1. SUCTION RECIRCULATION

OVERVIEW

Suction recirculation is caused by flow incidence angles that are significantly dissimilar to the inlet vane geometry. The stalled area on the inlet vane produces a hydraulic instability, resulting in the formation of fluid swirl.

Large inlet areas magnify the formation of fluid swirl as the fluid has enough "room" to recirculate. When severe, the fluid circulates out of the impeller eye and interferes with normal suction flow.

The detriments of suction recirculation are two-fold. First, the fluid swirl can cause the suction pressure to fall below the fluid vapor pressure, creating vapor bubbles. With changing pressure fields, the bubbles implode and release energy. If this collapse occurs on the vane itself, material damage can result. This is known as separation and/or cavitation which reduces the operating life of the impeller.

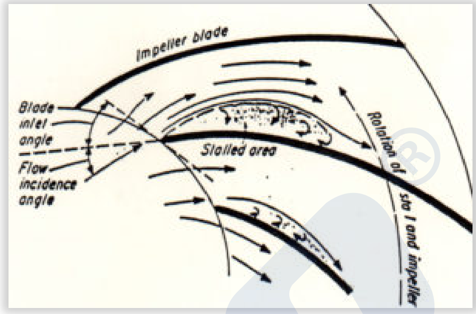


Figure 1 - Suction recirculation

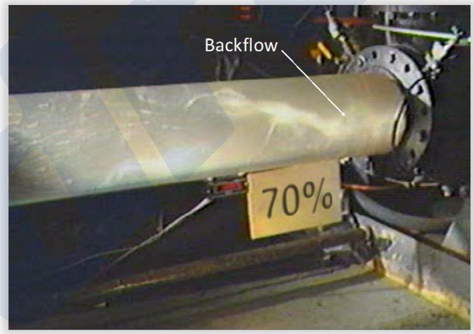


Figure 2 - Backflow

Figure 3 - Impeller damage due to hydraulic instability or suction recirculation

Secondly, the hydraulic instability creates a non-homogeneous fluid-field surrounding the impeller. This results in large radial loads pushing the rotor in different directions and causing contact at close-clearance areas – normally the wear rings. This is analogous to the uncomfortable feeling of flying through clouds.

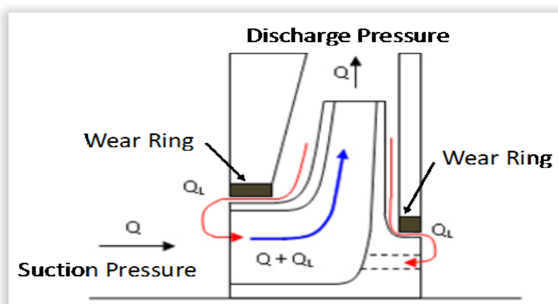


Figure 4 - Internal recirculation

The wear ring clearance will open as a result of the contact. The rate of opening is dependent on the material and its hardness.

The wear ring also has two important functions. The annular clearance between the ring and its mating component limits internal recirculation (the percentage of fluid that, in lieu of being pumped to the system, flows back to the impeller eye.)

It also acts as a fluid-lubricated bearing, providing stiffness and damping to the rotor. This is known as the Lomakin effect. A restoring force in the wear ring clearance is created whenever the rotor becomes eccentric to help maintain rotor centralization. However, as the wear ring clearance increases, the Lomakin effect is reduced, resulting in increased relative motion of the rotor to the stationary element and additional contact.

This vicious cycle continues until eventually the pump has to be refurbished to its original design clearances to remediate the resulting loss of performance or high vibration.

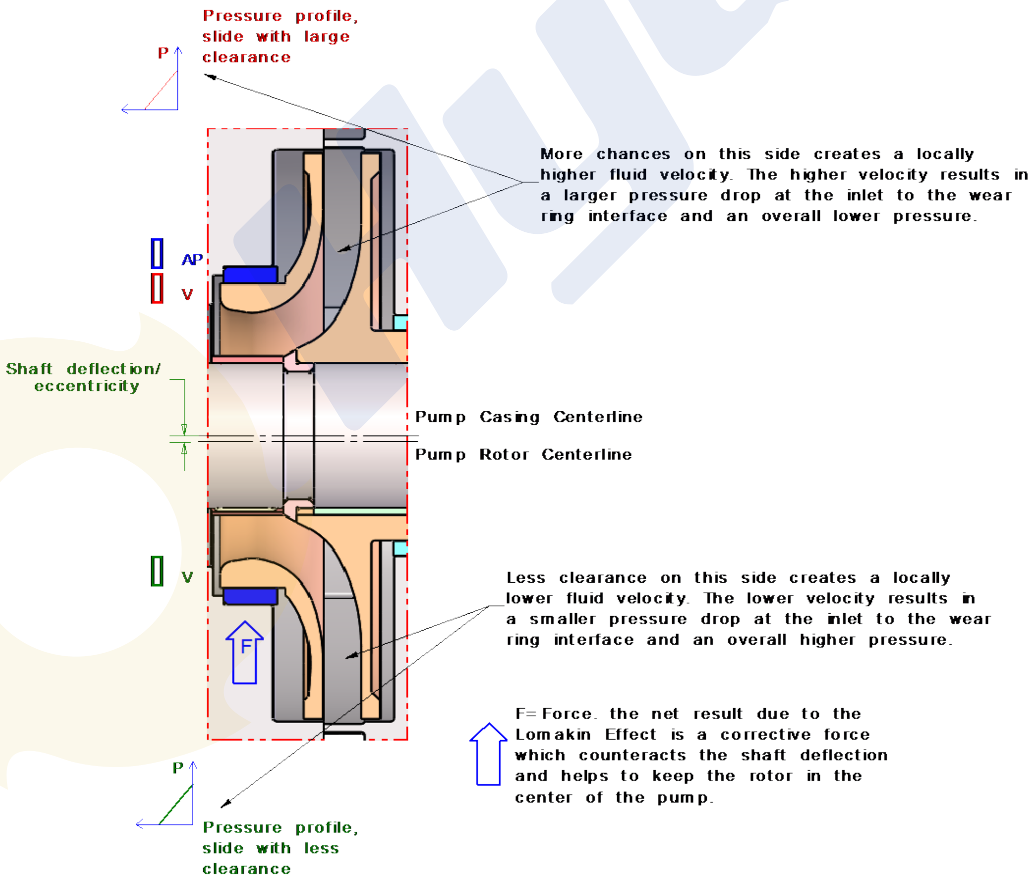


Figure 5 – The Lomakin effect

SOLUTIONS

The best way to mitigate suction recirculation is to operate at the pump best efficiency point (BEP). At BEP, the flow angle and impeller inlet angle are coincident.

System engineers can determine where the pump is operating relative to its BEP by obtaining suction and discharge pressure readings. The process is as follows:

- Obtain suction and discharge pressure gage readings (P_s and P_d), suction temperature, and suction and discharge pressure gage elevations (Z_s and Z_d)
- Determine specific gravity (*sg*) based on suction temperature
- Calculate total developed head (TDH)

$$TDH = \frac{2.31 \times (P_d - P_s)}{sg} + (Z_d - Z_s)$$

- Go to OEM curve and determine operating flow in “as-new” condition by intersecting the OEM curve at the calculated TDH
- Compare this flow to BEP
- If the ratio is greater than 10%, suction recirculation is probable

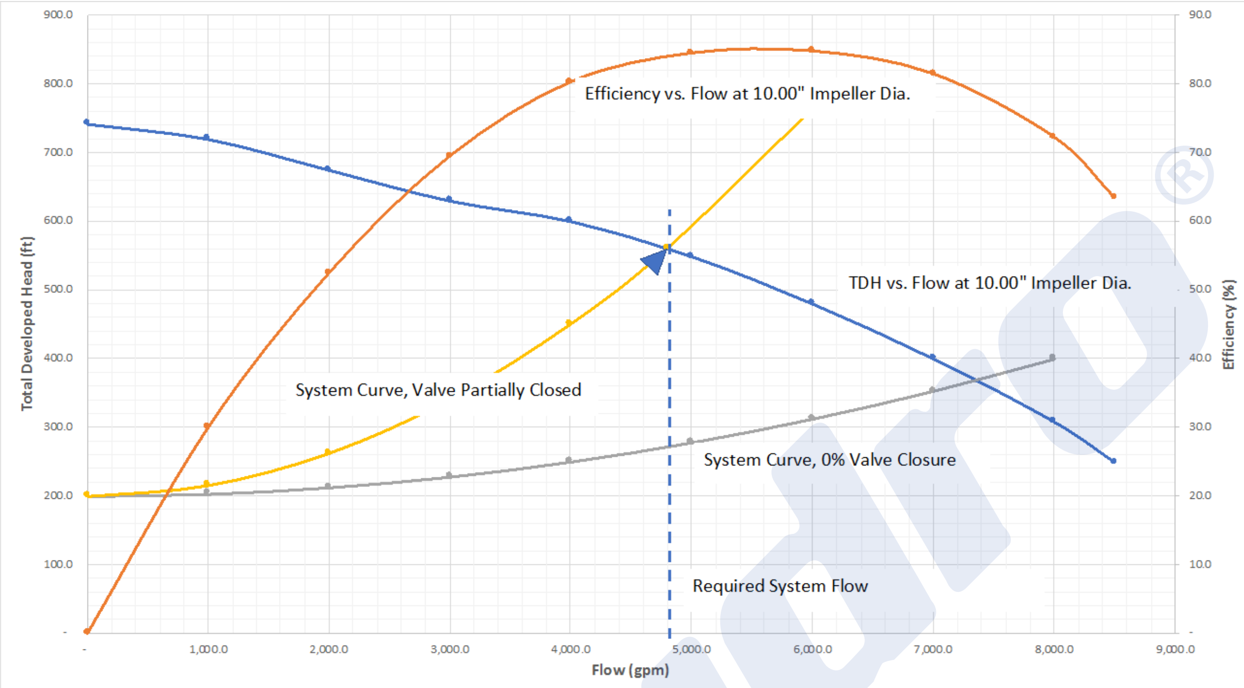
If the pump is operating significantly apart from BEP and the pump discharge is throttled, then an impeller cut should be considered using the affinity laws.

The affinity laws state that the pump flow is proportional to the impeller outside diameter and the pump TDH is proportional to the square of the impeller outside diameter. The efficiency remains virtually unchanged during these calculations.

$$\frac{Q_1}{Q_2} = \frac{D_1}{D_2}; \qquad \frac{TDH_1}{TDH_2} = \left(\frac{D_1}{D_2}\right)^2$$

The following example clarifies the possibility. An existing pump is required to produce 4,800 gpm. The system resistance at this flow rate is 275 ft. The pump is oversized, and the discharge valve has to be throttled to operate at the required system flow. The pump operates at 85.7% of its BEP flow resulting in suction recirculation that reduces the operating life by 5 years.

1. SUCTION RECIRCULATION

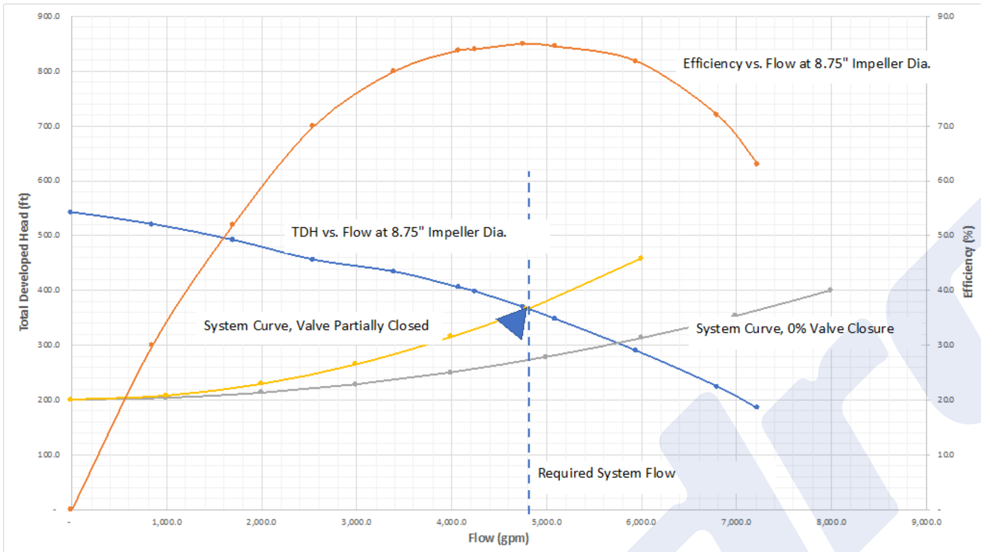


Using the affinity laws, the impeller diameter can be reduced from 10.00” to 8.5” to allow the pump to operate 100% of its time at BEP. The following benefits can be expected:

- Pump operating life will significantly increase since hydraulic instability has been removed
- The valve experiences less cavitation at the reduced pressure drop thus extending its operating life
- Annual energy savings by not throttling excessive head is approximately $150,000

Impeller Diameter:		10.00	Impeller Diameter:		8.50
Flow (gpm)	TDH (ft)	Efficiency (%)	Flow (gpm)	TDH (ft)	Efficiency (%)
-	750.0	-	-	541.9	-
1,000.0	720.0	30.0	850.0	520.2	30.0
2,000.0	680.0	52.0	1,700.0	491.3	52.0
3,000.0	630.0	70.0	2,550.0	455.2	70.0
4,000.0	600.0	80.0	3,400.0	433.5	80.0
4,800.0	560.0	83.8	4,080.0	404.6	83.8
5,000.0	550.0	84.0	4,250.0	397.4	84.0
5,600.0	510.0	85.0	4,760.0	368.5	85.0
6,000.0	480.0	84.5	5,100.0	346.8	84.5
7,000.0	400.0	81.8	5,950.0	289.0	81.8
8,000.0	310.0	72.0	6,800.0	224.0	72.0
8,500.0	255.0	63.0	7,225.0	184.2	63.0

1. SUCTION RECIRCULATION



If operating at BEP for the majority of the pump service is not practical, then reprofiling the impeller inlet blades to provide an airfoil shape will significantly mitigate suction recirculation and fluid swirl.

This upgrade is commonly referred to as a "biased-wedge impeller." The elliptical nose on the leading edge also reduces the formation of vortices at the vane-to-hub junction, thus eliminating fillet damage.

To summarize, suction recirculation will definitely affect pump reliability and shorten operating life. Today's technology provides solutions for the effective mitigation of this unwanted phenomenon.

Understanding where a pump operates relative to its BEP and exploring means of changing the impeller size can have enormous benefits including energy savings.

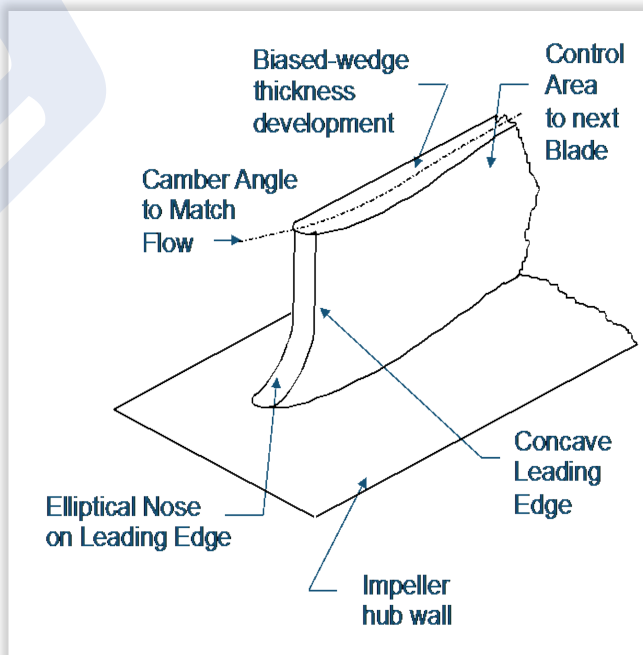


Figure 5 - Biased-wedge impeller

Please feel free to reach out to Hydro, Inc. to answer any questions relating to suction recirculation or any other issues you may be experiencing with your pumping systems.