VPT – VORTEX PROCESS TECHNOLOGY "REALICE"

TECHNICAL BRIEF

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TABLE OF CONTENTS

I. VPT TECHNOLOGY – *OVERVIEW* 3

EFFECTS PRODUCED BY VPT 3

AIR IN WATER AND ICE RINKS 5

HOW BIG IS A MICRO-BUBBLE? 6

SLIPPERY ICE 7

II. DEMONSTRATED EFFECTS OF VPT 8

I. VPT TECHNOLOGY – *OVERVIEW*

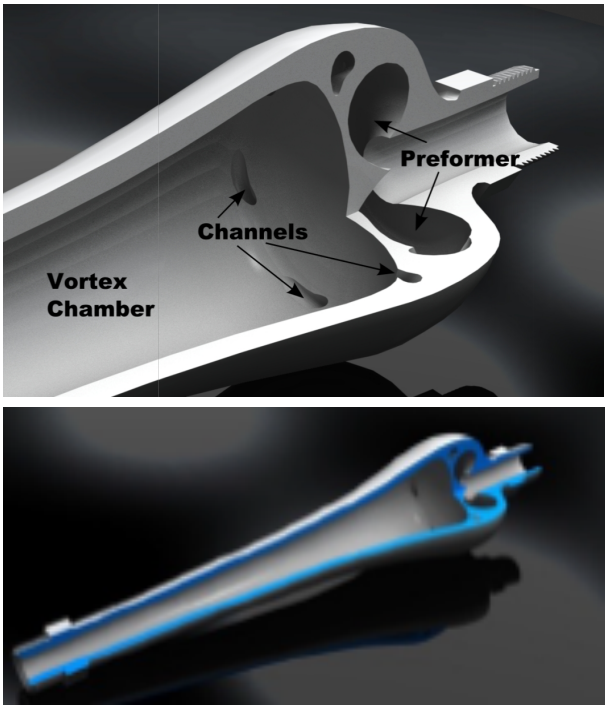
The patented Vortex Process Technology (**VPT**[1]) causes a fluid[2] to organize into an ordered vortex movement within the unit as a result of the intricate 3D design of the vortex chamber. There are observed physical changes to the fluid resulting from the process. The unit is 3D printed to achieve the proper design and is made from a dense polyamide food grade material and sized based on the end use application.

EFFECTS PRODUCED BY VPT

1. **Removes entrained micro-bubbles present in the water from the fluid flow**
2. **Lowers the viscosity of water and improves the heat transfer of water and ice**
3. **Removes (precipitates) calcium ions and forms calcite/aragonite crystals**
4. **In the "FlowMixer™" configuration with added venturi delivers high efficiency aeration that will increase the concentration of O^2 ppm in water**

The energy for the process originates from the pressure[3] of the incoming water. The technology is able to generate a well-defined vortex with a powerful sub pressure within the unit. The low pressure that has been measured in the unit is minus (-0.97) bar or approximately -0.957 atm (standard atmospheric pressure.) When the water is flowing through the trumpet-shaped vortex chamber (see below figure 1), its rotating speed increases as the radius of the "trumpet" narrows.

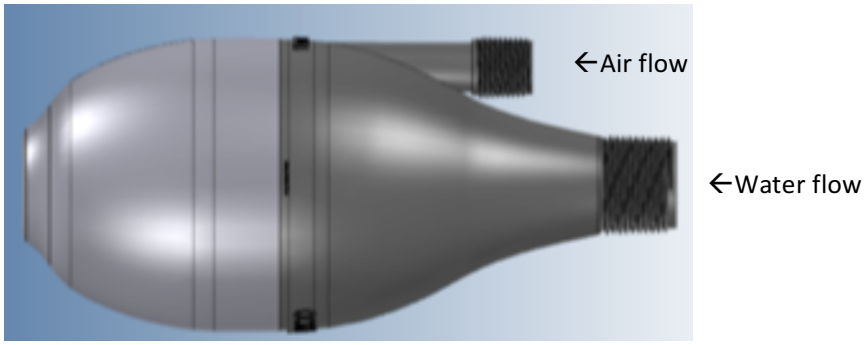
Figure 1 Vortex Chamber of a REALice unit



[1] *For Ice Rinks branded as "REALice"*
[2] *Water in the case of REALice and VPT- Cooling Tower end uses*
[3] *For REALice use the typical city water pressure of from 43 to 85 psi is sufficient. The VPT unit can withstand pressure to 1,500 psi*

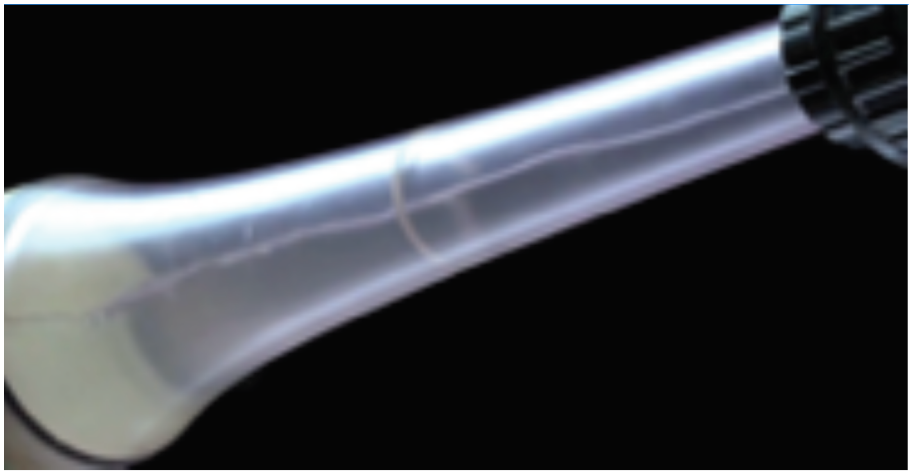
1. **Pre-former.** The inlet of the vortex generator provides a smooth outward direction of the flow through toroidal motion toward a set of well-defined channels.
2. **Channels.** After the pre-former, the fluid is directed through a set of channels, each with vortex-forming geometry. Each channel delivers a jet stream of vortex flow tangentially into a vortex chamber.
3. **Vortex chamber.** In the vortex chamber, the vortices from the channels are wound together. A strong and stable vortex flow is formed inside the vortex chamber, causing a strongly reduced pressure along the vortex axis. Depending on the application, the vortex chamber can have different shapes. A trumpet-shape (Figure 1) produces a well-defined vortex with a smooth transition to downstream piping. An egg FlowMixer™ shape (Figure 2) with a narrow outlet and air inlet venturi causes an extensive aeration and increase in the concentration of O^2 or other gasses.

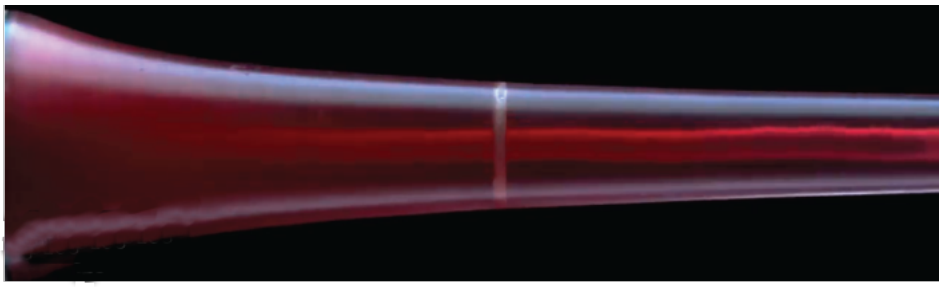
Figure 2 FlowMixer™ with venturi used in aeration applications



The effect of this process in the REALice branded unit or other VPT unit is that a large pressure gradient will be generated inside the vortex so that the pressure is at the lowest value in the center and the highest at the periphery of the vortex. The lowest pressure at the center extents the length of of the vortex consequently the entrained micro air bubbles move towards the center of the vortex, coalesce with other bubbles and gather into a shape resembling an elongated tornadic volume of air with a very low pressure.

Figure 3 Removal of Entrained Micro-Bubbles





AIR IN WATER AND ICE RINKS

Air is a gas with typical ratios by volume: nitrogen (78%), oxygen (20%), argon (0.93%), carbon dioxide (0.04%), plus traces of neon, helium, methane, etc. The solubility of air in water depends on two factors, **temperature** and **pressure**. The solubility of air in water decreases as temperature increases – higher temp means less air. Ice rink resurfacing water has historically been heated (120 F– 160F) using significant energy to first heat the water and then to freeze it. The water is heated to remove air from the water leading to better ice quality than ice that is made with a higher volume of air. For example, at 1 bar (14.7 psi) at 50F city water will hold approximately 2.3% air by volume. If the water is heated to 195 F – at the same pressure of 1 bar it can only hold about 0.3% air by volume.

However, it is also true that the air in water (**both** dissolved air and undissolved air microbubbles) can be *removed by lowering the pressure and this is what the REALice unit accomplishes*. Gases (air) within water are very dependent on the pressure of the system. The concentration of a gas (both dissolved air and undissolved air microbubbles), in a fluid (water) is directly proportional to the partial pressure in the system – this is Henry's Law.

$$c = p_g / k_H$$

Where

c= solubility of dissolved gas
k_H= proportionality constant depending on the nature of the gas and the solvent (water in this example)
p_g= partial pressure of gas (Pa, psi)

For example, at 75 psi, similar to incoming city water pressure @50F the water would have about 14% air by volume. If the water drops only to just atmospheric pressure of 14.7 psi the % air drops to 2.3%. The REALice unit however creates an intense sub-pressure as much as minus (-0.97) bar or approximately -0.957 atm within its vortex.

This, however, should not be misunderstood that the VPT when applied as REALice with typical city water pressures has its *primary impact* as the removal of dissolved gasses. The REALice unit does impact dissolved air, but very little. The primary impact on the resurfacing water is the removing of undissolved free gasses in micro-bubble form. It is common in water piping systems that there is entrained air in the water (hot or cold) with some of it in the form of micro-bubbles which will impact ice quality when resurfacing ice in rinks. The REALice technology is an in-line hydraulic device that strips entrained micro-bubbles from the fluid flow based on accepted fluid dynamics principles.

How big is a micro-bubble?

There needs to be some perspective in understanding the range in size of micro-bubbles to better understand how challenging they are able to be seen in the water within an ice rink or resurfacing machine. One millimeter is about 0.039 of an inch. For reference the period at the end of a sentence is about that size. Microbubbles can be much smaller – and that is what impacts ice quality.

There are 1,000 micrometers (uM) to 1 millimeter. **Micro-bubbles** range from as large as 0.039 inch (1,000 micrometers) to 1 uM or 1/25,400th of an inch. Anything smaller is considered a nano-bubble.

Table 1 Inch, mm and uM comparisons and examples

mm	uM	inch
25.4	25,400	1
1 mm	1000 uM	0.0393
0.001	1 uM	0.0000393
1–10 µm – length of a typical bacterium		
~ 100 µm diameter human hair		

The vortex flow with the REALice unit gives rise to strong pressure gradients, cavitation and shear forces. The radial pressure gradient in the vortex chamber causes a very strong sub-pressure along the vortex axis. As mentioned, when using water, this sub-pressure induces micro air bubbles (un-dissolved air) to move inward toward the vortex axis where they coalesce into larger bubbles and are removed as the water flows through the RELAice unit. The outlet of the REALice unit fills the resurfacing machine. If there is enough un-dissolved air in the water, a “vacuum string” along the axis can be clearly visible through a transparent vortex generator and the now larger macro bubbles will exit the REALice unit. At the standard operating pressure, that pressure gradient is strong enough that cavitation also occurs. The strong pressure gradient and removal of micro bubbles shifts chemical balances, giving rise to reactions that would not happen under normal water flow conditions in a pipe, i.e. no use of the REALice vortex chamber.

In the vortex generator, shear forces occur not only close to the wall, but also within the fluid itself. There are also shear forces close to the vacuum string along the vortex chamber axis. The powerful mixing capabilities of the vortex generator are largely due to the strong shear forces which cause a forced but still ordered convection in the flowing medium. The combination of pressure gradients and shear forces can cause formation, aggregation or fragmentation of solid matter in the fluid under certain circumstances.

SLIPPERY ICE

The silky layer[4] on the top of the ice is not (only) made by REALice and this is the standard explanation why ice is slippery. The Journal of Chemical Physics described the surface of ice. Rather than a layer of liquid water on the surface of ice, they found, there were loose water molecules. It can be compared it to a dance floor that is filled with marbles or ball bearings. Slipping across the surface of the ice is simply "rolling" on these molecular marbles. Ice has a very regular, neat crystal structure, where each water molecule in the crystal is attached to three others. The molecules on the surface, however, can only be attached to two others. Being so weakly bonded to the crystal allows these surface molecules to move more easily and attaching and detaching themselves to various sites on the crystal as they move. This layer on the top of the ice with REALice is thicker and more stable due to the decreases viscosity from removing the micro bubbles.

[4] https://pubs.acs.org/doi/10.1021/acs.jpclett.8b01188

II. DEMONSTRATED EFFECTS OF VPT

The Polymer Technology Group[5] Eindhoven BV (PTG/e), an independent research institute, and part of the Eindhoven University of Technology6 (TU/e) and others[7] have conducted an examination of the properties of VPT water. Samples were taken from municipal water in Holland before and after VPT treatment. Water treatment was made with a standard vortex generator at a water pressure of 3.5 bar (apx. 50 psi).

Removing Entrained Micro-bubbles

Micro air bubbles in water will be pulled into the low-pressure zone in the vortex chamber. The low pressure will cause them to expand and gather into large bubbles that can be easily extracted downstream the vortex generator. This process does not primarily affect dissolved gases due to the typical low city water pressures found (45 – 85 psi). Substances that gather at bubble surfaces may follow the bubbles toward the vortex axis, aggregate and then be separated out.

Decrease Viscosity

A decrease in viscosity occurs after REALice / VPT treatment due to the removal of micro bubbles. The difference measured by Polymer Technology Group Eindhoven BV (PTG/e), was between 3 and 17 percent, depending on water quality and temperature. Gas micro bubble content affects the viscosity of water. As bubbles (un-dissolved air) are removed, a decrease in viscosity was measured.

Electrical conductivity

Based on the testing at the Polymer Technology Group Eindhoven BV there was an increase of 3% in electrical conductivity after VPT treatment in the PTG/e study.

Heat transfer

VPT treatment changed the melting behavior of ice. The heat capacity was 5% higher for ice and 3% higher for liquid water. Water with air has a lower density and a lower heat transfer ability.

Cavitation

With a low enough pressure along the vortex axis, cavities (microscopic bubbles) form in the medium. As they move into high pressure zones, they will rapidly implode, producing shock waves and a release of heat within a small volume. Vapor filled bubbles develop when the water pressure is below the prevailing vapor pressure.

- **Controlled Cavitation**: leads to the formation of lime particles in hard water. The process results in low pressure and high temperature micro-zone (solubility of CaCO3 decreases) causing the dissolved calcium and carbonate ions to react and form colloidal calcium carbonate crystals. This increases pH and allows the particles to act as incubation sites for dissolved calcium and carbonate ions to grow on, in lieu of, metal surfaces.

[5] *https://www.ptgeindhoven.nl/en/*
[6] *https://www.tue.nl/en/*
[7] *https://www.bodec.eu/ https://www.ltu.se/?l=en*

- **Fragmentatio**n: Already formed lime particles fragment as they move through the pressure gradients and shear forces
- **Precipitation**- nuclei formation: Calcium bicarbonate $(CaHCO3)^2$ in the water is forced to precipitate out in the form of calcite (CaCO3) – primarily aragonite crystals which have minimal scaling properties and do not precipitate on warm surfaces. Such particles act as seeds (crystallization nuclei) for new lime growth. New lime formation will add to the lime particles rather than cause lime-scaling on the equipment.