

Step 1: Understand the Fundamental Governing Equation

Petroff's equation establishes that the frictional torque (T_f) generated in a concentric journal bearing is a function of fluid viscosity (μ), shaft radius (r), bearing length (L), rotational speed in revolutions per second (n), and the radial clearance (c_r):

$$T_f = \frac{4\pi^2 \mu r^3 L n}{c_r}$$

Alternatively, expressing this in terms of shaft diameter ($D = 2r$) and diametral clearance ($C_d = 2c_r$), the equation expands to:

$$T_f = \frac{\pi^2 \mu D^3 L n}{C_d}$$

Step 2: Convert Input Parameters to a Consistent System of Units (Imperial)

To solve the equation using $\mu = 2.5 \times 10^{-6} \text{ lb} \cdot \text{s}/\text{in}^2$, all geometric measurements must be converted from millimeters to inches (1 inch = 25.4 mm), and rotational speed must be converted from rpm to rps ($n = N/60$):

- **Journal Diameter (D):** 65 mm/25.4 $\approx$ 2.55906 in
- **Bearing Length (L):** 100 mm/25.4 $\approx$ 3.93701 in
- **Diametral Clearance (C_d):** 0.135 mm/25.4 $\approx$ 0.005315 in
- **Rotational Speed (n):** 1750 rpm/60 $\approx$ 29.1667 rps

Step 3: Compute the Frictional Torque (T_f)

Substitute the converted imperial values directly into the diameter-based variation of Petroff's equation:

$$T_f = \frac{\pi^2 \left(2.5 \times 10^{-6} \frac{\text{lb} \cdot \text{s}}{\text{in}^2} \right) (2.55906)^3 (3.93701 \text{ in}) (29.1667 \text{ rps})}{0.005315 \text{ in}} = 8.9336 \text{ in} \cdot \text{lb}$$

Step 4: Calculate Friction Power Loss (P) and Convert to Watts

Rotational power in traditional imperial engineering units (Foot-pounds per minute) is expressed as $P = 2\pi TN$. Because our torque is in inch-pounds, we divide by 12 in/ft to yield ft · lb, and then divide by 33,000 to determine the Horsepower (hp):

$$P_{HP} = \frac{2\pi TN}{33,000} = \frac{2\pi \left(\frac{8.9336}{12} \text{ ft} \cdot \text{lb} \right) (1750 \text{ rpm})}{33,000} = 0.24806 \text{ hp}$$

Finally, we transform this value into the SI unit of power (Watts) utilizing the conversion factor 1 hp=746 W:

$$P = 185.05 \text{ W}$$

Petroff's equation shows that power loss is inversely proportional to the diametral clearance (C_d). If a designer reduces the clearance to make the assembly tighter and increase mechanical precision, the fluid shear rate surges, causing the power loss and operating temperatures to climb rapidly. Viscous power loss scales exponentially with the square of the rotational speed (n_2). For high-speed rotating machinery like turbos or electric drivetrains, selecting a low-viscosity lubricant is critical to minimizing parasitic drag and keeping overall system efficiency high.