# Pump ED 101

## Calculating Radial Thrust

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The radial forces that form about the periphery of the impeller of a single volute pump are proportional to total pump head, impeller diameter and the width of the vanes. They are seldom balanced but, they reach their lowest intensity between 80 and 100 percent of BEP flow. The actual low point depends upon Pump Specific Speed (Ns) and moves closer to BEP as Ns increases. This unbalanced radial thrust increases quickly as operation moves to the left of BEP and typically reaches its maximum value at shut off head. Radial Thrust intensity is also a function of Ns and increases with an increase in Specific Speed.

Increased shaft deflection is the expected result of an increase in unbalanced radial thrust. Excessive shaft deflection can lead to premature seal, bearing, and wear ring damage and failure. In extreme cases it can result in shaft breakage. One of my ongoing concerns is that the H/Q curves published by many pump manufacturers allow operation in very questionable areas - - some well below 50% of BEP flow. This may not be a problem with low Specific Speed pumps that operate at lower flows and heads but, unfortunately, these broad operating ranges are often applied across the board. Increased radial thrust and the accompanying increase in shaft deflection can be especially problematic with higher head wastewater pumps due to the large vane width required to pass solid matter.

The equation below can be used to calculate radial thrust at any point on a pump H/Q curve.

$$F_R = K_R \times (H \times s/2.31) \times D_2 \times b_2$$

where:

$F_R$ is radial thrust in psi
$K_R$ is the radial thrust factor
$H$ is the head if feet at the flow point
$s$ is specific gravity
$D_2$ is the impeller diameter in inches
$b_2$ is the impeller width at the vane discharge including the shroud(s) in inches

Head and impeller diameter can be found on the performance curve while impeller width must be measured or obtained from the manufacturer. The radial thrust factor can be determined from a graph provided by the Hydraulic Institute (HI). If Pump Specific Speed (Ns) is not known it can be easily calculated from data that is available on the performance curve.

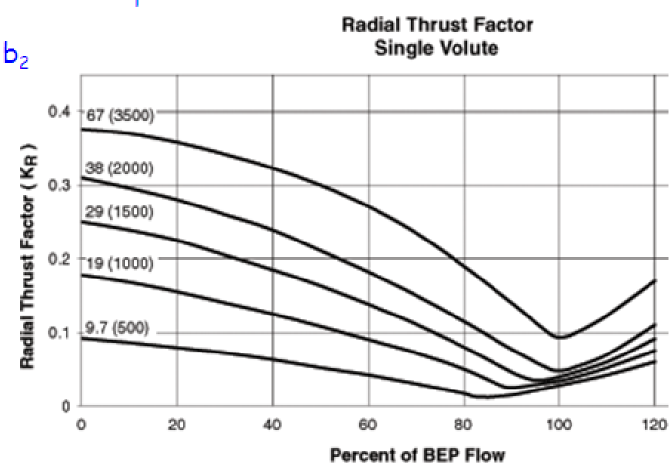
In order to promote greater use of the radial thrust equation, I developed a simple Radial Thrust Calculator in Excel format. It provides a simple way to calculate radial thrust at any point of the performance curve and identifies pumps that may be susceptible to high radial loading due to off BEP operation. A screen shot of the calculator is shown in Figure 1. It is available for download on my web site.

**Radial Thrust Calculator** - Joe Evans www.PumpEd101.com

Radial Thrust: $F_R = K_R \times (H \times s/2.31) \times D_2 \times b_2$

Enter the required data in the highlighted cells. If you do not know the pump specific speed use the Ns calculator below.

| | |
|---|---|
| Thrust Factor ($K_R$) @ flow point (from graph) | 0.21 |
| Head (H) per Stage @ flow point in feet | 138 |
| Specific Gravity (S) | 1 |
| Impeller Diameter (D2) in inches | 11.88 |
| Impeller Width (b2) @ discharge in inches | 3.5 |
| $F_R$ (Unbalanced Radial Thrust in PSI) = | 522 |




Pump Specific Speed: $Ns = N \sqrt{Q} / H^{0.75}$

Enter the required data in the highlighted cells

| | |
|---|---|
| Pump RPM (N) | 1750 |
| Flow (Q) @ BEP | 1200 |
| Head (H) @ BEP | 110 |
| Ns = | 1785 |

**Thrust Factor Instructions**

The numbers in ( ) are Pump Specific Speed (Ns). The curves represent the radial thrust factor from 0 to 120% of BEP flow for that particular specific speed. Select a point on the X axis that corresponds to the point to be evaluated on the pump H/Q curve. The thrust factor is the value on the Y axis where the curve intersects the selected X axis value. For values of Ns that fall between the ones shown you may interpolate the intersection. Impeller width (b2) is the width in inches at the discharge including the shroud(s). The example shown is for a sewage pump with a specific speed of 1785, operating at 40% of BEP flow. At 100% of BEP Flow, Radial Thrust is reduced to 59 PSI.

All of the information required by the calculator is available on the manufacturer's performance curve with the possible exception of impeller vane width. Pump Specific Speed (Ns) is needed to find the radial thrust factor from the HI graph. If it is not shown on the performance curve, it can be calculated by Ns calculator shown in the bottom left of the screen shot. Instructions for determining thrust factor are below the graph.

The sample data, shown in Figure 1, are for a sewage pump that has a manufacturer approved operating range of 25% to 137% of BEP flow. At a flow of 480 gpm (40% of BEP flow) the calculator shows an unbalanced radial thrust of 522 psi. If we recalculate thrust using the BEP flow data shown in the Ns calculator, the results would show an unbalanced radial thrust of just 59 psi at BEP flow. Is this shaft designed to accommodate an increase in radial thrust that is almost 8 times larger than that which occurs at BEP? I think that this is a reasonable question to ask the manufacturer.

*Joe Evans is responsible for customer and employee education at PumpTech Inc, a pumps & packaged systems manufacturer & distributor with branches throughout the Pacific Northwest. He can be reached via his website www.pumped101.com. If there are topics that you would like to see discussed in future columns, drop him an email.*