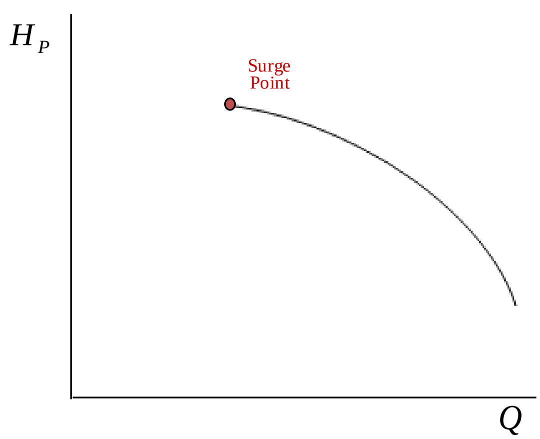
Why Compressors Surge - Exposing the real Culprit

Robert Moore, RMooreControls.com

Two typical explanation for why a compressor surges are that *a compressor will surge when its maximum head capacity is reached* and that *surge occurs when the compressor is unable to produce the required compression ratio*. Although these statements are often true, they can be misleading in their implication that excess head causes surge. That interpretation can lead to unnecessary concerns and inappropriate corrective actions.

Typical - Curve

Let's look at a typical compressor where surge does occur at maximum head. Performance with this shape is typical of a backward leaning impeller.

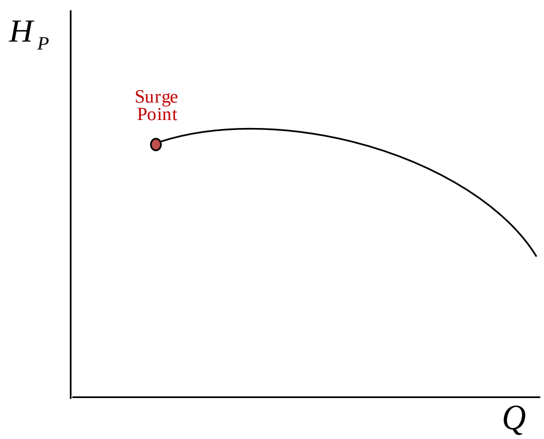


With this curve we can correctly observe that ***the compressor surges at maximum head,*** however, it is more instructive to observe that ***the rise in head resulting from reductions in flow rate stops when the compressor surges.***

The seemingly insignificant difference in wording reveals a big difference in view point. The first statement implies that ***excess head causes surge***. The second statement indicates that ***maximum head is determined by surge***.

Atypical - Curve

Now let's look at a compressor where surge does not occur at maximum head. This performance is characteristic of radial or forward leaning impellers. If you are convinced that surge occurs at maximum head, you may find it difficult to imagine such a compressor. However, they do exist and can be stable in the regions where the slope of the performance curve is positive.

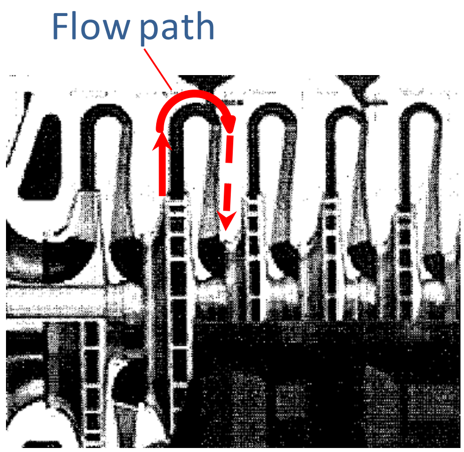


Notice that in this case ***the compressor does <u>not</u> surge at maximum head.*** All we can observe with this curve is that ***compressor head fails when surge occurs***.

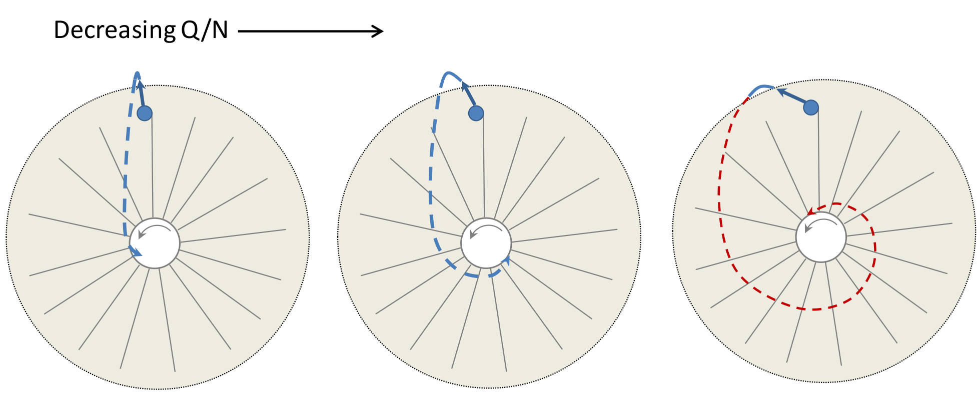
Since maximum head wasn't there when surge occurred it can't be accused of causing it! Rather than thinking of Head as the villain that causes surge, we should to think of Head as the victim of surge. To protect compressors we need to take our eyes off of pressure and focus on the real cause of surge which is **insufficient inlet volumetric flow rate**.

Surge - Diffuser Initiated

Surge can start in the diffuser. The flow path which is straight as it leaves the impeller, spirals as it changes directions and approaches the eye of the next impeller.

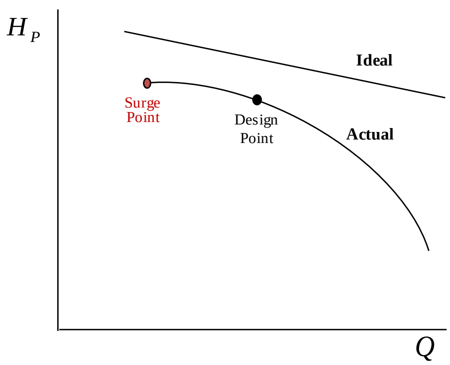


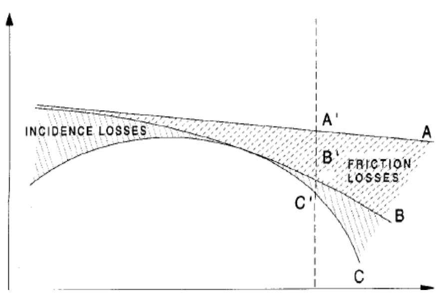
Decreasing values of Q/N create a longer path with frictional forces that eventually destabilize the flow pattern. The sudden destabilization in flow dissipates gas kinetic energy and causes a sudden failure of compressor head. The failure in head leads to a reversal in flow direction.

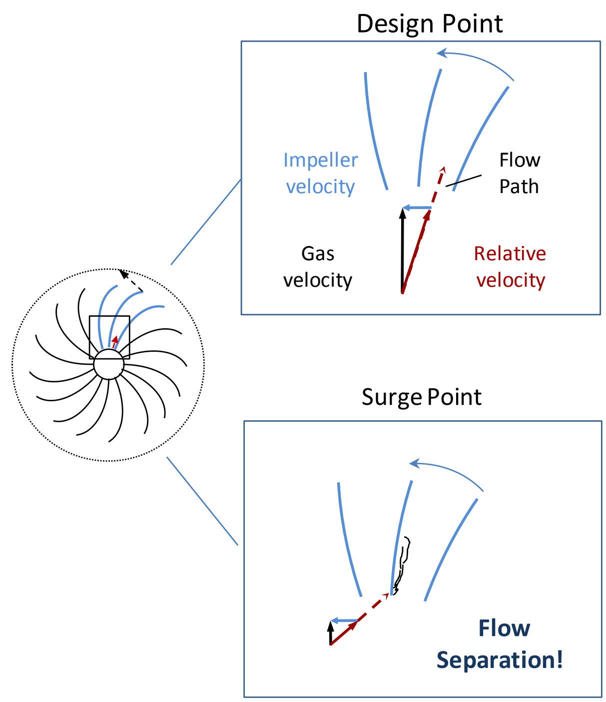


Surge - Inlet Initiated

Surge can also start at the compressor inlet if the "angle of attack" of the gas on the impeller is so steep that flow separation and instability occurs. At the design point, the gas path relative to the impeller results in minimum interference. As volumetric flow is reduced, or impeller speed increased, gas impinges on the face of the impeller. Eventually the impingement angle is so steep that flow separation occurs which destabilizes the flow pattern and triggers surge.

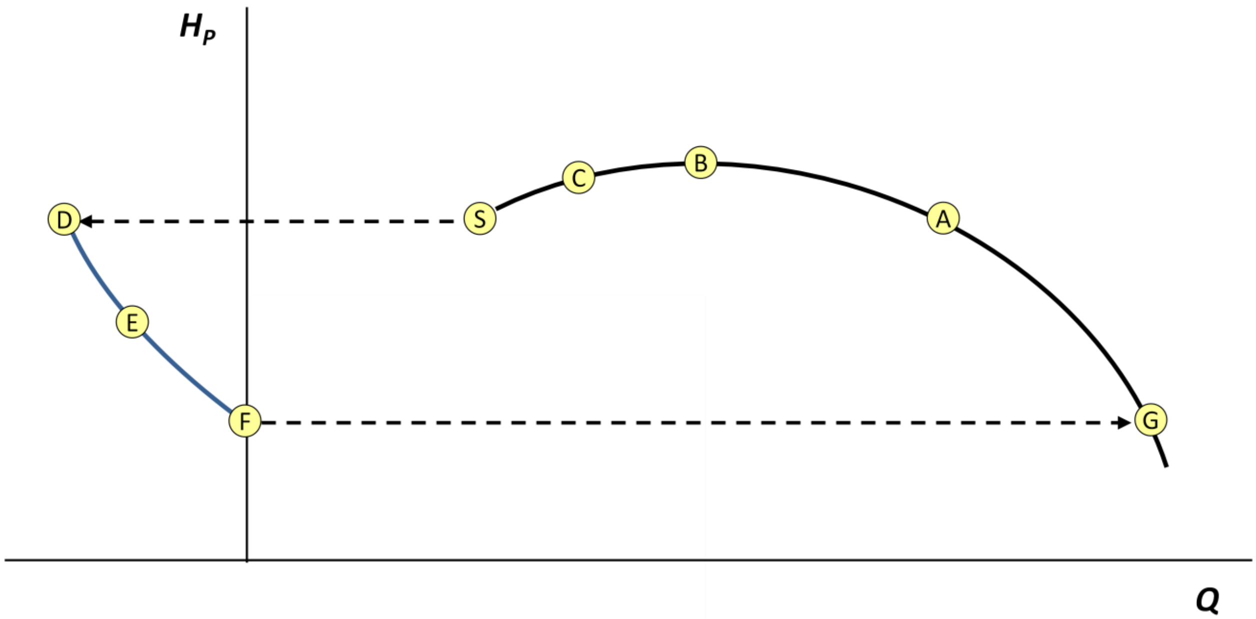






Surge Cycle

Using a radial performance curve let's examine a surge cycle. Our experiment begins at point A in the figure below. A decreased inlet flow rate shifts the operating point to B. Another reduction in flow shifts the stable operating point to C. Continued reductions in flow will eventually trigger surge (S) where failure in head results in flow reversal at point D. Head remains constant until suction and discharge pressures begin to equalize. As pressures begin to equalize, head and the reversed flow rate decrease leading to point E. Pressure equalization continues until point F where the compressor regains its ability to produce head and returns to its performance curve at point G.



If you object to the idea of operating stably at point C, please look for my next publication that will analyze operating without a negative slope.

The (blue) reverse flow section in the diagram above has nothing to do with the performance curve. It isn't a "mirror image" of performance as has been suggested. It's simply the dynamic result of flow reversal and pressure equalization.

Conclusions

The fact that surge and head failure occur simultaneously can lead to a real "whodunit" mystery. Is head the villain or the victim? Does excess head cause surge or does surge cause head failure? A look at a flat performance curve reveals that head is the victim of surge. The real villain is insufficient inlet volumetric flow rate.

Surge is avoided by maintaining a minimum inlet volumetric flow rate. Doing so will ensure that the compressor stays on its performance curve. Pay attention to the inlet volumetric flow rate and the compression ratio will take care of itself.

Publications in this series:

Compressor Performance - What shapes the curve
Why Compressors Surge - Exposing the real Culprit
Compressor Stability – No negative slope required!
Volumetric Surge Control - A better solution

References:

1. *Compressor Handbook* . Ed. Paul C. Hanlon. New York: McGraw-Hill, 2001. Print.
2. Moore, R. (2016). *Compressor Performance* - *What shapes the curve.* Retrieved from https://simsready.com/posts/Compressor-Performance--What-Shapes-the-Curve.pdf

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