larger than the required minimum (C MIN = 7.003). Assuming the pitch of the belt to be 5 mm, the actual center distance in mm is 28.937 x 5 = 144.685 mm. If 3 mm pitch belt is used, the center distance factor 28.937 has to be multiplied by 3, and a center distance of 86.811 mm is obtained.
<b>Note:</b> The following 64 pages represent the exact solutions of <b>Equation (22-3)</b> divided by the pitch, p, for various values of (N1 - N2) and (NB - N1).

Continued on the next page