Report on Vortex System Test

At Advanced Horticulture Company
Al Hayer, by Al Ain, U.A.E.

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Vortex-System Test

Objectives of the test:

This test was carried out in collaboration between the Advanced Horticulture Company (Al Hayer, by Al Ain, UAE) and H2O Vortex, Luxemburg. The main objective is to study the effect of using Vortex system on enhancing the productivity and other crop properties of cucumbers under the local conditions of the United Arab Emirates.

Vortex system properties: It is well established that Vortex system eliminates lime and air bubbles (positive loaded particles) in the water, reduces the viscosity and brake down any structures and clusters in the water (see enclosed VPT technical data of Vortex system - **Annexes 1&2**). These properties lead among other advantages to better absorption of the nutrients by the plants.

Test Location: Advanced Horticulture Company (Al Hayer, by Al Ain, Abu Dhabi Emirate, UAE.

Plant data:

Crop: Cucumber
Variety: SHAMS – GH – 3
Crop sowing (planting) date: 15/05/2011
Crop first harvesting date: 12/06/2011
Crop last harvesting date: 16/07/2011
Test Termination (Crop Pull out) Date: 17/07/2011

Greenhouse data:

Height:	8 m
Width:	25 m
Length:	200 m
Total crop area:	5000 m2
Net cropping area:	6 beds per arch, width of beds (40 cm) 1 meter between beds, Length 22m, by 24 arches, total 1267 m2
Water Supply:	Vortex & Normal water tanks **(Fig. 1)**.

Fig. 1 : Vortex Water Tank (left) & Normal Water Tank (right)

Conditioning, energy display, greenhouse properties and efficiency: not measured.

Test Conditions:

The Vortex crop (plants irrigated with water generated from Vortex system) as well as the reference/control crop (plants irrigated with normal water) were exposed to equal treatments and conditions in the greenhouse (**Table 1**) with regard to the followings:
Type of the soil (growth media);
Irrigation quantity and frequency;
Fertilizers (nutrients type, quantity and quality);
Plant protection chemicals (quantity and quality);
pH control of the soil;
Temperature & humidity measurement at 12:00 noon (**Fig. 2**);

Fig. 2 : Humidity & Temperature measurement during the entire test period

Training (lifting the plants);
Harvesting schedules;
Crop screening (rejection of unfit fruits/cucumbers)

Test results:

A number of parameters have been selected to study the effect of using Vortex system for the irrigation of cucumber crops vs. the irrigation of reference (control) crop using normal water. These parameters include plant growth, plant viability, the productivity measured on the basis of total yield in kgs of cucumbers, rejected fruits/cucumbers, roots weight, and shelf life of the cucumber fruits of both tested crops.

Plant growth: The growth of Vortex crop was relatively faster than the reference crop. This was obvious at the early stages of the test, and continues when the plants were trained (lifted). The Vortex plants were (2 cm) higher than the reference plants along the growth period until they reached the maximum length (**Table 1**).

Fig. 3 shows the development of the plants of both crops during the test period (e.g., after 13, 27, 45 and 63 days of planting). At day 63, the plants of both crops were pulled out due to low yield and increased fruit rejects.

<u>Fig. 3</u> Plants Development during the test period.

Left: Vortex crop Right: Reference crop

Plant viability: The Vortex crop shows better plant viability than the reference crop. Although the Planting (sowing of seeds) was equal for both crops, the number of viable plants in the area irrigated with Vortex system was much more higher than that of the plants irrigated with normal water (3740 plants Vortex vs. 3200 plants Normal, respectively).

Yield of Cucumbers: Harvesting the cucumbers from both the Vortex crop and the reference crop started on 12 June 2011. However, the yield of cucumbers harvested from the Vortex crop at this day was higher than that of the reference crop (320 kgs vs. 240 kgs, respectively).This trend continues along the test period, with 4 exceptional cases whereby the yield of reference crop was slightly higher than that of the Vortex crop (**Table 1 & Fig. 4)**.

In general, the total yield of cucumbers of the Vortex crop expressed in kgs at the end of the test period was much higher than that of the reference crop (7700 kgs vs. 7240 Kgs, respectively); in other words the Vortex crop yield was 6,35% higher than that of the reference crop.

The Vortex crop shows also less kg rejects of cucumber fruits than that of the reference crop (**Table 1 & Fig. 4**). The total rejects by Vortex crop were 1300 kgs compared to 1600 kgs by the reference crop; e.g. 19.75% less Kg rejects.

Roots weight: Roots of 5 plants of both Vortex crop and reference crop were pulled out, cleaned from soil, and weighed. The total weight of the roots of Vortex crop was slightly higher (135 gms) than the weight of the roots of reference plants (126.5 gms). However, it should be mentioned that it was not easy to collect all the roots, especially the capillary roots clustered in the soil. But from visual point of view, it was obvious that the mass of Vortex crop roots was much larger than that of the reference crop roots. This test, however, have showed that a much more conclusive result could be obtained, if it is carried out in a hydroponic media than in a soil media.

Shelf life of Cucumbers: A preliminary test was carried out to study the shelf life of cucumbers from both Vortex crop and reference crop stored at (4-5 °C) and at room temperature (22-25 °C). The parameters used for this test were the appearance, texture and taste of the cucumber fruits. The duration of the test was 11 days. The results (**Table 2**) showed that the cucumbers of Vortex crop stored at (4-5 °C) have had the best shelf life compared to the reference cucumbers stored at the same temperature; between 7-8 days vs. 5-6 days, respectively. Similar results were also achieved when the same crops were stored at room temperature. The shelf life of cucumbers from the Vortex crop ranged between 5-6 days, while the shelf life of cucumbers from the reference crop stored at the same temperature deteriorated quickly after 3-4 days. It is also worth mentioning that besides the freshness and appetising taste, the cucumbers from Vortex crop were juicier than those of the reference crop.

Table. 2: Shelf life of cucumbers

Date	Shelf life at (4-5 °C)						Shelf life at room Temp. (22- 25 °C)					
	Vortex Crop			Reference Crop			Vortex Crop			Reference Crop		
	A	TX	TS	A	TX	TS	A	TX	TS	A	TX	TS
17-07-2011	Bright green	Solid & crunshy	Fresh & tasty	Bright green	Solid & crunshy	Fresh & tasty	Bright green	Solid & crunshy	Fresh & tasty	Bright green	Solid & crunshy	Fresh & tasty
18-07-2011	Bright green	Solid & crunshy	Fresh & tasty	Bright green	Solid & crunshy	Fresh & tasty	Bright green	Solid & crunshy	Fresh & tasty	Bright green	Solid & crunshy	Fresh & tasty
19-07-2011	Bright green	Solid & crunshy	Fresh & tasty	Bright green	Solid	Fresh & tasty	Bright green	Solid	Fresh & tasty	Green	Semi Solid	Slightly lost freshness& original taste
20-07-2011	Bright green	Solid	Fresh & tasty	Bright green	Semi solid	Acceptable	Bright green	Solid	Fresh & tasty	Green, wrinkled at the ends	Soft & bends easily	Slightly lost freshness& original taste
21-07-2011	Bright green	Solid	Fresh & tasty	Bright green	Semi solid	Acceptable	Bright green	Solid	Fresh & tasty	Wrikled at the ends	Soft & bends easily	Eatable, lost original taste
22-07-2011	Bright green	Solid	Fresh & tasty	Green	semi solid	Acceptable	Bright green	Solid	Fresh & tasty	Wrinkled	Soft & bends easily	Eatable, lost original taste
23-07-2011	Bright green	Solid	Fresh & tasty	Green,ends slightly wrinkled	Soft, bends easily	Acceptable	Bright green	Solid	Fresh & tasty	Very wrinkled	Soft & bends easily	Lost original taste
24-07-2011	Bright green	Semi solid	Fresh & tasty	Changed color, slightly wrinkled	Soft, bends easily	Lost taste	Bright green	Slightly soft	Acceptable	Very wrinkled	Soft & bends easily	Not eatable
25-07-2011	Color slightly changed	Slightly soft	Acceptable	Dark green, wrinkled	Soft, bends easily	Lost taste	Color slightly changed	Slightly soft, bends easily	Acceptable	Very wrinkled	Too soft	Not eatable
26-07-2011	Color moderatly changed	Slightly soft, bends easily	Acceptable	Dark green, wrinkled	Too soft	Not acceptable	Color slightly changed	Slightly soft, bends easily	Acceptable	Dark green & strongly wrinkled	Very soft	Not eatable
27-07-2011	Dark green, wrinkled at the ends	Slightly dehydrated, bends easily	Eatable but not tasty	Dark green, very wrinkled	Very soft	Not acceptable	Dark green, wrinkled at the ends	Slightly dehydrated, bends easily	Eatable but not tasty	Dark green & strongly wrinkled	Very soft	Not eatable
28-07-2011	Dark green, wrinkled at the ends	Slightly dehydrated, bends easily	Not eatable	Dark green, very wrinkled	Very soft	Not acceptable	Dark green, wrinkled at the ends	Slightly dehydrated, bends easily	Not eatable	Dark green & strongly wrinkled	Very soft	Not eatable

A = Appearance; TX = Texture; TS = Taste

Conclusions & Recommendations:

Although the test of Vortex system was carried out under harsh weather conditions (15 May -17 July 2011) and the crop variety used was not the proper one (Dr. Michael Karim), it can be concluded that Vortex crop showed in general better results than the reference (control) crop with regard to all parameters tested.

The growth of the Vortex crop was slightly faster than that of the reference crop, the viability of the plants was much higher, and the total yield expressed in kgs was also higher by 6.35 %. The kgs rejects of cucumbers using Vortex system was less by 19.75%, and the mass and weight of the roots of Vortex crop, although not conclusive, was slightly better than that of the reference crop.

The results also showed that the shelf life of cucumbers from the Vortex crop was much better than that of the reference crop when stored at low temperature in a household fridge (4-5 °C) and at room temperature (22-25 °C).

These results indicate that Vortex system has positive effects not only on the plant growth and yield, but also on product quality and shelf life as well as on product consistency and taste, and confirm results obtained else where in the Netherlands and Canada.

Thus, it is recommended to utilize this system (Vortex system) in a wider scale in the UAE and the Gulf region.

Table 1: Test conditions & harvest data

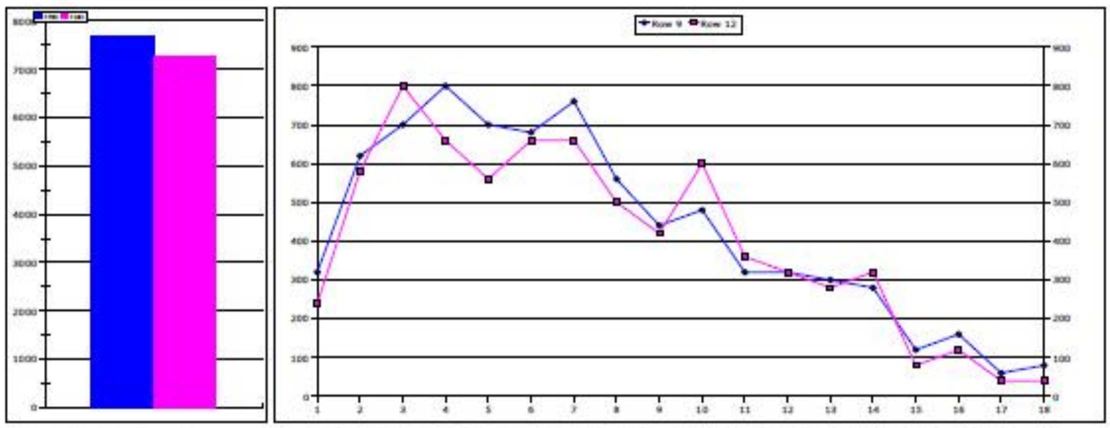
Date	Temp C°	Humidity %	Age of Plants	Plant Growth (cm)		Yields (Kg)		Yields Reject (Kg)	
	12:00 noon	12:00 noon	Days	Vortex	Normal	Vortex	Normal	Vortex	Normal
16/5/2011 to 22/5/2011	35	48	02 to 08						
23/5/2011 to 29/5/2011	36	44	09 to 15						
30/5/2011 to 05/6/2011	35	45	16 to 22						
06/6/2011 to 12/6/2011	35	44	23 to 29	1,21	1,19	320	240	40	60
13.06.2011	36	44	30						
14.06.2011	35	46	31	1,34	1,33	620	580	30	30
15.06.2011	35	45	32						
16.06.2011	35	46	33			700	800	20	40
17.06.2011	34	46	34						
18.06.2011	36	60	35	1,60	1,58	800	660	10	20
19/06/2011	37	60	36						
20/06/2011	37	65	37			700	560	20	30
21/06/2011	36	65	38	1,62	1,60				
22/06/2011	36	65	39			680	660	20	40
23/06/2011	34	70	40						
24/06/2011	34	70	41			760	660	20	20
25/06/2011	34	99	42						
26/06/2011	31	99	43			560	500	20	40
27/06/2011	31	99	44						
28/06/2011	32	99	45			440	420	40	100
29/06/2011	33	55	46						
30/06/2011	34	53	47			480	600	80	40
07.01.2011	32	59	48						
07.02.2011	32	59	49			320	360	80	100
07.03.2011	32	59	50						
07.04.2011	34	61	51			320	320	60	120
07.05.2011	19,7	65	52						
07.06.2011	28,8	58	53			300	280	180	240
07.07.2011	26,5	51	54						
07.08.2011	27,6	60	55			280	320	240	180
07.09.2011	25,1	56	56			0	0	0	0
07.10.2011	25	56	57			120	80	160	160
07.11.2011	29,8	71	58						
07.12.2011	25,4	58	59			160	120	80	160
13/7/2011	25	53	60						
14/7/2011	25	48	61			60	40	120	80
15/7/2011	25	45	62						
16/7/2011	25	45	63			80	40	80	160
						7.700	**7.240**	**1.300**	**1.620**
PLANT COUNT		JUNE 29 2011		Plant Growth (cm)		Yields (Kg)		Yields Reject (Kg)	
		VORTEX	3.740	**1,62**	**1,60**	106,35%	**100,00%**	80,25%	**100,00%**
		NORMAL	3.200	Vortex	Normal	Vortex	Normal	Vortex	Normal

Pesticides used - Description and abbreviations:

PPC: Plant Protection Chemicals e.g. Forcebell, Prevex, Beltinol and Phyton
Humic: Humic acid to reduce the pH value
Micro: Micro elements; zinc, magnesium, baron, and sodium molibdate
MAP: Mono ammonium phosphate
CaO: Calcium oxide

RESULTS IN KG

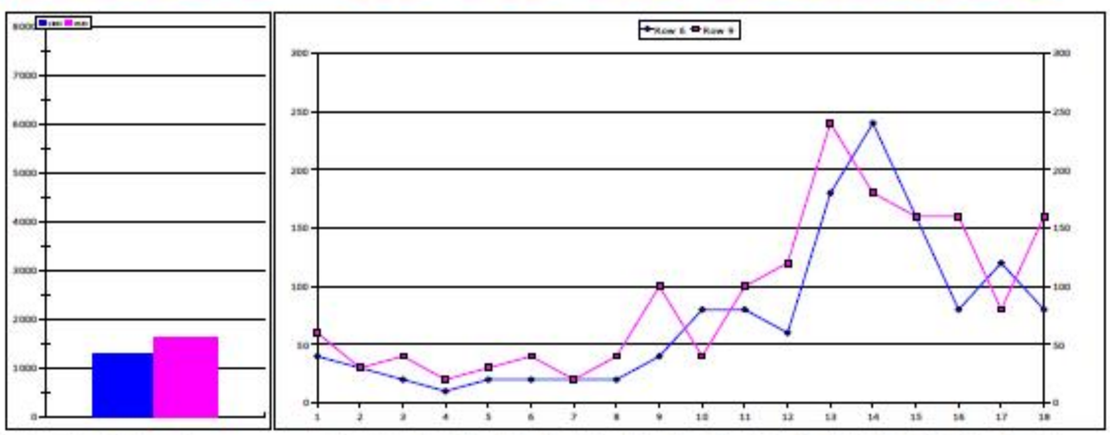
16.05.2011	SEED HARVEST	11.06.2011	12.06.2011	14.06.2011	16.06.2011	18.06.2011	20.06.2011	22.06.2011	24.06.2011	26.06.2011	28.06.2011	30.06.2011	02.07.2011	04.07.2011	06.07.2011	08.07.2011	10.07.2011	12.07.2011	14.07.2011	16.07.2011
7700	KG yields	Vortex	320	620	700	800	700	680	760	560	440	480	320	320	300	280	120	160	60	80
7240	KG yields	Normal	240	580	800	660	560	660	660	500	420	600	360	320	280	320	80	120	40	40



Temp C° 12:00 noon	35	35	35	36	37	36	34	31	32	34	32	34	28,8	27,6	25	25,4	25	25
Humidity % 12:00 noon	45	46	46	60	65	65	70	99	99	53	59	61	58	60	56	58	48	45

RESULTS IN REJECTS

16.05.2011	SEED HARVEST	11.06.2011	12.06.2011	14.06.2011	16.06.2011	18.06.2011	20.06.2011	22.06.2011	24.06.2011	26.06.2011	28.06.2011	30.06.2011	02.07.2011	04.07.2011	06.07.2011	08.07.2011	10.07.2011	12.07.2011	14.07.2011	16.07.2011
1300	KG rejects	Vortex	40	30	20	10	20	20	20	20	40	80	80	60	180	240	160	80	120	80
1620	KG rejects	Normal	60	30	40	20	30	40	20	40	100	40	100	120	240	180	160	160	80	160



Temp C° 12:00 noon	35	35	35	36	37	36	34	31	32	34	32	34	28,8	27,6	25	25,4	25	25

<u>Fig. 4</u>: Harvest data graph, kilos yields & rejects of cucumbers

ANNEX 1

VPT – Vortex Process Technology technical overview

Johan Kronholm, MSc, PhD, Research Manager, Watreco AB, Revision 201101

Introduction

The idea behind VPT - Vortex Process Technology is to allow a fluid to self-organize into an ordered vortex movement. Vortex movement is fundamental in nature. It occurs in galaxies, tornados, mountain streams and human blood flow. The unique biomimetic design of Watreco's vortex generators allows the harnessing of the extreme power of a tornado in industrial applications.

The Watreco vortex generator has no moving parts, continuously processes fluids and requires a minimum of maintenance.

The vortex generator is inspired by Viktor Schauberger, an Austrian forester who spent his entire life studying natural water flow. During the first half of the 20th century, Schauberger came up with eco-friendly alternatives to some of the non-sustainable technology still in use today.

VPT - Vortex Process Technology

The Watreco vortex generator is protected by an international patent. It is able to generate a well-defined and controlled vortex at a considerably lower pressure and flow than what can be achieved through other techniques.

As illustrated in Figure 1 and Figure 2, the vortex generator shapes the fluid flow in three stages:

- **Preformer.** The inlet of the vortex generator provides a smooth outward direction of the flow through toroidal motion toward a set of well-defined channels.
- **Channels.** After the preformer, 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.
- **Vortex chamber.** In the vortex chamber, the vortices from the channels are wound together, similar to how a rope is spun together from a set of threads. 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 shape with a narrow outlet (Figure 2) causes an extensive spread of the fluid which is useful for example in a spraying application or when a large volume of water needs stirring.

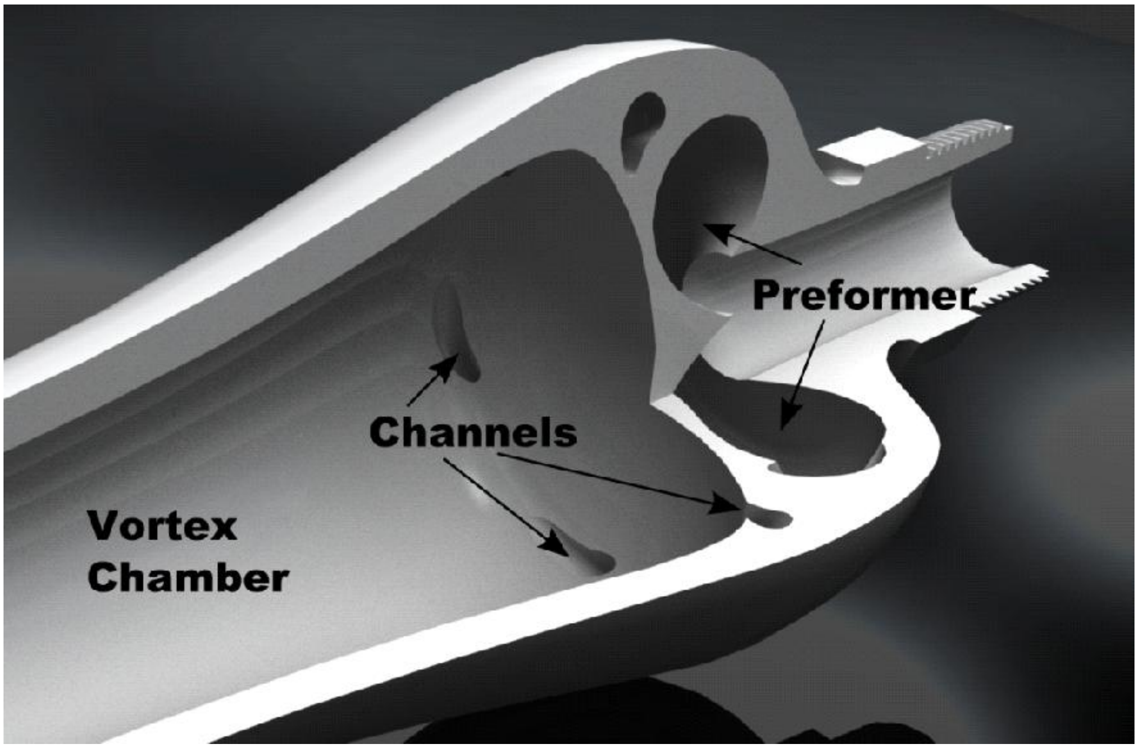


Figure 1: The Watreco vortex generator with trumpet-shaped vortex chamber.

The vortex flow gives rise to strong pressure gradients and shear forces. A pressure gradient is the transition between low and high pressure. Shear forces in a flowing medium occur when the flow velocity changes rapidly over a short distance.

The radial pressure gradient in the vortex chamber causes a strong subpressure along the vortex axis. When using water, this subpressure forces gas bubbles (undissolved gas) to move inward toward the vortex axis. If there is enough undissolved gas in the water, a “vacuum string” along the axis can be clearly visible through a transparent vortex generator. If the pressure gradient is strong enough, cavitation occurs (see below). The strong pressure gradient shifts chemical balances, giving rise to reactions that would not happen under normal flow conditions.

In the vortex generator, shear forces occur not only close to the wall, but also within the fluid itself, for example when the jet streams exiting the channels are wound together. 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 causes formation, aggregation or fragmentation of solid matter in the fluid under certain circumstances.

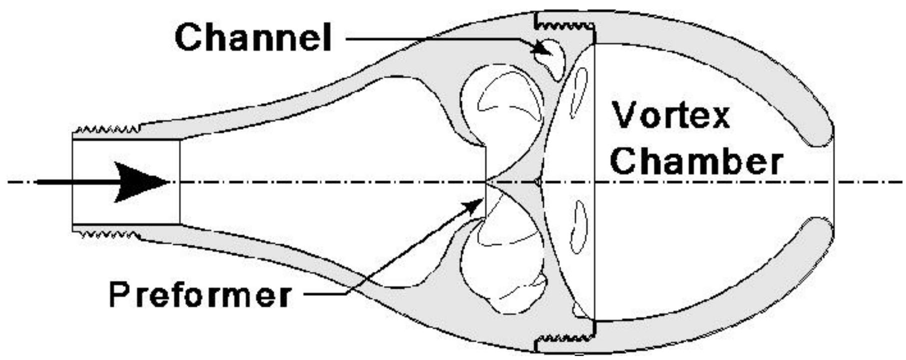


Figure 2: Cross section of vortex generator with egg-shaped vortex chamber.

Vortex flow phenomena

Degassing

Macroscopic and microscopic gas 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. Dissolved gases are not generally affected by this process. Substances that gather at bubble surfaces may follow the bubbles toward the vortex axis, aggregate and then be separated out.

Mixing

As the low pressure in the vortex chamber goes below the ambient pressure, gases or liquids can be sucked into the vortex chamber. The sucked-in fluid will be efficiently mixed with the spinning medium in the chamber. This process is very powerful in mixing for example water with air or other gases, or water with oil, thus producing stable emulsions.

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 an extreme release of heat within a small volume. This process is called cavitation and may for example induce the formation of lime (calcium carbonate) particles.

Properties of vortex processed water

An examination of the properties of vortexed water was made in 2010 and 2011 by the Polymer Technology Group Eindhoven BV (PTG/e), an independent research and knowledge institute which is a part of the Eindhoven University of Technology (TU/e). Samples were taken from municipal water in Holland, before and after VPT treatment. Water treatment was made with a standard Watreco vortex generator at a water pressure of 3.5 bar.

Viscosity

A decrease in viscosity was observed by PTG/e after VPT treatment. The difference was between 3% and 17%, depending on water quality and temperature. As shown by Albert Einstein in 1905, gas bubble content affects the viscosity of water. As bubbles (undissolved gases) are removed, a decrease in viscosity can therefore be expected.

Heat transfer

VPT treatment changed the melting behaviour of ice. The heat capacity was 5% higher for ice and 3% higher for liquid water.

Electrical conductivity

There was an increase by 3% in electrical conductivity after VPT treatment in the PTG/e study. This can be due to either changes in viscosity or a change in the properties of charged particles and/or ions in the water.

Surface tension

Even though viscosity is reduced by VPT treatment, changes in surface tension were not observed by PTG/e.

ANNEX 2

VPT – Vortex Process Technology Limescale Prevention

Johan Kronholm, MSc, PhD, Research Manager, Watreco AB, Revision 201101

Limescale formation (precipitation) in hard waters normally occurs on surfaces of for example pipes, heating elements and shower walls. After treatment with the Watreco Vortex Generator, limescale formation is reduced and can even be eliminated. Old scalings often fall off over time.

The Watreco Vortex Generator is a passive system that doesn't use chemicals or electromagnetic fields. It creates a powerful vortex motion in the water, which causes strong pressure gradients and shear forces within the fluid. These extreme conditions induce lime particle formation within the fluid rather than at surfaces. Lime particle formation in the water inside the Vortex Generator occurs in three stages:

- **Formation.** In the Vortex Generator, water rapidly moves between very low and very high pressure. This causes cavitation, the formation and implosion of microscopic bubbles. Each bubble implosion produces extreme local heat, which leads to the formation of lime particles in hard water.
- **Fragmentation.** Already formed lime particles fragment as they move through the pressure gradients and shear forces of the Vortex Generator, so that large particles break down into several small particles.
- **Precipitation nuclei formation.** Lime formation occurs at surfaces. With large amounts of microscopic lime particles in the water, the total surface area of those particles can be much bigger than that of pipes or heating elements. Such particles act as seeds (crystallization nuclei) for new lime growth. New lime formation will in this case add to the lime particles rather than cause limescaling on the equipment.

If enough lime particles have been formed under the extreme conditions of cavitation in the Vortex Generator, the chemical balance is shifted so that lime to some extent can be dissolved rather than formed. This dissolving occurs on both new and old lime, which explains why old limescale often falls off after the installation of the Watreco Vortex Generator.

The formation of lime particles means that lime sludge can form at the bottom of tanks, or a white lime powder can remain on dried surfaces, where hard scale would form without vortex treatment. However, the total hardness remains the same after treatment, since no calcium has been removed.

Figure 1: SEM image (50x magnification) of dried lime particles after vortex treatment (courtesy of Pathema, Holland).

A Surface Electron Microscopy (SEM) image of dried lime sludge from a cooling tower water basin, where the water was treated with a Watreco Vortex Generator, is shown in Figure 1. Most particles in the image are around 100 □m. Smaller particles also exist in the water, but did not settle at the bottom in this case due to water motion in the basin. Without VPT treatment, hard limescale forms at surfaces, leading to costly maintenance.