Optimum Suction Conditions for Rotary Lobe Pumps

According to limited Atmospheric pressure on earth the maximum lifting height for a fluid column inside a suction hose is limited too. The positions influencing the maximum lifting level are

- Atmospheric pressure
- Specific gravity of the fluid
- Pressure loss by friction
- Vapor pressure of the fluid
- Amount of trapped gas in the fluid
- Required NPSH-value

The diagram in Fig 1 shows how the pressure head caused by each item has to be summed up for to calculate the maximum lifting height of a fluid column. To avoid cavitation and/or capacity loss a certain positive pressure head is required at the suction inlet – the so called Net Positive Suction Head NPSH\textsubscript{R}-value.

The Maximal Lifting Height is the Meter/Ft-value corresponding to the Maximum Recommended Under-pressure (MRU) created by the pump.

As explained in Fig. 1 the MRU is based on the Atmospheric pressure reduced by the vapor-pressure of the fluid and a certain pressure to avoid the bubbling of solved gas and reduced by the pump’s NPSH-value. The result has to be reduced again by the pressure drop in the suction line caused by the fluid friction.
<table>
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<th>Term</th>
<th>Description</th>
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<tr>
<td>Atm. pressure</td>
<td>This is the atmospheric pressure at the pump’s location. The Atmospheric pressure is reduced at increasing geodetic height.</td>
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<tr>
<td>Vapor pressure</td>
<td>This is the fluid’s vapor pressure. The vapor pressure is increasing at increasing temperature.</td>
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<tr>
<td>Trapped gas</td>
<td>Trapped or solved gas inside of fluids creates bubbles at under-pressure conditions. The bubbles reduce the pumps capacity (example: sparkling water).</td>
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<tr>
<td>NPSH-value</td>
<td>Net Positive Suction Height. Even at high speed the suction side fluid needs a certain positive pressure to avoid cavitation (creating and imploding of vapor bubbles) caused by the dynamic displacement process inside the pump.</td>
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<tr>
<td>Max. Recommended Under-pressure (MRU)</td>
<td>The MRU-value is the limit under-pressure at which the pump is able to operate continuously with neither capacity loss nor cavitation noises.</td>
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<tr>
<td>Pressure loss in the suction line</td>
<td>Due to friction loss of the flowing fluid the maximal lifting height of a fluid column is reduced. The pressure loss is increasing with the fluid velocity with power of two.</td>
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<tr>
<td>Lifting height</td>
<td>To calculate the height out of a pressure: Height = pressure / (fluid density * acceleration of gravity).</td>
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**Table 1: Definition of Terms in Fig. 1**

The previous considerations are based on the condition that the pump is able to prime, that means the pumps is able to create a certain vacuum without being already continuously flushed with the fluid. Below we discuss the conditions how a rotary lobe pump is operating as an air pump best – to put it another way how rotary lobes pumps are able to prime best.

**Theory**

Basically two-shafted Rotary Lobe Pumps are able to deliver air or gas. At a sample we took a Roots Blower which operates with lobes shaped like our two-wing lobe of the Vogelsang R-Pumps. Also for Roots Blowers small clearances between rotors and housing are essential to minimize the internal leakage forced by the pressure difference between discharge and suction side. Because of the small mass density of air the leakage of air or gas is much higher than a fluid leakage through the same gap. Already an under-pressure of some 7 PSI gives the critical pressure ratio at that sonic velocity is reached.

The sonic velocity in the pump’s gaps limits the maximum leakage rate. A leakage area of 1 square inch gives a leakage volume of about 7 Gal/sec of gas. Compared with water leakage at the same condition this is 20 times as much.

To enable a reasonable under-pressure at “dry” condition a Rotary Lobe Pump should run 20 times faster than at “wet” condition. The tip speed should be increased to some 50 to 80 m/s (164 to 290 ft/sec). This is no problem if we use a roots blower with metal lobes but it’s impossible for a pump with rubber-coated lobes.

The solution of this basic problem is to add a little amount of water to the air. In a two-phase mixture of water and air there is a drastic
reduction of the sonic velocity and as a result a reduction of the leakage rate. That is because the sonic velocity is determining the flow rate through a gap for gaseous media. For example, at an under-pressure of only 0.5 bars (7.2 PSI) the maximum air velocity is 343 m/s (1125 ft/sec). This value remains constant even at higher under-pressure values.

If you add water in drop shape the sonic velocity is reduced extremely and the leakage flow as well.

As you see at the right part of the diagram in Fig. 4 the sonic velocity decreases to values of fewer than 50 m/s (164 ft/sec) at 10% addition of water, that is fewer than 15% of the value at pure air.

The explanation is the following: the air molecules are permanently slowed down by the heavy water drops.

At 50% partial amount of water in the air/water mixture inside the gaps – no problem if the connectors are filled with water – we come down to 20 m/s (65ft/sec) sonic speed. That means the air leakage rate is reduce to normal liquid leakage rates. The pump is operating with reasonable volumetric efficiencies.

These considerations explain the fact that a Rotary Lobe Pump is able to prime even at worn-out condition with increased clearances. Simply expressed, the gaps are able to be sealed by the fluid.

The left part of the diagram is not relevant for us because a fluid gap flow is determined by the fluids specific gravity, not by its sonic velocity.

**Practical consequences**

Rotary Lobe Pumps with rubber-coated lobes have the advantage of being designed with small clearances. Even zero spacing is possible without blocking or damaging. This is a positive fact with regard to self priming.

But in general a Rotary Lobe Pump is operating with clearances caused by abrasive solids to be pumped with the fluid. Even under abrasive condition a pump has to prime safely.

There are some principles to pay attention to. The following measures are able to be practiced in most cases if a flooded suction is out of the question:

- **Filling-up water**
  
  If rotary pumps ought to prime their gaps have to be filled with fluid in drop shape. That means there must be a fluid reservoir available to feed the gaps with fluid drops continuously.

- **High speed**
  
  The second principle is high speed. Only high speed can guarantee that the gaps at the top lobe are sufficiently filled with drop shaped liquid.

To make sure that the above measures have an effect we have to design the pump connectors in a special way.

The principle is: to design the connectors on both sides of the pump in a way that the filled-up water is able to remain in the pumps as long as the priming

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**Fig. 5:** Straight connection: top gaps will be insufficiently supplied with liquid drops

**Fig. 6:** Gooseneck – Connectors: top gaps will be better supplied with liquid
situation is lasting. Some samples may explain different situations.

In **Fig. 5** straight connectors are shown. Only the housing segment below is filled with fluid. When the pump is operating the fluid will be pushed into the discharge pipe.

Different to straight connection the wing-type or gooseneck connectors shown in **Fig. 6** allow that a larger amount of fluid remains in the pump’s surrounding. Additionally a large fluid quantity is able to separate and is able to flow back into the pump. Forced by the rotor’s speed the liquid splashed into drop shape enters into the gaps to affect its sealing.

**In Fig. 7** the optimum connector arrangement with 90°-connectors is shown. Beside the fact that a significantly bigger liquid quantity is collected the condition for liquid separation at the discharge side is optimal. The air bubble underneath the upper housing segment will be easily pushed into the discharge line.

**Common mistakes when built-in Rotary Lobe Pumps**

At the following some often made mistakes are demonstrated when rotary pumps are fitted in an existing piping system. These mistakes can complicate the priming process or stop it completely.

In **case 1** the Connectors have got a too small cross area. This is dangerous particularly on the discharge side. What happens is that - caused by too high flow velocity - the fluid will be blown out of the pump.

In **case 2** the fluid collected in the lower housing segment is flowing into the discharge pipe immediately after turning on the pump.

In **case 3** with a pump lying on its side – suction side on top – there is no chance to collect even a little rest of fluid in the pump. A so mounted pump has to be flooded in every case by a top inflow. If needs be for mounting a pump lying on its side the flow direction should be from bottom to top and a fluid reservoir has to be foreseen.

**Samples in the field:**

**Sample 1  **  *Lifting from pits*
Rotary Lobe Pumps fitted with both-sides gooseneck connectors (or 90°-connectors) are able to prime even with worn-out lobes.

A Vogelsang double pump station shown in Fig. 8 has to lift the waste water from a sweets factory out of a 4 m (13 ft) pit. The pump has to prime through a RotaCut 3000 E. The discharge is a 120m (400 ft) pipe with a diameter of 65 mm (2.5”).

**Problem:**

The user couldn’t start the pump at first because in spite of a frequency controlled drive the pump was unable to prime.

**Temporary solution**

Priming was successful only when the user was continuously feeding water through the drain cock into the discharge connector.

**Expanation:**

The pump has to create a vacuum in the suction hose in order to lift the water column up to 4m (13 ft) in height. Because of straight connectors the pump’s fluid reservoir was not enough to seal the gaps sufficiently particularly at the upper housing segment. Also the fluid collected inside the RotaCut stone catcher didn’t help because it was all drained into the pit. The internal leakage was higher than the delivered air. The created under pressure was unable to lift the water column up to the pumps level.

A single water supply didn’t solve the problem. The temporary solution was a continuous water supply into the draining cock as shown in Fig.10. Now a sufficient quantity of fluid flows back into the pump and is splashed into drops. The drops are sealing also the upper gaps. The pump is priming.

The user is able to evade those starting troubles even without changing the connectors if he cares that the pump is switched off before the pump is slurping. An additionally a non return valve cares that the pumps will not drain dry during stop.
**Optimum solution**

Fit gooseneck connectors (better 90°-connectors) on both sides of the pump (Fig. 11). Then there is a sufficient fluid reservoir as a basis for creating the necessary sealing effect. The pump is able to build-up a vacuum.

It is important that the diameter of the discharge-side connector is as big as possible to allow the fluid being well separated from the air/water mixture.

**Sample 2  Pumping bio-active Sludge with Trapped Gas Bubbles**

Rotary Lobe Pumps fitted with both-sides gooseneck connectors (or 90°-connectors) are able to pump bio-active sludge even with worn-out lobes.

Even at flooded suction condition it happens some times that rotary lobe pumps fitted with straight connectors are unable to start. That is when bio-active with trapped gas bubble have to be pumped.

**Problem:**

If using straight connectors not only part of the pipes but also the top housing segment section is completely filled with biogas. In critical cases – that is if a worn-out pump operating at low speed – the pump is unable to convey the gas bubble into the discharge hose.

**Solution:**

Build-in gooseneck connectors (or 90° pipe bend) according to Fig. 12. The gas bubble will be created as well but there is enough liquid remaining in the pump to seal the gaps so that gas bubble will be conveyed problem-free. A larger amount of liquid has
a change to separate in the discharge hose and - after flowing back into the pump – can seal the gaps better.