

Effect of the Turbu-Flow on Calcium Carbonate Scaling

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October 2004

Titre : Study of the effect of the Turbo-Flow on calcium carbonate scaling	No. de rapport : REP-2004-01
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Client : Walter Bauer	Nombre de pages : 17

Summary

This document presents an up to date summary of the observation made on the effects of the Turbu-Flow on calcium carbonate scaling. Some other observations regarding the effects of the Turbu-Flow treated waters are presented: namely the effect on microorganisms high killing rates. Some explanations of these effects are presented.

Bernard Daigle, Ph. D. Chemistry

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1. Introduction

The Turbu-Flow is a patented anti-scaling water treatment unit. It is designed and manufactured in Australia. The manufacturer presents the unit as a “proven system” and claims the following:

- ◇ It will stop calcium carbonate scaling
- ◇ It will dissolve existing calcium carbonate scale
- ◇ Retards the corrosive action of iron sulphide and iron oxide
- ◇ Stops the deposition of free sulphite and in most cases brings it back to solution
- ◇ Retards the corrosive action of hydrogen sulphide upon metal (steel)
- ◇ Stops the deposition of salt, and in all cases brings it back into solution
- ◇ Inhibits the formation of algae
- ◇ Works in either hot or cold water

These technical claims would result in reduced maintenance costs and allow equipment to work more efficiently.

In this document we start looking at the basic observations already made on this device as well as to fundamental explanation of some of the phenomena observed.

2. Observations and measurements

In the following sections we will present the observations reported or made regarding the effects of the Turbu-Flow or Turbu-Flow treated water on different systems.

2.1. Zeta potential

The Zeta potential is a measure of the electric charge of a particle in water. It is a very powerful indicator of the possibility of particles to agglomerate and form larger particles. The Zeta potential of particles in raw and Turbu-Flow treated waters was measured. Results are presented in figures 1 (raw water) and figure 2 (treated water). These results were obtained by Mr Claude Vizcaino from CAD Instrumentation in Les Essarts le Roy, France. During a discussion with Mr Vizcaino, he insisted on the fact that they did not prepare these samples and that a single sample of each of the raw and

treated waters was analysed. However he confirmed that repeated measurements on these samples gave consistent results.

Figure 1

Zeta Potential of particles in raw water

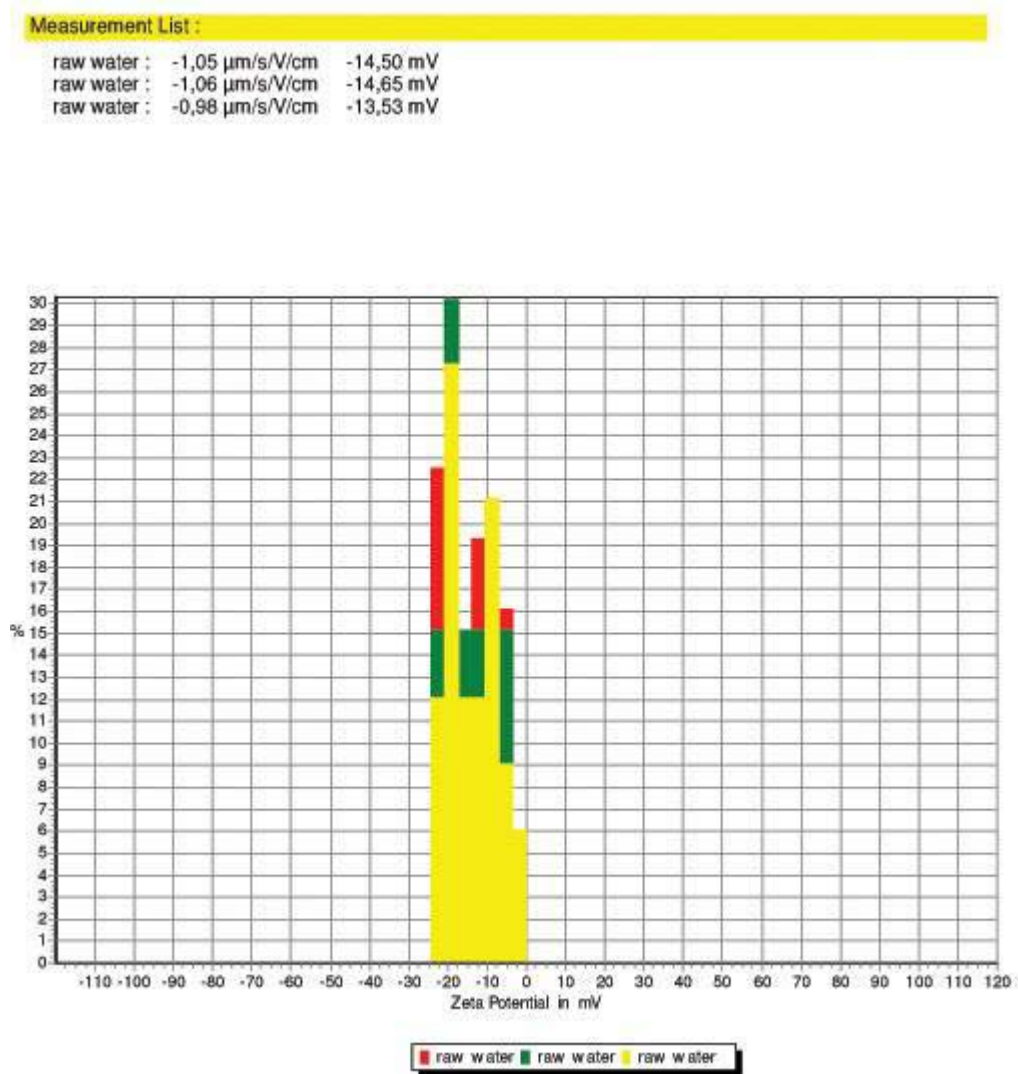
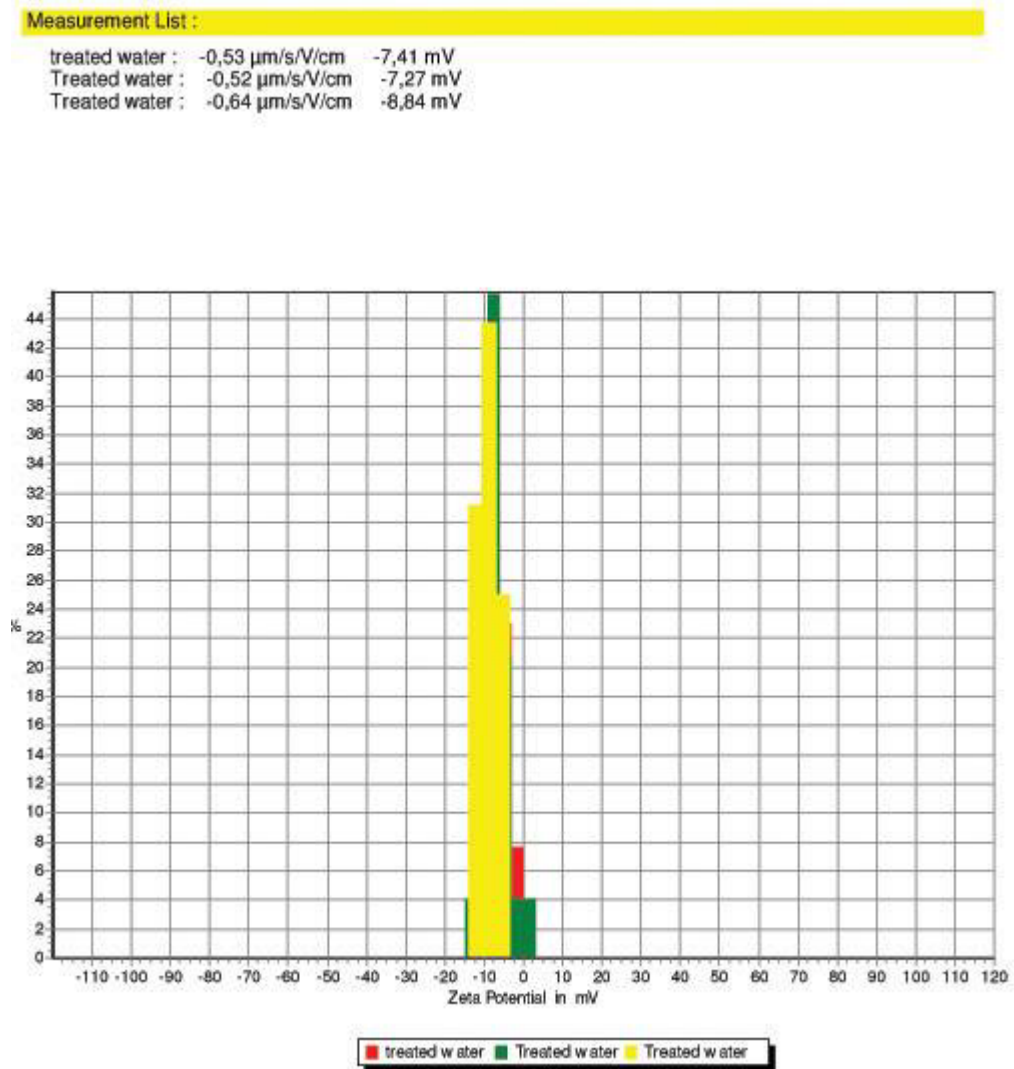


Figure 2

Zeta Potential of particles in Turbu-Flow treated water



These results suggest that the Turbu-Flow has a great influence on zeta potential. In fact for water of the same origin, Zeta Potential is decreased by a factor of almost two.

The importance of this Zeta Potential shift can not be overstressed. Many of the important properties of particulate systems are determined directly (or indirectly) by the electrical potential present on the particles. The potential distribution determines

the interaction energy between particles. In many cases this is responsible for the stability of particles towards coagulation and flow behaviour of suspensions. There are many situations in which the Zeta potential is a parameter of great importance such as the flow of liquid or particles through membranes. This will have a major impact on microbial systems in contact with treated water.

2.2. Crystallisation of calcium carbonate

Understanding calcium carbonate chemistry is key to understanding the effects of the Turbu-Flow on calcium carbonate scaling and on deposits of other minerals. Calcium carbonate chemistry is very complex and even though it has great impacts on environmental chemistry and industrial operations, very few comprehensive texts are available on it. To understand its impact on the industrial applications of steam production and boiler operations, we have to look closely at it and to understand some of the mathematical tools that have been developed to monitor this chemistry.

One of these tools is the Langelier Stability Index (LSI). It is a number that predicts the stability of calcium carbonate in water systems. It will indicate if the water will precipitate and form scale or if it will dissolve calcium carbonate. Langelier developed a mathematical expression able to predict the pH at which water will be saturated with calcium carbonate. The saturation pH is named pH_s . The actual LSI is expressed as the difference between the pH of the solution and the saturation pH. One can then write:

$$LSI = pH - pH_s$$

From this equation, one can see that when the actual pH is higher than the pH_s , the LSI is positive. This implies supersaturation of the solution in calcium carbonate and therefore the solution will have a tendency to produce scale. An increasing LSI positive value indicates an increasing scaling potential.

If the pH is lower than the pH_s , the LSI value will be negative and have a very limited capability to scale. In fact as the absolute value of the negative LSI grows, the ability of the water to dissolve calcium carbonate increases.

If the LSI is close to zero this indicates a borderline situation. Any change in water quality, temperature change, and evaporation could change the index and change the ability of the water to create scale.

Computation of pH_s implies knowledge of the following variables: Concentration of Ca^{2+} (mg/l), concentration of total dissolved solids (mg/l), temperature of the water and actual pH. Higher concentration of calcium, total dissolved solids and hardness will promote scaling. Higher temperature will also promote scaling. Lowering pH will tend to diminish scaling tendency.

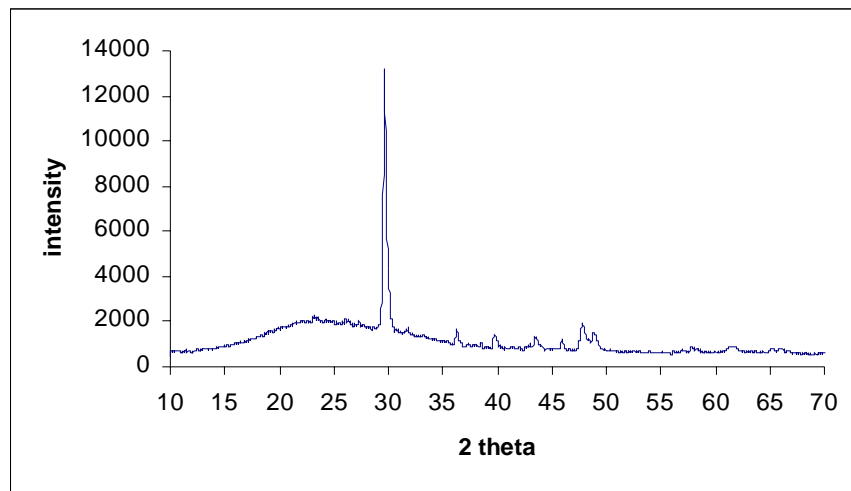
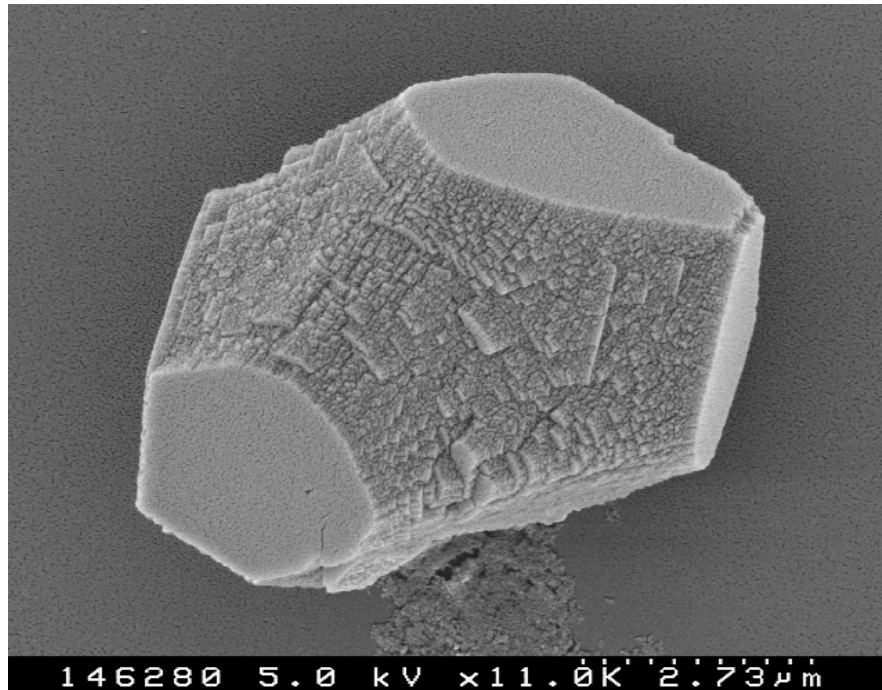
Now the evidence we have suggests that passage of a calcium carbonate containing solution through the Turbu-Flow changes the crystallisation conditions in that solution. Observations were made of two things:

- ◇ A very soft, non sticking deposit of calcium carbonates at low points in circulation systems
- ◇ A solubilisation of the existing scale in pipes and other equipment

It has been shown with scanning electron microscope that the calcium carbonate crystals produced after passage through the Turbu-Flow are of a different nature than the ones obtained from the untreated water. Figure 3 shows the crystals obtained from the raw water as well as the SEM analysis of its crystal structure while figure 4 shows the crystals obtained from the treated water as well as the SEM analysis of this crystal structure.

Figure 3

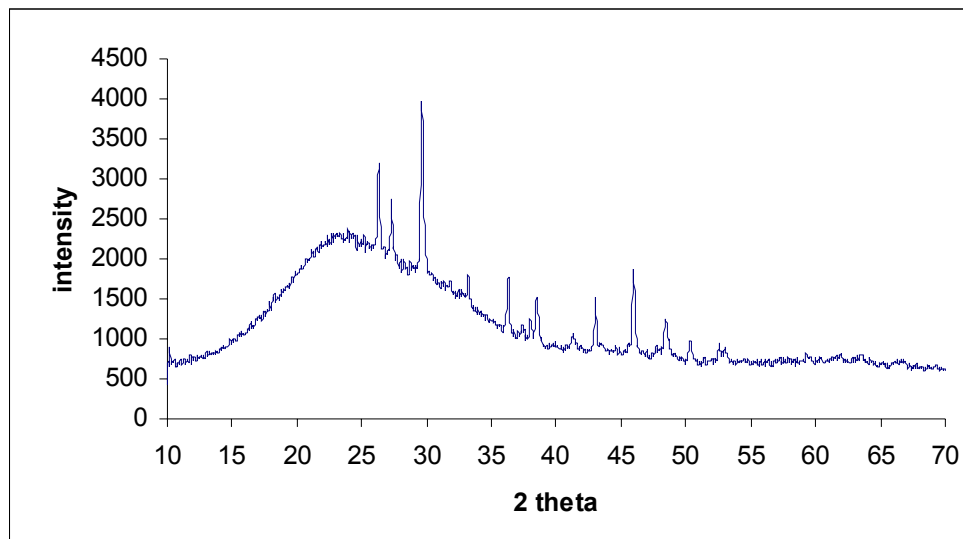
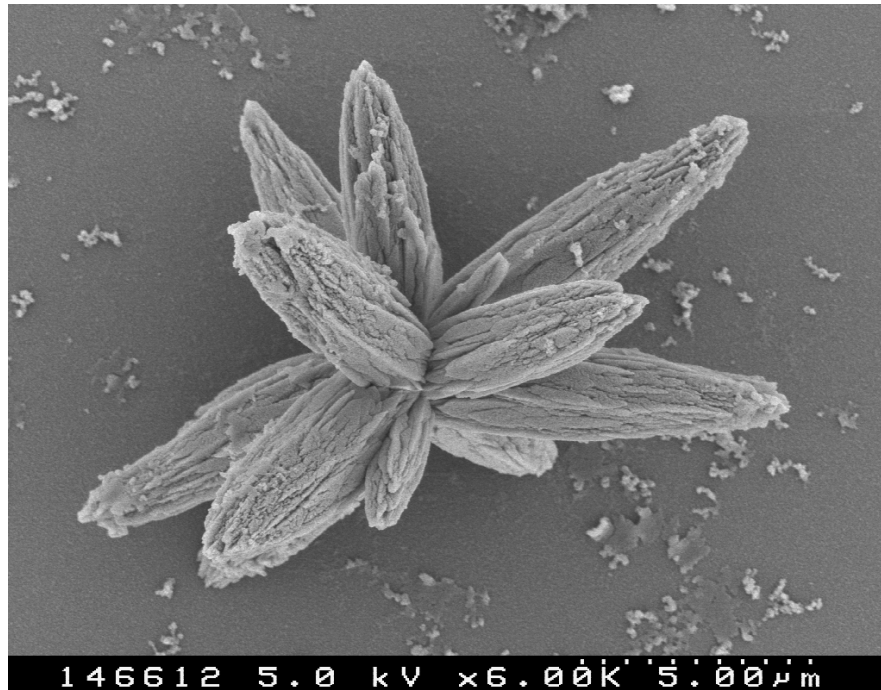
Calcium carbonate crystals from the raw water.



This diagram is typical of calcite crystals.

Figure 4

Calcium carbonate crystals from the treated water.



This diagram is typical of aragonite crystals.

Passage of the solution through the Turbu-Flow changes the electrochemical conditions and therefore changes the crystallisation conditions in such a way that a

different crystalline structure is obtained from the crystallization of the calcium carbonate present in solution.

The hypothesis made is that when the solution is passing through the Turbu-Flow, very fine (nanosize) crystals are created and are seeding the solution. If the conditions are right (positive LSI) growth of these crystals will occur to the point where LSI comes close to zero. Since very many of these seeds are created, each crystal does not grow very much creating a very fine non sticking deposit. Chemical analysis of the raw and treated water is presented in table 1. When one looks at these results, one can see that very little change can be measured in the water after treatment except for turbidity: An increase in turbidity is observed. The fact that turbidity increases and calcium concentration remains stable supports our hypothesis that very small crystals (that can not be differentiated from ionized calcium with standard measurement methods) are generated in the Turbu-Flow

Table 1

Chemical analysis of raw and Turbu-Flow treated water

		Instrument Detection Limit	Raw Water	Turbu-Flow Treated Water
Wet Chem.	Conductivity (us/cm)	3	720	720
	pH (pH units)	0.1	7.8	7.7
	Turbidity (NTU)	0.10	0.30	0.50
Metals	Aluminum (mg/L)	0.01	0.02	0.02
	Barium (mg/L)	0.01	0.08	0.08
	Beryllium (mg/L)	0.001	<0.001	<0.001
	Boron (mg/L)	0.05	<0.05	<0.05
	Cadmium (mg/L)	0.0001	<0.0001	<0.0001
	Calcium (mg/L)	0.5	84	85
	Chromium (mg/L)	0.001	0.001	0.001
	Cobalt (mg/L)	0.0008	<0.0008	<0.0008
	Copper (mg/L)	0.001	0.059	0.052
	Iron (mg/L)	0.05	0.11	0.11
	Lead (mg/L)	0.001	<0.001	<0.001
	Magnesium (mg/L)	0.5	20	20
	Manganese (mg/L)	0.001	0.004	0.004
	Molybdenum (mg/L)	0.001	<0.001	<0.001
	Nickel (mg/L)	0.002	<0.002	<0.002
	Potassium (mg/L)	0.5	1.9	1.9
	Silver (mg/L)	0.0001	<0.0001	<0.0001
	Sodium (mg/L)	0.5	19	20
	Strontium (mg/L)	0.001	0.24	0.24
	Thallium (mg/L)	0.0003	<0.0003	<0.0003
	Uranium (mg/L)	0.005	<0.005	<0.005
	Vanadium (mg/L)	0.001	0.003	0.003
	Zinc (mg/L)	0.003	0.004	0.004
	Zirconium (mg/L)	0.001	<0.001	<0.001

2.3. Dissolution of existing scale

In the preceding paragraphs we have concluded that the Turbu-Flow effectively lowers the calcium ions concentration in solution by generating a large number of very small

calcium carbonate crystals. This results in a lowering of the Langelier index. It does so by crystallising calcium carbonate in nanocrystals that remain in suspension and are non sticking. In fact they are non sticking because the calcium ions concentration is too low and would not allow them to grow and get attached to surfaces or between themselves. To use an image, the glue that would allow them to stick to surfaces or between themselves is no longer available. This lower calcium carbonate concentration causes the LSI to fall below the zero value. This causes existing calcium carbonate to dissolve. A large portion of the existing calcium carbonate scale will be carried by the flow of water as a non sticking sludge and will deposit at a low point in the circulation system.

It should be noted that this technology can not lower calcium ion concentration in solution at a lower value than the one defined by solubility constant of either calcite or aragonite.

2.4. Destruction of biofilm

Observation has been made that water treated with the turbu flow will stop and reverse the growth of biofilm. This observation has been made at numerous occasions and will be the object of scientific investigation in the near future. Our hypothesis is made of two suppositions: first the loss of calcium carbonate solids in the system leaves no place to the micro-organisms to attach. Second, the change in Zeta Potential modifies the interaction between particles and cell membrane. We do believe that the modification of this interaction could be responsible for the control of the growth of biofilm. Essentially, nano size crystals with modified zeta potential could cross the zeta potential modified membrane cell and poison the cell. This would however imply that this treatment would have to be done with water that is originally charged enough in calcium carbonate to produce crystals during its passage through the Turbu-Flow.

2.5. Effects on pH

Treatment with the Turbu-Flow has shown no effect on pH. These results were obtained by all sources, known by us, experimenting with the Turbu-Flow. These

results are consistent with a change in solid content of calcium carbonate since total acidity does not change as $\text{CaCO}_{3(s)}$ precipitates or dissolves.

3. Disinfection using Turbu-Flow treated water

Table 2 presents the results of measurements of micro-organism population before and after sterilisation using Turbu-Flow treated water.

Table 2

Results of sterilisation using Turbu-Flow treated water

PRELIMINARY DATA

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LAB NUMBER: 274841

SAMPLE ID: Dry Steam Vapor System, 2400 Series or Better

TEST REQUESTED: Surface Disinfectant Validation Test

DATE: 25 Oct 2004

TABLE 1. Results

COUPON

SURFACE/

ORGANISM

Application AVERAGE

CONTROL

TITER (CFU)

AVERAGE

RECOVERED

(CFU)

PERCENT

REDUCTION

(%)

LOG₁₀

REDUCTION

Tile

S. aureus

1 $2.5 \times 10^7 \sim 2.8 \times 10^4 \sim 99.89 \sim 2.95$

2 $2.5 \times 10^7 < 1.0 \times 10^0 > 99.999996 > 7.40$

3 $2.5 \times 10^7 < 1.0 \times 10^0 > 99.999996 > 7.40$

Tile

S. epidermidis

1 $1.1 \times 10^7 < 1.0 \times 10_0 > 99.999991 > 7.04$

2 $1.1 \times 10^7 < 1.0 \times 10_0 > 99.999991 > 7.04$

3 $1.1 \times 10^7 < 1.0 \times 10_0 > 99.999991 > 7.04$

Tile

P. aeruginosa

1 $1.8 \times 10^7 < 1.0 \times 10_0 > 99.999994 > 7.26$

2 $1.8 \times 10^7 < 1.0 \times 10_0 > 99.999994 > 7.26$

3 $1.8 \times 10^7 < 1.0 \times 10_0 > 99.999994 > 7.26$

Tile

S. choleraesuis

1 $1.4 \times 10^7 < 1.0 \times 10_0 > 99.999993 > 7.15$

2 $1.4 \times 10^7 < 1.0 \times 10_0 > 99.999993 > 7.15$

3 $1.4 \times 10^7 < 1.0 \times 10_0 > 99.999993 > 7.15$

Tile

E. coli

1 $1.8 \times 10^7 < 1.0 \times 10_0 > 99.999994 > 7.26$

2 $1.8 \times 10^7 \sim 1.3 \times 10_1 \sim 99.999931 \sim 6.16$

3 $1.8 \times 10^7 < 1.0 \times 10_0 > 99.999994 > 7.26$

TABLE 1. RESULTS (continued)

COUPON

SURFACE/

ORGANISM

Application AVERAGE

CONTROL

TITER (CFU)

AVERAGE

RECOVERED

(CFU)

PERCENT

REDUCTION

(%)

LOG₁₀

REDUCTION

Tile

L. monocytogenes

1 $4.6 \times 10_6 \sim 1.6 \times 10_1 \sim 99.99966 \sim 5.47$

2 $4.6 \times 10_6 \sim 1.0 \times 10_0 \sim 99.999978 \sim 6.66$

3 $4.6 \times 10_6 < 3.5 \times 10_0 > 99.999924 > 6.12$

Tile

E. faecium

1 $2.1 \times 10^7 < 1.0 \times 10_0 > 99.999995 > 7.32$

2 $2.1 \times 10^7 < 1.0 \times 10_0 > 99.999995 > 7.32$

3 $2.1 \times 10^7 < 1.0 \times 10_0 > 99.999995 > 7.32$

Tile

C. albicans

1 $2.9 \times 10^7 \sim 2.0 \times 10_0 \sim 99.999993 \sim 7.16$

2 $2.9 \times 10^7 \sim 2.0 \times 10_0 \sim 99.999993 \sim 7.16$

3 $2.9 \times 10^7 < 1.0 \times 10^0 > 99.999997 > 7.46$

Tile

A. niger

1 $4.9 \times 10^5 < 1.0 \times 10^0 > 99.99980 > 5.69$

2 $4.9 \times 10^5 < 1.0 \times 10^0 > 99.99980 > 5.69$

3 $4.9 \times 10^5 < 1.0 \times 10^0 > 99.99980 > 5.69$

Tile

T. mentagrophytes

1 N/A N/A N/A N/A

2 N/A N/A N/A N/A

3 N/A N/A N/A N/A

Application 1 = Nozzle brush used with a towel placed over the brush. The sample was exposed

for 7 seconds.

Application 2 = Tri-Brush used with a towel placed over the brush. The brush was scrubbed/rubbed

back and forth on the sample for 10 seconds

Application 3 = Tri-Brush used with the towel placed over the brush. The brush was scrubbed/rubbed over the sample for 30 seconds.

(~) values are approximated based on counts outside the range of 25-250 for bacteria or 8-80 for

molds and fungi.

(>) Greater than values are where a <1 count/mL recovery per sample was found

(<) Less than values are where no colonies were found for a sample.

Advanced Vapor Technologies, Inc. Lab # 274841

Preliminary Results Page 3 of 2

DISCUSSION:

The data looks very good for all organisms and applications. The data for the *T.*

mentagrophytes

should be available within 10 days. Please feel free to contact me regarding any questions on the

above data.

STUDY DIRECTOR

This document contains preliminary data. This information has not been reviewed by our quality departments. Although not anticipated, some changes may be reflected in the results of the detailed final report that will follow. Please contact the Customer

Service Department if you have any questions.

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PRINTED: 25 OCT 2004 / 15:52:04 V-001-01/032001

The efficiency of this treatment to kill micro-organisms is impressive especially when the exposure time is considered. Again the exact mechanism which kills these micro-organism has not yet been clearly identified however, we suspect that a mechanism similar to the one described for the destruction of biofilm to be responsible for these good results. The

combined action of the heat and the creation of nano-size crystals that can efficiently disrupt or penetrate the cell membrane are probably responsible for such a high killing rate of these micro-organisms.

4 - Conclusion

This overview of the effects of the Turbu-Flow water treatment system shows a lack of scientific background explanations of the observations made by people using this system. The empirical observation, although not yet explained by a proven theory, can not be denied. The Turbu-Flow prevents scaling in high calcium content water, permits the elimination of existing scaling, stops biofilm from forming, and Turbu-Flow treated water in addition to heat, will disinfect surfaces very efficiently.

CAD실험결과보고서, Turbu-Flow스케일방지

Document prepared by:

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October 2004

Title : 터브플로우의 탄산칼슘스케일 제거효과에 대한 시험, 연구	리포트번호 : REP-2004-01
Author : Bernard Daigle, Ph. D. Chemist	리포트 일자 : October 2004
Client : Walter Bauer	리포트 페이지 : 총 17페이지

<p>요약 :</p> <p>본 자료는 터브플로우의 탄산칼슘(Calcium Carbonate) 제거효과를 시험관찰한 결과를 요약한 것이다.</p> <p>터브플로우로 처리된 물의 스케일제거 효과이외에도 각종 미생물살균효과에 관한 관찰 기록도 수록되어 있다.</p>

Bernard Daigle, Ph. D. Chemistry

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1. 소개

터브플로우는 특허출원된 스케일방지 수 처리장치이다. 호주에서 설계되고 제작 공급된다. 제조사(시험의뢰자)는 시험용 견본을 제출하였으며, 아래와 같은 성능이 입증되었다고 주장한다.

- ✧ 탄산칼슘스케일이 방지된다.
- ✧ 기존의 탄산칼슘스케일이 용해되어 제거된다.
- ✧ 황화철(Iron Sulphide)와 산화철(iron Oxide)의 부식작용을 저지한다.
- ✧ 황화물(Free Sulphide)의 부착을 정지시키고 이를 물로 되돌려서 분산시킨다.
- ✧ 황화수소(Hydrogen Sulphide)의 철의 부식작용을 저지한다.
- ✧ 소금(염분)의 부착을 막고 물로 분산시켜 되돌린다.
- ✧ 조류(Algae)의 형성을 방지한다.
- ✧ 냉수 또는 온수 모두에 효과를 발휘한다.

이와 같은 터브플로우의 기술적 효과에 대한 주장은 설비의 유지와 보수비용을 경감시키고 설비의 효율을 증대시킨다. 이 자료에서는 터브플로우의 이미 입증된 성능에 대한 확인관찰 뿐 만이 아니고 다른 관찰된 현상에 대해서도 기본적인 설명을 추가한다.

2. 관찰과 측정 :

아래 내용에서 보는바와 같이 터브플로우로 처리된 물의 터브플로우 효과에 대한 관찰기록을 기술한다.

2.1 제타포텐셜(Zeta Potential)

제타포텐셜이란 물속의 고형물입자의 전하량을 재는 측정도구다. 이것은 입자가 응집결합하고 성장하는 강력한 지표가 된다. 입자의 제타포텐셜값은 원수와 터브플로우로 처리수 각각 측정했다. 결과는 Figure 1(원수)와 Figure 2(처리수)로 표시되었다. 이 결과들은 Mr. Claude Vizcaino : CAD Instrumentation in Les Essarts le Roy, France 에 시험 관찰에 의해 얻어졌다. Mr. Vizcaino는 시험에 이용된 물의 시료의 준비에 여하한 인위적인 조작도 하지 않았으며, 다만 원수와 처리수로 구분 시험 분석했다.

Figure 1
Zeta Potential of particles in raw water

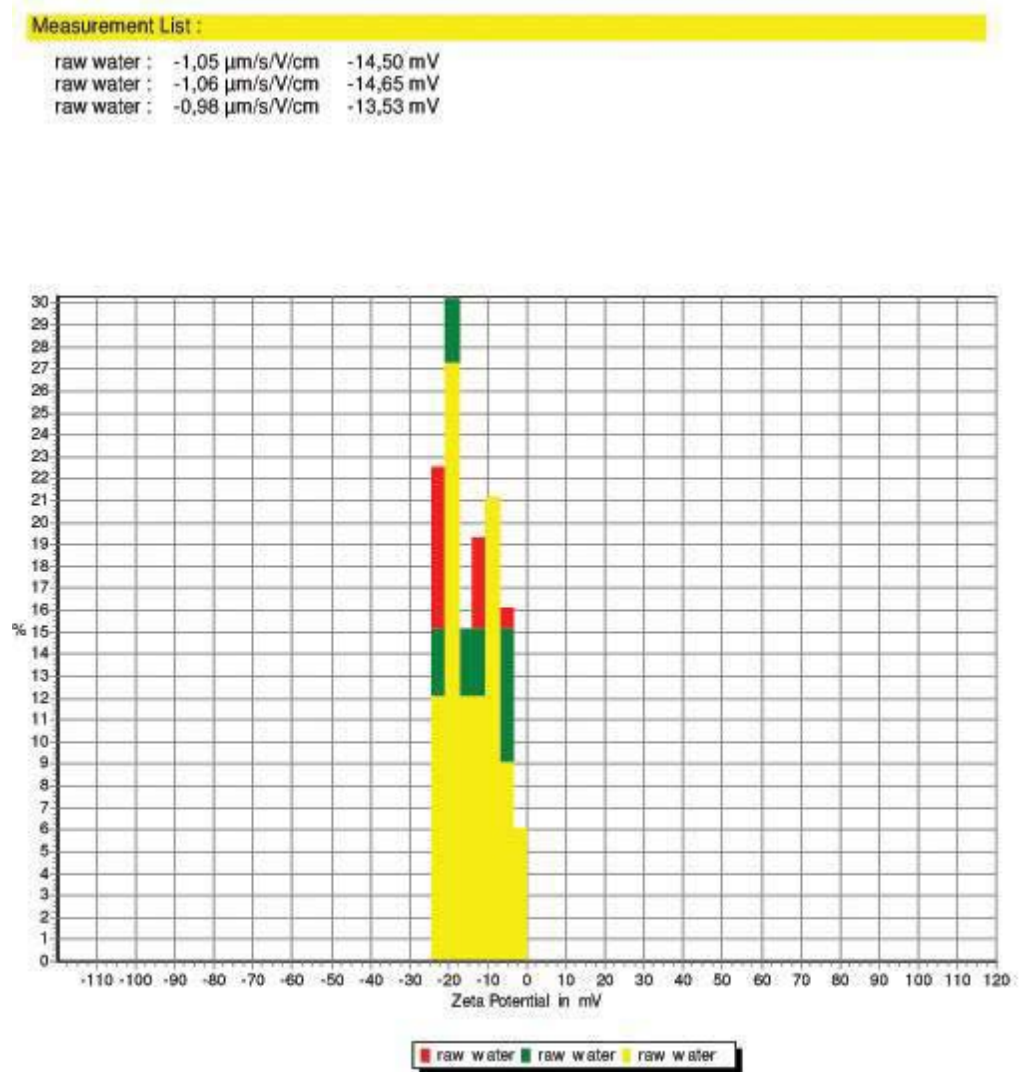
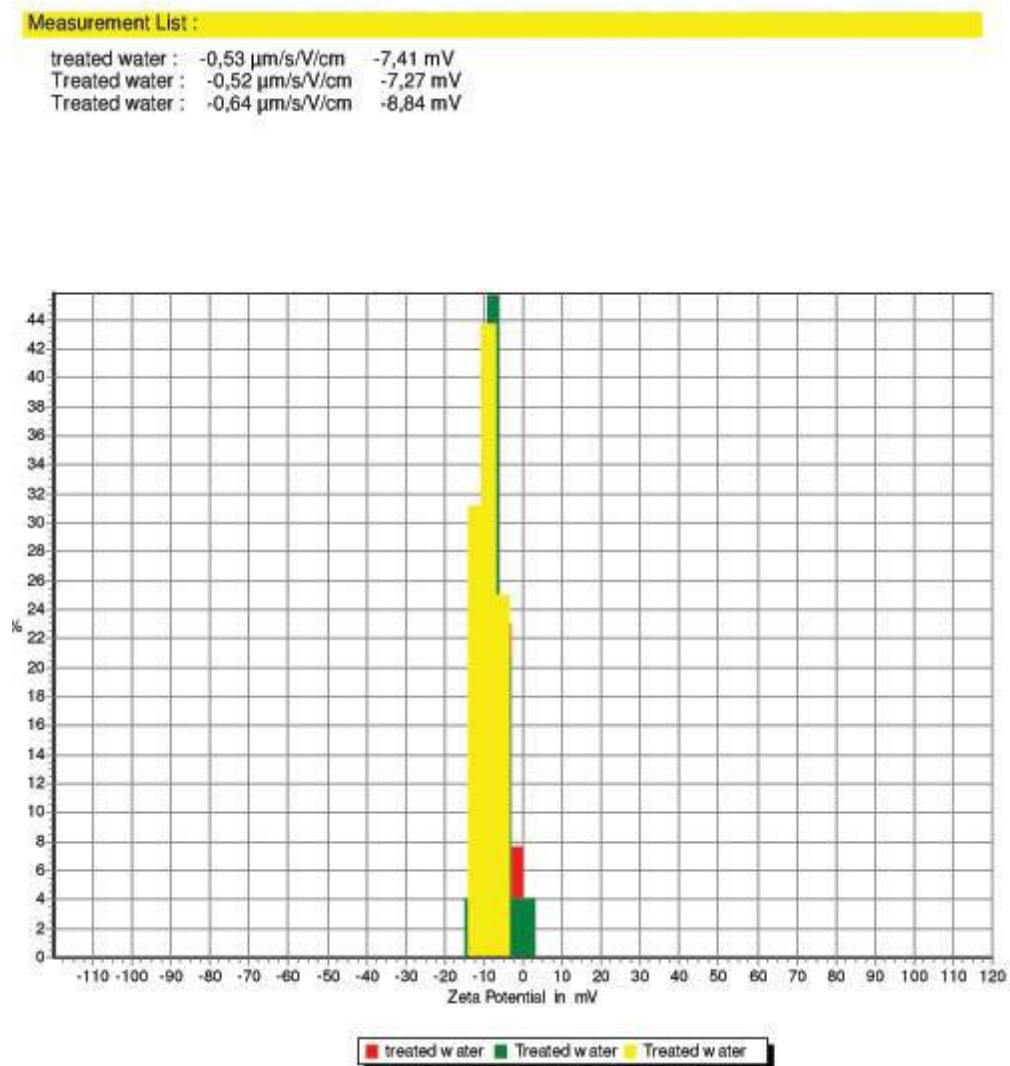


Figure 2
Zeta Potential of particles in Turbu-Flow treated water



위의 시험결과는 터브플로우가 수중에 함유된 미네랄입자의 제타포텐셜에 대단히 큰 영향을 미치는 것을 보여준다. 실제로 동일한 물의 경우에 터브플로우가 제타포텐셜값을 반감시킨다는 사실이 확인되었다.

제타포텐셜값의 변화의 중요성은 아무리 강조해도 지나치다 할 수 없다. 각각의 미립자의 중요성은 직접적으로 또는 간접적으로 입자들이 가진 전위에 의해서 결정된다. 전위의 분배는 입자 간에 상호작용하는 에너지에 의해서 결정된다. 많은 경우에 입자

가 안정되게 응집하려는 현상과 현수물질을 함유하고 있는 물의 흐름이 위의 현상에 의해서 결정된다.

제타포텐셜은 많은 경우에 액체의 흐름 또는 입자가 멤브레인을 통과하는데 있어 가장 크고 중요한 변수가 된다. 그리고 이와 같은 변수는 처리수가 미생물시스템(Bio Film)에 접촉하여 효력을 발휘하는 결정적인 성능을 구현한다.

2.2 탄산칼슘의 결정작용

미네랄과 탄산칼슘 스케일을 제거, 방지하는 터브플로우의 효과에 대해 이해하려면 먼저 탄산칼슘의 화학적 성질에 관해서 이해해야 한다. 환경과 산업측면에서 탄산칼슘이 대단히 중요하지만 이에 복잡한 화학적 특성으로 인해서 이에 대한 참고문헌은 그리 많지 않다.

보일러와 스팀생산설비에서 탄산칼슘의 영향력을 이해하기 위해서 화학적 특성을 관찰하기 위해 개발된 수학측정도구들에 대해서 이해해야만 한다.

여러 도구들 중 하나는 Langelier Stability Index(LSI)이다. 이 도구는 물속의 탄산칼슘의 안정도를 측정하는데 이용된다. 이 도구는 어떤 물이 침전이 발생하고 스케일이 생성될지 아니면 탄산칼슘이 용해될지를 나타낸다.

Langelier는 물이 어떤 pH에서 탄산칼슘에 의해서 포화될지 예측하는 능력이 있는 수학적인 표시방법을 개발했다. 그 포화 pH를 pHS 이라 표한다. 실질적인 LSI는 용액의 서로 다른 pH값과 포화 pH값으로 표시된다. 아래와 같이 표기할 수 있다.

$$LSI = pH - pHS$$

이 화학방정식으로부터 LSI가 양(Positive : 陽)인 경우, 실제로 있어서 pH가 pHS 보다 높을 때가 언제인지 알 수 있다. 이것은 탄산칼슘용액이 과포화상태임을 암시하고 있으며 따라서 이 용액은 스케일을 만드는 경향을 띤다. LSI의 Positive값이 증가하면 만들어질 가능성이 증대된다.

만일 pHS 보다 pH값이 낮아지면, LSI값이 음(Negative : 陰)이 되었을 경우는 스케일이 만들어질 가능성이 매우 낮아진다. 실제로 Negative LSI값이 커지면, 물이 탄산칼슘을 용해하는 능력이 증가한다.

만일 LSI값이 Zero에 근접하는 경우는 위의 상황의 경계에 속함을 의미한다. 수질의 변화, 온도, 증발과 같은 현상이 물의 스케일형성현상을 바꿀 수 있다.

pHS 의 계산을 통해서 아래와 같은 변수를 이해할 수 있다. Ca^{2+} (mg/l)의 농도, TDS 농도, 물의 온도와 pH값 칼슘의 높은 농도, TDS가 높은 경수일 때 스케일의 형성이 촉진된다. 높은 온도일 때 스케일은 쉽게 형성되며, 낮은 pH는 스케일이 형성되는 현상을 감소시킨다.

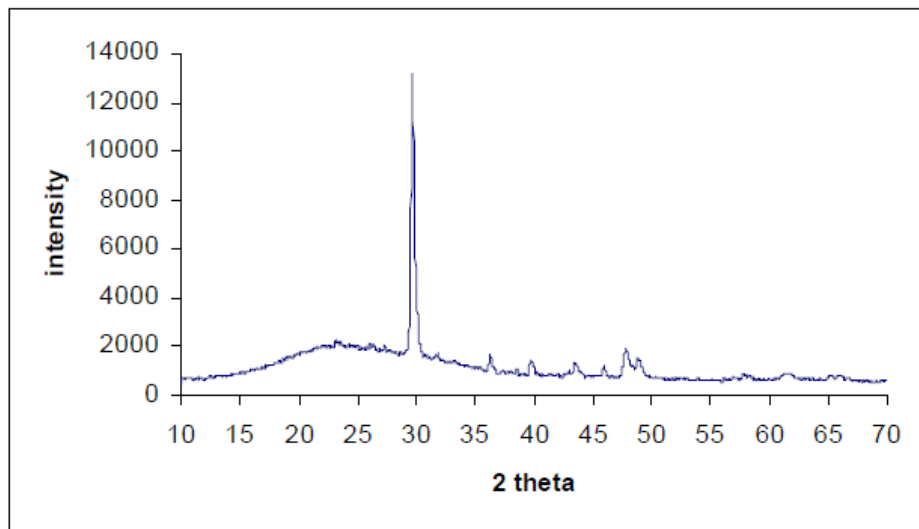
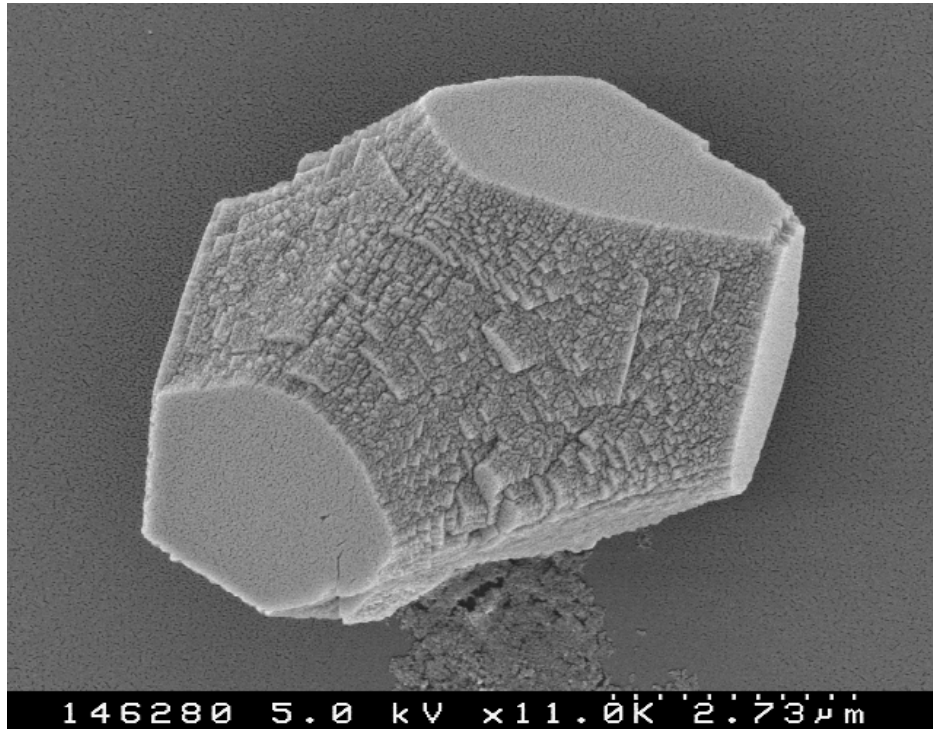
이제 탄산칼슘을 함유한 물을 터브플로우에 통과시킴으로서 결정작용이 일어난 증거를 제시하려한다. 두 가지를 관찰했다.

- ✧ 설비의 아래쪽에 매우 부드럽고, 들어붙지 않은 탄산칼슘이 투여된 물 순환장치 관찰
- ✧ 파이프와 다른 설비부분에 이미 형성된 스케일의 용해성 관찰

터브플로우로 처리한 후의 물이 처리되지 않은 물보다 탄산칼슘을 결정 상태로 바꾸는 변화를 전자현미경사진이 극명하게 보여준다.

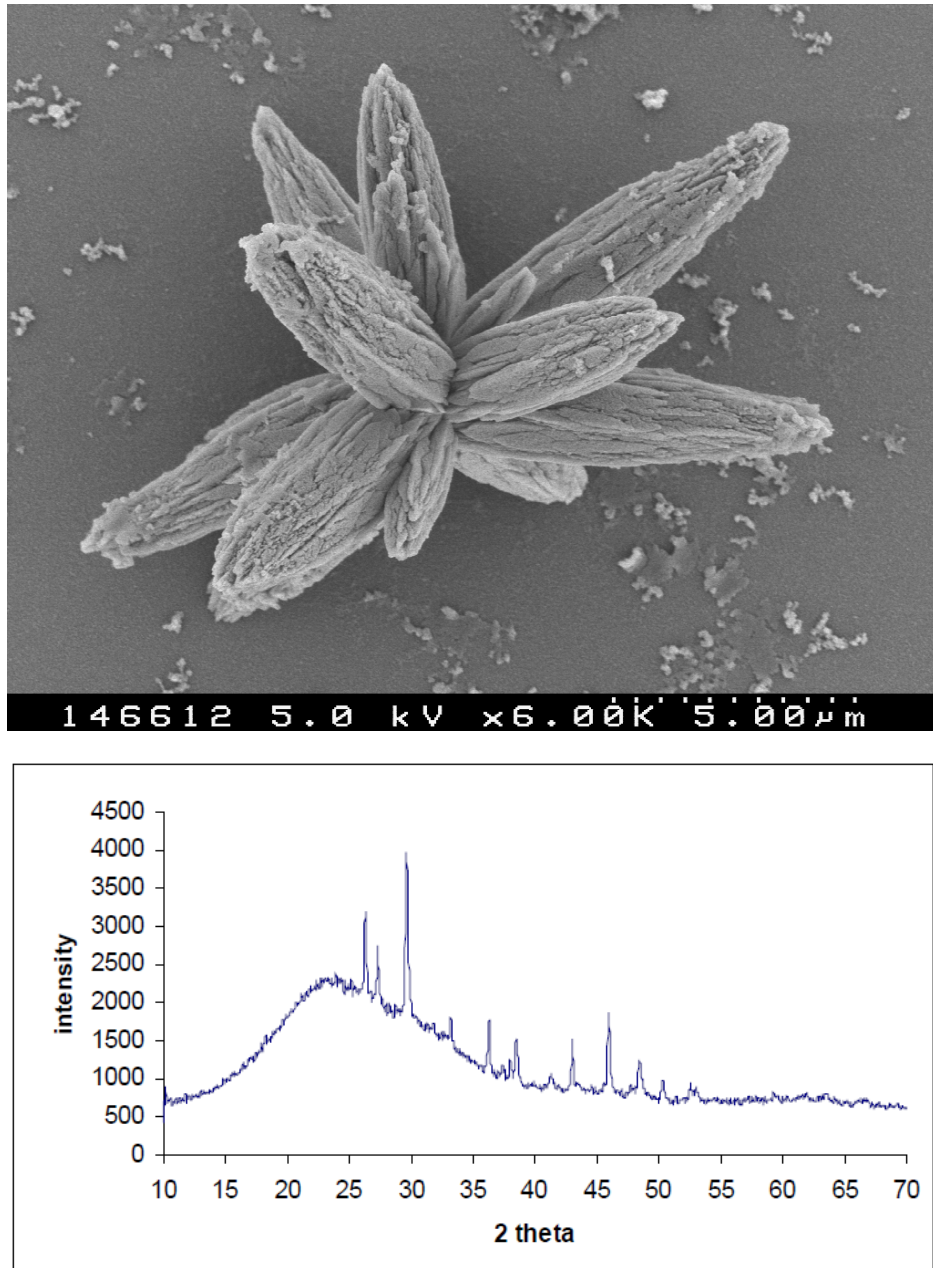
Figure 3은 SEM분석 자료에서 보는바와 같이 원수로 부터 얻어진 결정을 보여주는 반면, Figure 4는 터브플로우로 처리한 후의 변화한 결정상태를 보여준다. Calcite가 Aragonite결정으로 형상변화 되었음.

Figure 3
Calcium carbonate crystals from the raw water.



이 그림은 대표적인 Aragonite Crystals의 형태를 보여준다.

Figure 4
Calcium carbonate crystals from the treated water.



이 그림은 대표적인 Aragonite Crystals의 형태를 보여준다.

물이 터브플로우를 통과하면 전기화학적 변화가 일어나고, 이로 인해서 결정화 조건이 변하여 결정구조가 다른 탄산칼슘 결정이 만들어진다.

물이 터브플로우를 통과할 때 그 크기가 매우 작은 미립결정(nanosize)으로 탄산칼슘이 바뀌고, 그 미립자는 물에 분산된다는 가설을 세워본다. 만일 조건(positive LSI)이 맞는다면, LSI가 Zero에 근접한 위치지점에서 결정의 성장이 일어날 것이다.

많은 수의 입자가 존재하므로, 각각의 입자는 성장하지 못하고 부착성이 없는 극도로 작은 입자로 변화된다.

Table 1은 처리되지 않은 원수와 터브플로우로 처리한 처리수의 화학적 분석의 결과를 보여준다.

이 결과를 보면, 물의 탁도 이외에는 매우 근소한 측정치상의 변화만을 확인할 수 있다. 탁도가 높아진 것을 볼 수 있다. 이와 같이 탁도가 증가하고 칼슘농도가 안정된다는 함은 극도로 작은 칼슘 결정들이 터브플로우에 의해서 만들어진다는 가설을 지원한다.

Table 1
Chemical analysis of raw and Turbu-Flow treated water
(원수와 터브플로우로 처리된 물의 화학분석)

		Instrument Detection Limit	Raw Water	Turbu-Flow Treated Water
Wet Chem.	Conductivity (us/cm)	3	720	720
	pH (pH units)	0.1	7.8	7.7
	Turbidity (NTU)	0.10	0.30	0.50
Metals	Aluminum (mg/L)	0.01	0.02	0.02
	Barium (mg/L)	0.01	0.08	0.08
	Beryllium (mg/L)	0.001	<0.001	<0.001
	Boron (mg/L)	0.05	<0.05	<0.05
	Cadmium (mg/L)	0.0001	<0.0001	<0.0001
	Calcium (mg/L)	0.5	84	85
	Chromium (mg/L)	0.001	0.001	0.001
	Cobalt (mg/L)	0.0008	<0.0008	<0.0008
	Copper (mg/L)	0.001	0.059	0.052
	Iron (mg/L)	0.05	0.11	0.11
	Lead (mg/L)	0.001	<0.001	<0.001
	Magnesium (mg/L)	0.5	20	20
	Manganese (mg/L)	0.001	0.004	0.004
	Molybdenum (mg/L)	0.001	<0.001	<0.001
	Nickel (mg/L)	0.002	<0.002	<0.002
	Potassium (mg/L)	0.5	1.9	1.9
	Silver (mg/L)	0.0001	<0.0001	<0.0001
	Sodium (mg/L)	0.5	19	20
	Strontium (mg/L)	0.001	0.24	0.24
	Thallium (mg/L)	0.0003	<0.0003	<0.0003
	Uranium (mg/L)	0.005	<0.005	<0.005
	Vanadium (mg/L)	0.001	0.003	0.003
	Zinc (mg/L)	0.003	0.004	0.004
	Zirconium (mg/L)	0.001	<0.001	<0.001

2.3. 기존스케일의 용해

전장에서 확인한 바와 같이 터브플로우가 극도로 작고 무수히 많은 수의 탄산칼슘입자로 바꾸어 물의 탄산칼슘이온 농도를 낮춘다는 사실을 알아내고 그 효과가 있음을

확인한다.

이와 같은 결과는 Langelier Index를 낮추는데 있다. 나노결정(nanocrystals)상태인 탄산칼슘은 용액 속에 있을 때 침전 또는 부착성(들어 붙는)을 상실한 상태로 존재한다. 실제로, 나노결정입자는 칼슘이온농도가 너무 낮고, 물체의 표면이나 입자 상호간에 결합하려는 성질을 가지지 않기 때문에 스케일이 만들어지지 않는다. 상상해 보면, 다른 물체의 표면에 들어붙도록 하는 접착제가 없어졌으므로 더 이상 스케일이 만들어질 수 없게 된 것이다. 이와 같이 낮아진 탄산칼슘농도가 LSI를 Zero값까지 떨어뜨린다. 이 현상이 이미 형성된 기존 스케일도 용해시킨다.

대부분의 기존 탄산칼슘스케일은 더 이상은 스케일이 될 수 없는 슬러지 상태로 용해되고, 물에 의해 운반되어 순환시스템(Circulation System)의 아래쪽에 쌓인다.

2.4. 바이오필름(Biofilm)의 파괴

터브플로우가 바이오필름의 성장을 정지시키는 현상을 관찰했다. 이 관찰은 무수히 많은 회수를 시행했으며, 머지않은 장래에 과학적조사가 이루어져야 과제가 될 것이다.

우리의 가설은 두 가지 주제에 관한 것 이었다 :

첫째, 탄산칼슘스케일의 제거는 미생물이 부착, 서식할 환경을 제거한 것.

둘째, 변화된 제타포텐셜이 미네랄입자와 미생물 세포막간의 상호작용에 변화를 가져온다.

이와 같은 상호작용의 변화가 미생물막(Biofilm)의 성장을 억제하는 것이 확실하다고 믿는다. 제타포텐셜에 의해서 나노입자로 바뀐 결정입자들이 미생물의 세포막을 침투, 파괴 독살하는 것으로 판단된다.

2.5. pH에 미치는 효과

터브플로우로 처리한 경우 pH는 변하지 않았다. 이와 같은 현상은 탄산칼슘이 스케일화 되어 있거나 또는 탄산칼슘의 양이 증감되어도 일관되게 나타나는 현상이다.

3. 터브플로우로 처리된 물을 이용한 소독

Table 2는 터브플로우로 살균하기 전과 후의 미생물 수치를 측정한 결과를 보여준다.

Table 2
Results of sterilisation using Turbu-Flow treated water
터브플로우로 처리된 물을 이용해서 살균한 결과

PRELIMINARY DATA

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LAB NUMBER: 274841

SAMPLE ID: Dry Steam Vapor System, 2400 Series or Better

TEST REQUESTED: Surface Disinfectant Validation Test

DATE: 25 Oct 2004

TABLE 1. Results

COUPON

SURFACE/

ORGANISM

Application AVERAGE

CONTROL

TITER (CFU)

AVERAGE

RECOVERED

(CFU)

PERCENT

REDUCTION

(%)

LOG₁₀

REDUCTION

Tile

S. aureus

1 $2.5 \times 10^7 \sim 2.8 \times 10^4 \sim 99.89 \sim 2.95$

2 $2.5 \times 10^7 < 1.0 \times 10^0 > 99.999996 > 7.40$

3 $2.5 \times 10^7 < 1.0 \times 10^0 > 99.999996 > 7.40$

Tile

S. epidermidis

1 $1.1 \times 10^7 < 1.0 \times 10_0 > 99.999991 > 7.04$

2 $1.1 \times 10^7 < 1.0 \times 10_0 > 99.999991 > 7.04$

3 $1.1 \times 10^7 < 1.0 \times 10_0 > 99.999991 > 7.04$

Tile

P. aeruginosa

1 $1.8 \times 10^7 < 1.0 \times 10_0 > 99.999994 > 7.26$

2 $1.8 \times 10^7 < 1.0 \times 10_0 > 99.999994 > 7.26$

3 $1.8 \times 10^7 < 1.0 \times 10_0 > 99.999994 > 7.26$

Tile

S. choleraesuis

1 $1.4 \times 10^7 < 1.0 \times 10_0 > 99.999993 > 7.15$

2 $1.4 \times 10^7 < 1.0 \times 10_0 > 99.999993 > 7.15$

3 $1.4 \times 10^7 < 1.0 \times 10_0 > 99.999993 > 7.15$

Tile

E. coli

1 $1.8 \times 10^7 < 1.0 \times 10_0 > 99.999994 > 7.26$

2 $1.8 \times 10^7 \sim 1.3 \times 10_1 \sim 99.999931 \sim 6.16$

3 $1.8 \times 10^7 < 1.0 \times 10_0 > 99.999994 > 7.26$

TABLE 1. RESULTS (continued)

COUPON

SURFACE/

ORGANISM

Application AVERAGE

CONTROL

TITER (CFU)

AVERAGE

RECOVERED

(CFU)

PERCENT

REDUCTION

(%)

LOG₁₀

REDUCTION

Tile

L. monocytogenes

1 $4.6 \times 10_6 \sim 1.6 \times 10_1 \sim 99.99966 \sim 5.47$

2 $4.6 \times 10_6 \sim 1.0 \times 10_0 \sim 99.999978 \sim 6.66$

3 $4.6 \times 10_6 < 3.5 \times 10_0 > 99.999924 > 6.12$

Tile

E. faecium

1 $2.1 \times 10^7 < 1.0 \times 10_0 > 99.999995 > 7.32$

2 $2.1 \times 10^7 < 1.0 \times 10_0 > 99.999995 > 7.32$

3 $2.1 \times 10^7 < 1.0 \times 10_0 > 99.999995 > 7.32$

Tile

C. albicans

1 $2.9 \times 10^7 \sim 2.0 \times 10_0 \sim 99.999993 \sim 7.16$

2 $2.9 \times 10^7 \sim 2.0 \times 10_0 \sim 99.999993 \sim 7.16$

3 $2.9 \times 10^7 < 1.0 \times 10^0 > 99.999997 > 7.46$

Tile

A. niger

1 $4.9 \times 10^5 < 1.0 \times 10^0 > 99.999980 > 5.69$

2 $4.9 \times 10^5 < 1.0 \times 10^0 > 99.999980 > 5.69$

3 $4.9 \times 10^5 < 1.0 \times 10^0 > 99.999980 > 5.69$

Tile

T. mentagrophytes

1 N/A N/A N/A N/A

2 N/A N/A N/A N/A

3 N/A N/A N/A N/A

Application 1 = Nozzle brush used with a towel placed over the brush. The sample was

exposed

for 7 seconds.

Application 2 = Tri-Brush used with a towel placed over the brush. The brush was scrubbed/rubbed

back and forth on the sample for 10 seconds

Application 3 = Tri-Brush used with the towel placed over the brush. The brush was scrubbed/rubbed over the sample for 30 seconds.

(~) values are approximated based on counts outside the range of 25-250 for bacteria or 8-

80 for

molds and fungi.

(>) Greater than values are where a <1 count/mL recovery per sample was found

(<) Less than values are where no colonies were found for a sample.

Advanced Vapor Technologies, Inc. Lab # 274841

Preliminary Results Page 3 of 2

DISCUSSION:

The data looks very good for all organisms and applications. The data for the *T. mentagrophytes*

should be available within 10 days. Please feel free to contact me regarding any questions

on the

above data.

STUDY DIRECTOR

This document contains preliminary data. This information has not been reviewed by our quality departments.

Although not

anticipated, some changes may be reflected in the results of the detailed final report that will follow. Please contact the

Customer

Service Department if you have any questions.

NELSON LABORATORIES, INC. / POST OFFICE BOX 17557 / SALT LAKE CITY, UT 84117-0557-57 / 801-963-

2600

PRINTED: 25 OCT 2004 / 15:52:04 V-001-01/032001

미생물의 살균효과를 시험하는 것은 매우 인상적이었다. 어떻게 터브플로우를 통과한 물이 미생물의 살균효과를 발휘하는지 그에 대한 구체적인 메카니즘은 아직 확인되지 않았다.

추측컨대, 바이오필름을 파괴하는 성능과 유사한 메카니즘이 작용하는 것이 아닐까 판단한다. 나노결정입자와 결합한 열의 작용으로 미생물 세포막으로 침투하여 그것들을 붕괴시킴으로서 것처럼 높은 미생물 살균력을 발휘하는 것으로 판단된다.

4. 결론

터브플로우 효과에 대한 본 실험과 관찰은 이 시스템을 이용하는 사람들에게 과학적인 배경을 설명하는데 있어 미흡한 점이 있다.

관찰을 통한 경험으로 볼 때, 비록 터브플로우의 효과를 설명할 입증된 이론이 아직은 없으나, 그 성능에 대해서는 부인할 수 없다.

터브플로우는 탄산칼슘의 함량이 높은 물의 스케일형성을 저지하고, 기존 스케일을 제거하며, 바이오필름의 형성을 정지시키고, 물체표면의 살균작용(열이 있으면 효과증대)에도 탁월한 효과가 확인되었다.

---끝---