

Pumps are operated in series or as a multistage units when a Total Dynamic Head (TDH)<sup>1</sup> higher than what can be practically provided by a single pump is desirable. This month's issue presents the facts and considerations for staged pump operation<sup>2</sup>.

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- Principles of staged pump operation:
- The TDH developed by all staged elements is the sum of the TDH developed by each stage minus losses that occur between the staged units.
- The flow rate developed is dictated by the intersection of the system head curve with the system performance curve for the pump stages.
- For similar stages, the first stage is generally determinative of the Net Positive Suction Head Required (NPSHR).
- Total staged efficiency is determined by the sum of power consumed by each stage adjusted for interstage losses.



1. The TDH developed by the staged pumps or impellers is the sum of the TDH developed by each stage minus losses that occur between the staged units.

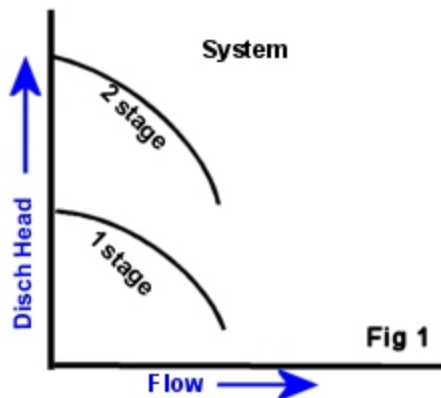


Figure 1 depicts the performance of two pumps in series. Ignoring any losses, the total head at any given flow rate is the sum of the head developed by each stage. Impellers may be of different diameters and, in the case of pumps in series, may even operate at different speeds. In fact, it is not uncommon for manufacturers to trim the 1<sup>st</sup> impeller on a multistage pump in order to achieve the required TDH and leave subsequent stage impellers at full diameter.

When similar pumps are placed in series, it is a common practice for all of the pumps to be rated for the highest pressure location. This

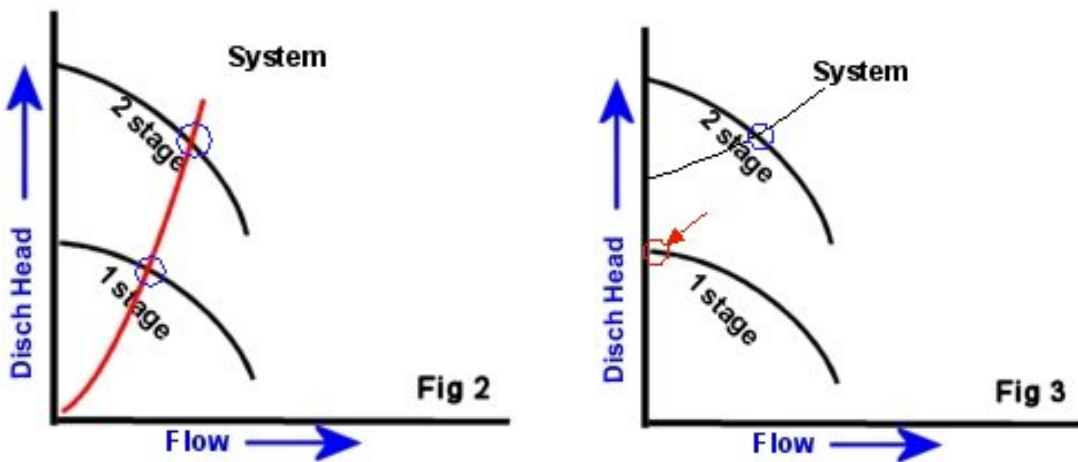
<sup>1</sup> For an explanation of Total Dynamic Head see [http://www.lawrencepumps.com/Newsletter/news\\_v02\\_i10\\_Oct05.html](http://www.lawrencepumps.com/Newsletter/news_v02_i10_Oct05.html)

<sup>2</sup> For the purposes of this newsletter staged can be either pumps arranged in series or multiple impellers on a common shaft.

allows for commonality of parts and prevents incorrect parts from being installed in the wrong location.

**2. The flow rate developed is dictated by the intersection of the system head curve with the system performance curve.**

Figure 2 adds a frictional system curve to Figure 1. The combined system will operate at the intersection of the system head curve and the system performance curve. If the stages are comprised of independently driven pumps, loss of one pump will cause performance to follow the system head curve to the intersection with the performance curve of the remaining pump(s). However, if multistage performance is used to overcome static pressure, the loss of one pump of a multi-pump train may force the remaining unit(s) to dead head, a dangerous condition that may result in pump failure. (Figure 3)



**3. The first stage is generally determinative of the Net Positive Suction Head Required (NPSHR)<sup>3</sup>**

The lowest absolute suction pressure in the entire staged system will most often be found at the inlet to the first stage, making it the gating stage for NPSHR. It is not uncommon to have a first stage impeller that is of different design than downstream impellers, with the first stage optimized for NPSHR and the downstream impellers optimized for efficiency. However, in any series arrangement, loss of a stage may result in cavitation of downstream impellers due to insufficient NPSHA. A common example of this can be found in pipeline pumps where the TDH developed by each pump may be substantially consumed by pipe friction before the next pump in series is reached. In a pipeline transport configuration, failure of any pump in the series can create NPSH issues for downstream units.

**4. Total staged efficiency is determined by the sum of power consumed by each stage adjusted for interstage losses.**

<sup>3</sup> Net Positive Suction Head Required, for more information see [http://www.lawrencepumps.com/Newsletter/news\\_v01\\_i5\\_oct.html](http://www.lawrencepumps.com/Newsletter/news_v01_i5_oct.html)

Referring back to item 1, the TDH produced by the sum of the stages is net of interstage losses, which are mostly frictional. Whenever staged elements are grouped into a single pump there are losses due to recirculation back to prior stages. As a result of all of these losses, the total efficiency of multiple staged elements in series can be lower than that of a single stage machine at the same rating. However, the increase in interstage losses is mitigated by the presence of higher specific speed ( $Ns^4$ ) elements in a staged assembly<sup>5</sup> which will generally yield higher stage efficiencies.

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<sup>4</sup> For a explanation of Specific Speed see [http://www.lawrencepumps.com/Newsletter/news\\_v01\\_i3\\_Aug.html](http://www.lawrencepumps.com/Newsletter/news_v01_i3_Aug.html)

<sup>5</sup> For a discussion of  $Ns$  and Efficiency see [http://www.lawrencepumps.com/Newsletter/news\\_v01\\_i4\\_Sep.html](http://www.lawrencepumps.com/Newsletter/news_v01_i4_Sep.html)