VPT – Vortex Process Technology - including REALice

Technical Brief

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I. REMOVING AIR FROM WATER

The water used can be from any source such as city water or well water. It will have air in it as both undissolved micro bubbles or as dissolved air. Air is a gas and it is soluble in water.

If the air is left in the resurfacing water, the resulting ice will be fragile, brittle and chippy. When skate blades penetrate the ice, they create scars and gouges, leaving behind snow shavings that make skating both difficult and dangerous.

There are a couple of different ways to remove the air from water.

1. Temperature – Heating the Water

Using temperature -- heating the water -- is one method to remove the air from the water.

The solubility of air in water ***decreases*** as the temperature ***increases***: higher temperatures mean less air. At 14.5 psi (1 bar) at 50°F, city water contains approximately 2.3% air by volume. If the water is heated to 195°F at 14.5 psi (1 bar), it will contain about 0.3% air by volume.

Heating the water to temperatures ranging from 120-160°F has been the common way to remove the air from the water. Each day, a rink can use thousands of gallons of hot water to maintain the ice. By heating the water to high temperatures, a percentage of the air in the water is removed. The hot water is then frozen. This is an effective, but very energy intensive, method.

2. Pressure – Running the Water through REALice

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 in the ice rink application. 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, 50°F water at 75 psi contains about 14% air. If the pressure of that 50°F water is now dropped to 14.5 psi (1 bar), the percentage of the air in the water drops as well, to just 2.3%. The REALice unit creates an even more intense sub-pressure, as much as minus (-0.97) bar / (-14) atm within its vortex. This, however, should not be misunderstood that 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.

- The REALice technology is an in-line hydraulic device that strips entrained micro-bubbles from the fluid flow based on accepted fluid dynamics principles.
- It does this without adding any external energy

II. VPT TECHNOLOGY FOR REALICE – *OVERVIEW*

The patented Vortex Process Technology (**VPT**[1]) forces a fluid[2] to organize into an ordered vortex movement within the unit due to the design of the vortex chamber. There are observed physical changes to the fluid resulting from this process:

EFFECTS PRODUCED BY THE VPT PROCESS:

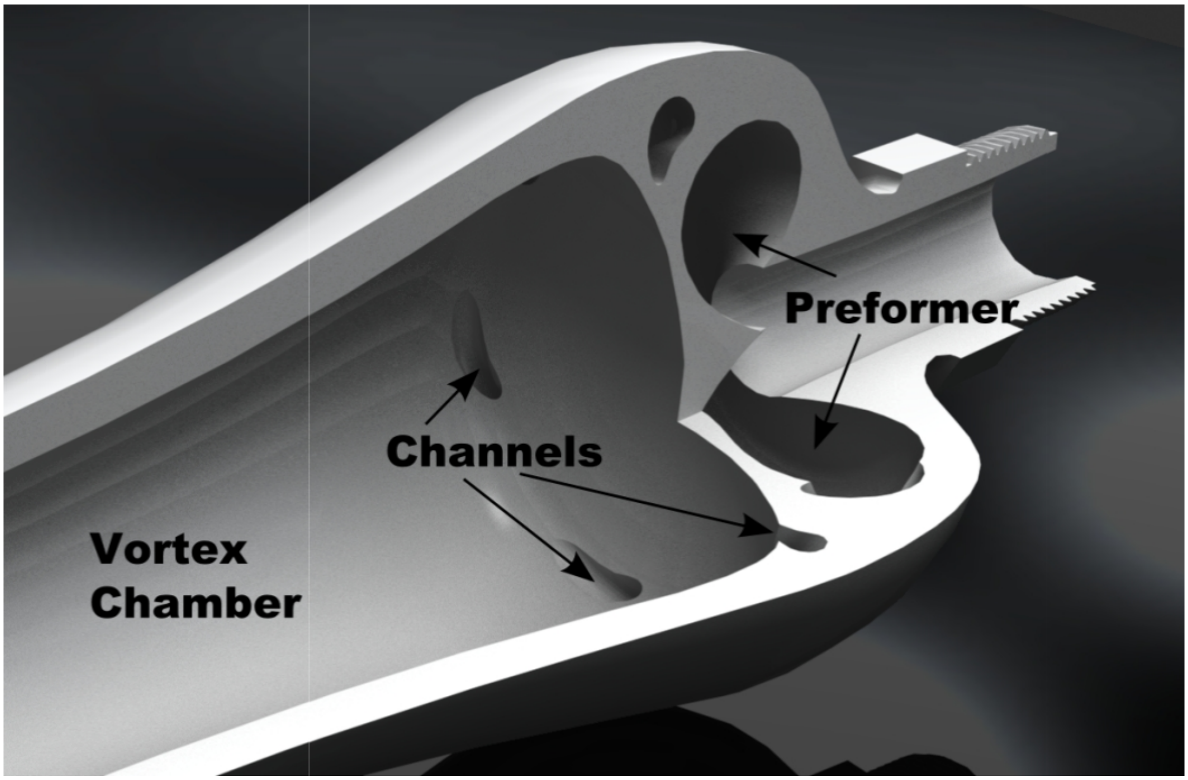
1. **Removes entrained micro-bubbles present in the water from the fluid flow**
2. **Lowers the viscosity of water and improves the heat transfer of the water and, eventually, ice**
3. **Removes (precipitates) calcium ions to form calcite/aragonite crystals**

The energy needed for the entire process originates from the pressure[3] of the incoming water. As the water is forced through the unit, a well-defined vortex with a powerful sub-pressure is generated at the center of the

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

chamber. The low pressure that has been measured in the unit is -0.97 bar or approximately -14 psi. As the water flows through the trumpet-shaped vortex chamber (see Figure 1), its rotating speed increases as the radius of the trumpet narrows.

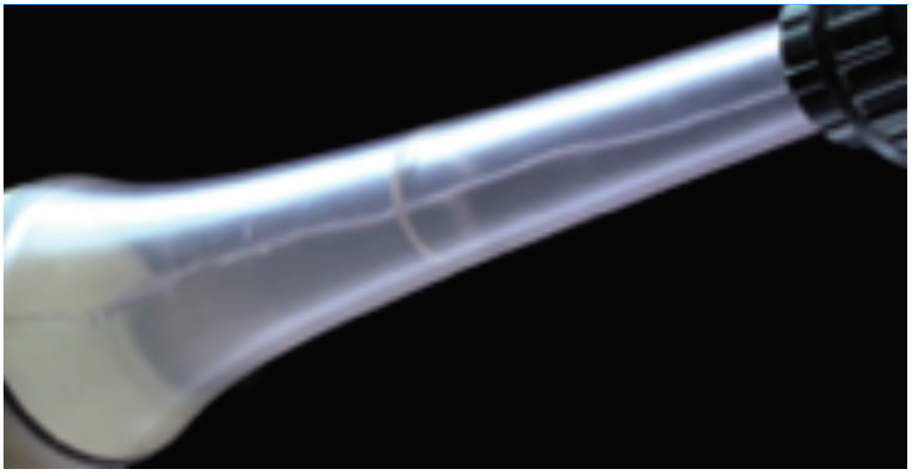
Figure 1 Vortex Chamber of a REALice Wall Unit



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. The trumpet-shaped REALice wall unit (Figure 1) produces a well-defined vortex with a smooth transition to downstream piping.

The effect of this process is that a large pressure gradient is generated inside the vortex. The pressure is at the lowest value in the center of the unit and at the highest at the periphery of the vortex. The lowest pressure at the center extends the entire length of the trumpet. As a consequence, the entrained micro air bubbles are pulled towards the center of the vortex where they coalesce with other bubbles and gather into a shape resembling an elongated tornadic volume of air, with a very low pressure.

Figure 2 Removal of Entrained Micro-Bubbles



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 this sentence is about that size. Microbubbles can be much smaller – and that is what impacts ice quality.

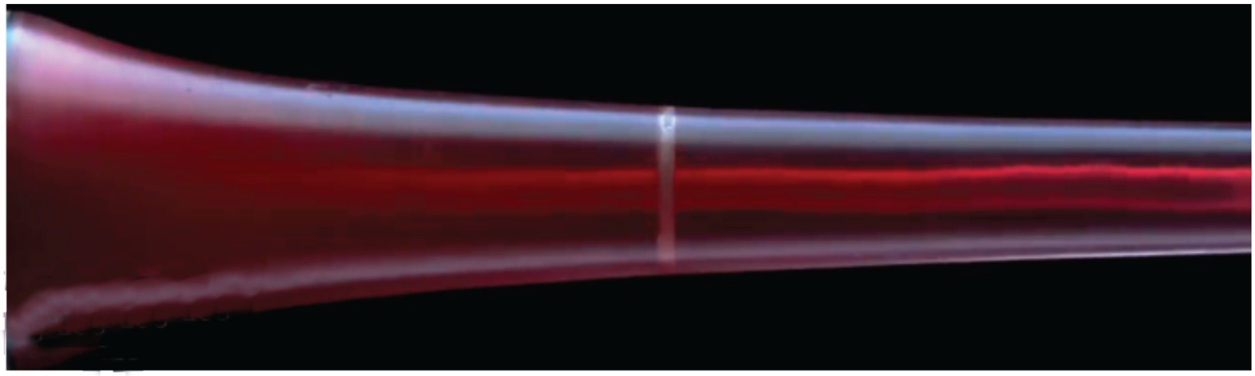
There are 1,000 micrometers (uM) to 1 millimeter. **Micro-bubbles** range from as large as 0.039 inch (1,000 micrometers) to 1 uM or 1/25,400th of an inch. Anything smaller is considered a nano-bubble.

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 creates strong pressure gradients, cavitation and shear forces. As mentioned, this sub-pressure induces micro air bubbles (undissolved air) to move inward toward the vortex axis where they coalesce into larger bubbles.

Figure 3 – The VPT's Vacuum String of Air



In Figure 3, using a transparent, trumpet-shaped VPT, a ***vacuum string*** containing the micro air bubbles pulled to the axis can be clearly seen. They have now become larger and exit the REALice unit. At the standard minimum operating pressure of at least 43 PSI city water pressure, the 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, for example, if the REALice vortex chamber was not used to treat the water.

In the vortex generator, shear forces occur not only close to the wall, but also within the fluid (water) 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 but contributes to the standard explanation why ice is slippery. The Journal of Chemical Physics describes the surface of ice. Rather than a layer of liquid water on the surface of ice, they found the surface was made of loose water molecules, rather like 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 attaches 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, attaching and detaching themselves to various sites on the crystal as they move.

The layer on the top of the ice made with REALice is thicker and more stable due to the decreased viscosity that results from removing the micro bubbles.

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

III. 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-treated 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 (approximately 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.

Decreased 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 the bubbles (undissolved 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 shockwaves 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 $CaCO_3$ 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*

- **Fragmentation**: 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.