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REGENERATIVE TURBINE AERATION TECHNOLOGY

The gas dissolution process utilizing a regenerative turbine pump provides for precise control of input and output fluid/gas parameters. Once set, a well designed system will return to operating duty each start-up. The goal is to enlighten wastewater technicians about this high quality gas dissolving technology and how to apply it. And importantly, the technician may find regenerative turbine technology has many potential uses which benefit their clients.

Gas Dissolution and Regenerative Turbines

Gas is dissolved into a fluid solution through pressure. The regenerative turbine pump applies pressure through a combined triple action force (centrifugal, axial and friction) to the gas and fluid during a single pass through the pump head. Whether dissolving compressed or atmospheric air, nitrogen or other gasses to the fluid, the regenerative turbine pump achieves the highest possible saturation level at a given temperature.

Gas Solubility- Air Example

A common application for this pump technology is the dissolving of air into water. The amount of air that can be dissolved in water increases with the system pressure and decreases with the temperature. Using air as an example, regenerative turbine pump gas dissolution can be calculated as follows:

Solubility Ratio: The solubility of air in water can be expressed as a solubility ratio.

$S_a = m_a / m_w$ *where*
S_a = *solubility ratio*
m_a = *mass of air (lb_m, kg)*
m_w = *mass of water (lb_m, kg)*

Solubility- Henry's Law

Henry's Law states "the amount of air dissolved in a fluid is proportional with the pressure of the system".

$c = p_g / k_H$ *where*
c = *solubility of dissolved gas*
k_H = *proportionality constant depending on the nature of the gas and the fluid*
p_g = *partial pressure of the gas*

Please note that the solubility of oxygen in water is higher than the solubility of nitrogen. Air dissolved in water contains approximately *35.6%* oxygen compared to *21%* in air.

Solubility- Calculation

Given Henry Law's constants at a system temperature of *25^{o}C (77^{o}F)* the amount of air dissolved in water can be calculated as:

Oxygen - O_2 : *756.7 atm/(mol/liter)*
Nitrogen - N_2 : *1600 atm/(mol/liter)*

Molar Weights

Oxygen - O_2 : *31.9988 g/mol*
Nitrogen - N_2 : *28.0134 g/mol*

Partial fraction in Air

Oxygen - O_2 : *~ 0.21*
Nitrogen - N_2 : *~ 0.79*

The oxygen dissolved in the water at atmospheric pressure can be calculated as:

c_o = *(1 atm) 0.21 / (756.7 atm/(mol/liter)) (31.9988 g/mol)= 0.0089 g/liter, ~ 0.0089 g/kg*

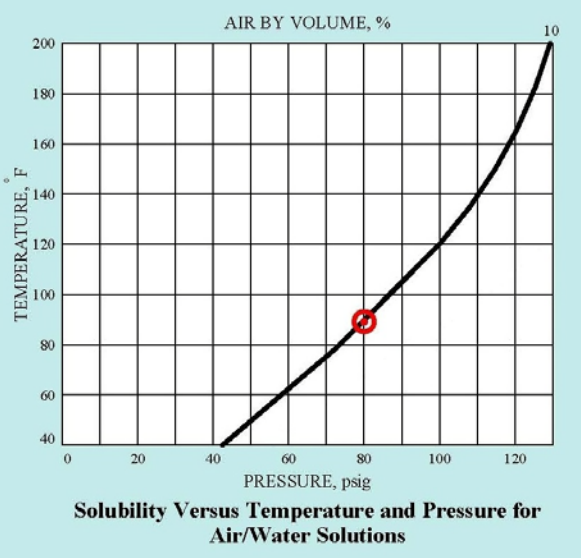
The nitrogen dissolved in the water at atmospheric pressure can be calculated as:

c_n = *(1 atm) 0.79 / (1600 atm/(mol/liter)) (28.0134 g/mol) = 0.0138 g/liter, ~ 0.0138 g/kg*

Since air is the sum of nitrogen and oxygen it follows:

c_a = *(0.0089 g/liter) + (0.0138 g/liter) = 0.0227 g/liter ~ 0.023 g/kg*

Applying the above information to the regenerative turbine pump a performance curve can be graphed. Note that the gas dissolution for air peaks at 10% by volume under normal system operating conditions of temperatures of less than 100F. Thus with just 80-85psi the regenerative turbine pump discharge pressure meets or exceeds discharge requirements for most dissolved air flotation (DAF), membrane and oil recovery applications. Please refer to Graph 1 at the right.



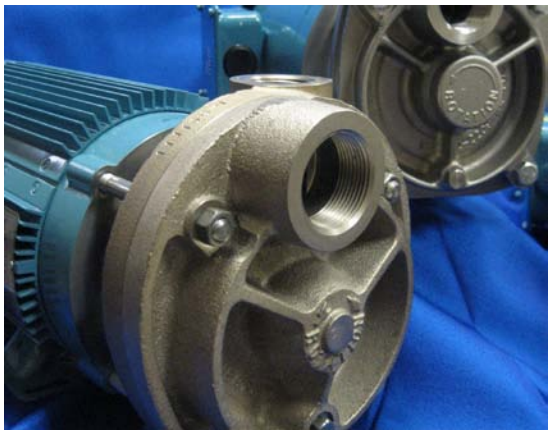
Solubility Versus Temperature and Pressure for Air/Water Solutions

Graph 1

Why Change?
There are several older technology options to dissolving gasses into a solution. Examining the resulting quality and efficiency with which the regenerative turbine pump performs these duties may help convince one to take a closer look. The pump offers a competitive alternative for achieving gas dissolution in a fluid for the following reasons:

- Generates 20-30 micron bubble release.
- Uses low energy consumption.
- Gas dissolved at modest pressures.
- Low wear pump fluid interface.
- Simple design is easy to implement.
- High efficiency without cavitation.
- Safety and control features assure reliability.

Design & Applications
Typically a regenerative turbine pump is sized in saturation applications for just 20% of total system flow. This means they are well suited for dissolved air flotation (DAF), membrane and oil recovery systems. The wastewater technician will find these pumps useful in the Food and Beverage, Laundry, Pulp & Paper, Brewery and Petroleum industries. With a little exploration they will find there are many other special process applications to be found.



Close coupled pump- lower flows

Flex coupled pump- higher flows

Pump Features
Regenerative turbine pumps have a robust construction. The list below gives some quick reference points to look for in a quality pump design:

- Materials: Stainless steel, iron, brass
- Close and flex coupled models
- Can be mounted in many locations
- Capacities of 5 to 120+ GPM
- Heads in excess of 200 Feet
- Economical seals

Hydraulic Design

Regenerative turbine pumps can be offered in single and dual impeller mechanical units. The internal hydraulic cavity is engineered to achieve maximum capacity and pressure while minimizing horsepower requirements. The hydraulic cavity design optimizes the fluid pumping dynamics within the interior passageway to improve the efficiency and overall pressure achieved. Near complete dissolution of entrained gasses are achieved to the maximum volume possible during the pump cycle. This is done in a single pass and equates to minimized horsepower requirements.

Optimized hydraulic cavity

Impeller Tuning

Each regenerative turbine impeller has a profile which is uniquely performance tuned. Tuning is based on both engineered and field testing by optimizing the width and length of the impeller vanes. Significantly reduced horsepower is required by the pump to efficiently dissolve the gas into the fluid. This also has the benefit of improved off peak horsepower requirements.

Performance tuned impeller

Blade Efficiency

Each impeller is built with a blade profile and count which has been engineered for its particular fluid passageway cross-section. The impeller blade count increases the efficiency without complex blade contours. Thus the regenerative turbine pump yields high performance characteristics exceeding those of more expensive units.

Adding It Up

Looking back at the air solubility calculations and applying the regenerative turbine pump design results in the expected efficiency. This can be verified by an air rotometer indicator matching the calculated volume. The net result equals a dissolved air release with 20-30 micron bubbles. The picture at the right vividly illustrates those bubbles within a DAF vessel. This is often referred to as “whitewater”.

DAF 20-30 micron “whitewater”

Setting Up Gas Dissolution Systems

The wastewater technician should select a pump and the piping materials based on fluid type and temperature. It is very important to have full control of the system and build in automatic safety features. A system should be piped such that saturation time is maximized. The regenerative turbine pump should be matched to overall system flow and hydraulic capacity. There are also several system limitations under which to operate. They are as follows:

Discharge Pressure	125 psi
Seal Pressure	200 psi
Suction Vacuum	26” Hg
Speed (Flex)	1750 rpm
Speed (Close)	3450 rpm
Temperature	-20 F to 150 F

System Components

A well designed gas dissolution system will have a number of components beyond the pump itself. These items are usually either schedule 80 PVC or stainless steel as required. The list of items are:

1. Regenerative turbine pump
2. Inlet fluid control valve
3. Fluid vacuum gauge
4. Gas flow meter with adjustment knob
5. Gas tubing
6. Injection check valve
7. Discharge pressure gauge
8. Saturation and coalescing purge tank (optional)
9. Safety relief
10. Swing check valve
11. Discharge control valve
12. All necessary connecting piping
13. Mounting frame or plate

Example Setup

The following pictures illustrate a typical dissolved air flotation (DAF) system upgrade. In picture 1 a regenerative turbine pump is fed clarified effluent water through a control valve with air injected via an acrylic rotometer. A slight vacuum is applied when atmospheric air is utilized. The wastewater technician may find more controllable results by using compressed air at just 10-20psi. This assures a more even flow and discourages fouling of the airline and rotometer. In picture 2 a 125psi safety and pump discharge pressure gage are shown. In picture 3 the “whitewater” is introduced to the incoming system flow.

Picture 1- pump setup

Picture 2- safety relief

Picture 3- “whitewater” introduction

Regenerative Turbine Results!

The results of these efforts are a smooth running gas dissolution system. The treatment operator will find they have a low maintenance unit and reliable efficiency. Picture 4 shows the “whitewater” produced by super saturated 20-30 micron bubbles and the formation of a dry sludge layer on the surface of the water. The final results are depicted in picture 5 with spilling of clarified water over the DAF effluent weir.

Picture 4- super saturation

Picture 5- clarified effluent

Acknowledgments to ***Rogue Pump Company*** for providing the photos.