Principle of operation and specific characteristics

Active anode system

The active anode system investigated (AQUABION® AB-S15, manufactured and developed by ION Germany GmbH), based on the assumption, that the addition of zinc ions (Zn^{2+} ions) retards or totally prevents the formation of scale (calcium carbonate, $CaCO_3$ and magnesium carbonate, $MgCO_3$), which is difficult to dissolve. This assumption has been confirmed in a study conducted by the Institute of Chemistry and Bio-chemistry of the Rand Afrikaans University, Johannesburg.[4]

An article in the technical magazine, “Journal of Crystal Growth“, reports a similar finding.[5]

The electro—galvanic principle is used in active anode systems. As a result of the conductive connection of the brass housing with the zinc sacrificial anode using potential equalisation, a galvanic element is formed together with the flowing water having a cell voltage of about 0.7 to 1.0 volt, which depends on the property of the water. There are substances causing turbulence made of Nirosta (rust-proof steel) either upstream or downstream, which stir up the suspended matter in the water. With this the contact surface obtained is as large as possible, which has a positive effect on the handling effect. In addition, the substances causing turbulence ensure that the zinc sacrificial anode does not get clogged.

Figure 1: *AQUABION® AB-S15 with potential equalisation*

Apart from the known effect of providing protection against corrosion in the case of copper or iron pipes used as sacrificial anodes, this system is also expected to offer effective protection against formation of scale. According to manufacturers, this happens because the zinc ions released by the sacrificial anode in small quantities promote the agglomeration (build-up) of the substances contained in the water, particularly calcium carbonate, and, as a result, fewer but large particles are created. According to the lessons on current flow, these particles offer a larger contact surface and are discharged by the water more easily.[6]

Another effect of the zinc ions is that they affect the structure of the scale. Thus, in this manner, the Zn^{2+}-ions should inhibit the formation of the hard, almost insoluble calcite (modification of the calcium carbonate), as a result of which, indirectly, the formation of the soft, more easily soluble, aragonite (also a modification of $CaCO_3$) is facilitated. The aragonite can be discharged by flowing water more easily and is far less likely to get deposited on the walls of the pipes or other neuralgic spots. Moreover, deposits already existing should get carried away by the large particles, until only one desired protective layer remains.[6], [7]

Experimental systems and experiments

General Notes

To perform the experiments for verification of the effectiveness of the physical softening of the water, a saturated calcium carbonate solution was prepared by dissolving calcium carbonate distilled water until it was saturated and finally, carbon dioxide gas was introduced in the solution for about 20 minutes.
This solution was then filtered a number of times using different paper filters in order to remove excess of $Ca(HCO_3)_2$.

A calcium hydrogen carbonate solution was selected as the reference solution, since this form of soluble scale is primarily contained in the water, and forms the almost insoluble calcium carbonate ($CaCO_3$) during the crystallisation process, which is primarily responsible for the calcinations of pipes and machine components.
Moreover, no ordinary pipeline water could be used, since very small quantities of scale are formed with its crystallisation, as that which was required to be able to arrive at a clear conclusion about the effectiveness of the method described.

A total of five series of experiments were performed, whereby the experimental series 1, 2, 3 and 5 were aimed at investigating the effectiveness of the electro—magnetic scale converter and the experimental series 4 was aimed at checking the effectiveness of the active anode system.

The copper and stainless steel pipes, the pipe clamps as well as the active anode system AQUABION ® AB-S15 for the series of experiments 1 to 5 were provided free of cost by S + H Sanitary and Heating Technology GmbH, Schweinfurt, as a friendly gesture, which made the experiments possible in the first place.

The investigation of all test samples took place in the Department for Electron Microscopy of the Theodor-Boveri Institute for Bio-sciences in the bio-centre of the Wuerzburg University, with assistance provided by Dr. Georg Krohne. He facilitated the investigation of the crystalline structure of the carbonate crystals using the grid electron microscope and also provided the micro-litre pipette and the cover glass plates for this purpose. Conclusions could be drawn regarding the effect of the handling of the scale on the crystal structure based on the photographs taken during the course of these experiments. However, these shall be discussed in detail in the final evaluation of the outcome of these experiments.

Figure 2: Arrangement for experimental series 3 (below) and 4 (above)

Experimental series 4

The fourth series of experiments was aimed at investigating the effects of the active anode system AQUABION® AB-S15 on the crystallisation behaviour of the calcium hydro-carbonate solution.

For this purpose a similar experimental set-up was selected as that used for the previous series of experiments, with the exception that this time a straight piece of pipe with the scale converter was replaced with a bent stainless steel pipe having the active anode system fixed and installed in it.

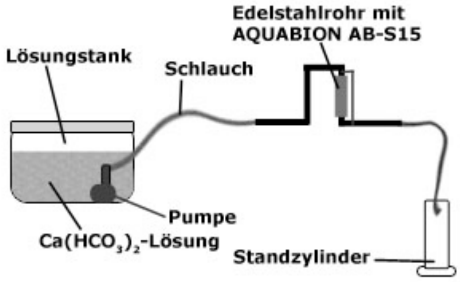

Figure 3: *Sketch of the experimental set-up for sample 4/1*

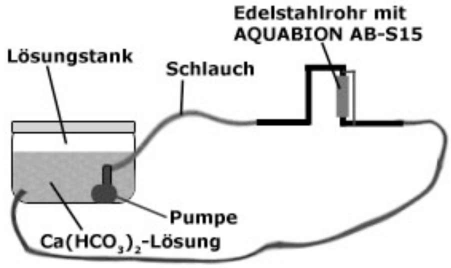

Figure 4: *Sketch of the experimental set-up for samples 4/2 and 4/3*

As is already evident from the sketches, even in this case samples of the carbonate solution were removed and crystallised both after a single flow through and also after multiple run-throughs of circulatory flows.

However, for this series of experiments, the new control sample 4/0 was withdrawn prior to the treatment, since it was a separate calcium hydro-carbonate solution used for this series of experiments.

Sample 4/0	**08.08.2007**	**$Ca(HCO_3)_2$ solution for the active anode system, untreated**
Sample 4/1		**After a single flow-through**
Sample 4/2		**After 15 minutes of circulation**
Sample 4/3		**After 30 minutes of circulation**

Table 1: *Experimental series 4 dated 08.08.2007*

Assessment of the experimental series 4

For the assessment of this series of experiments it is important to note that the active anode system, AQUABION® AB-S15, has a different principle of operation and, thus, should also have a different effect as compared to the electro-magnetic scale converter.

In contrast to the scale converter, the formation of crystalline substances is not prevented, but, instead, promoted. However, the crystals originally in the solution consist of calcite modification, whereas, those after the treatment should be those of the aragonite modification.

First of all, the photographs shown here are those of the separate comparative solutions, since a separate solution was used for this series of experiments.

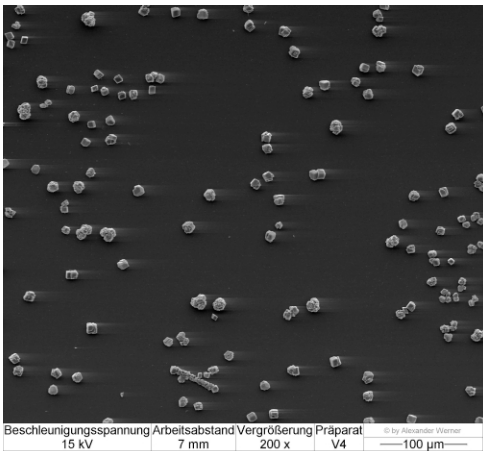

Figure 5: *Series 4, sample 4/0 (untreated $Ca(HCO_3)_2$ solution, magnified 200x times*

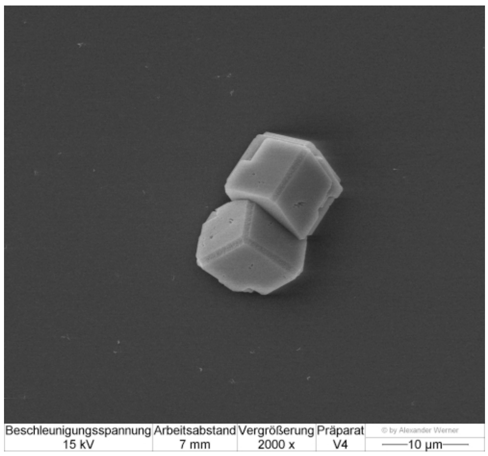

Figure 6: *Series 4, sample 4/0 (untreated $Ca(HCO_3)_2$ solution, magnified 2000x times*

The calcium hydro-carbonate crystals in the comparative sample 4/0 shows many, irregular individual crystals of various sizes and crystal groups. What is important here is that the calcium hydro-carbonate crystals, as seen in the picture having a 2000x magnification, show the typical rhomboidal shape of the calcite modification. [8], [9]

Clear changes could be detected after a single flow through of AQUABION ® AB-S15:

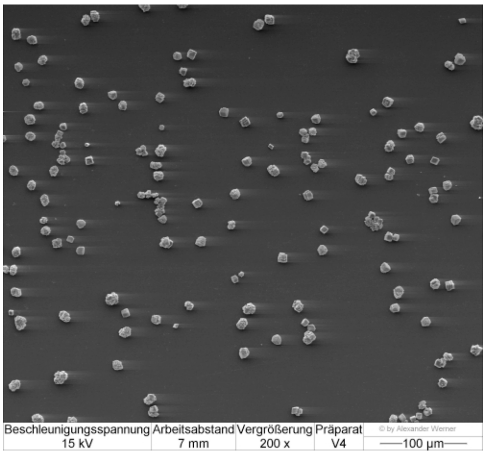

Figure 7: *Series 4, sample 4/1 (single flow-through of Aquabion), magnified 200x times*

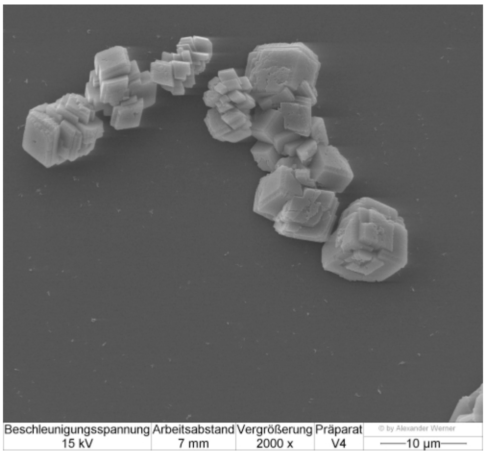

Figure 8: *Series 4, sample 4/1 (single flow-through of Aquabion), magnified 2000x times*

While more crystal aggregates can be recognised in the photograph having the smaller magnification, it is clear from the picture having 2000x magnification that the aggregates are relatively large. The characteristic orthorhombic shape of the aragonite modification cannot be identified clearly owing to the large number of individual crystals combined together to form the crystal aggregate. [8]

The enlargement and increase in the number of aggregates are the primarily desired effects, which should be achieved with the use of the active anode system.

These effects are even more evident with the experiments involving circulation with multiple flow-through of the active anode system, since a larger proportion of the highly concentrated calcium hydro-carbonate gets collected. However, there is barely any discernible difference between the experiment conducted with a single flow-through (picture on the left) and that with 15 minutes circulation.

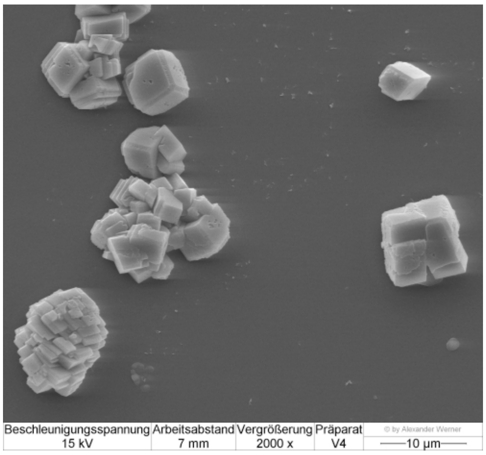

Figure 9: *Series 4, sample 4/1 (single flow-through of Aquabion), magnified 2000x times*

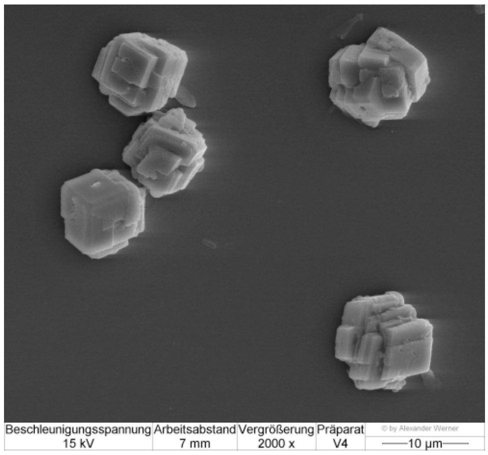

Figure 10: *Series 4, sample 4/2 (15 minutes circulation of Aquabion), magnified 2000x times*

The changes are most clearly discernible after 30 minutes of circulation:

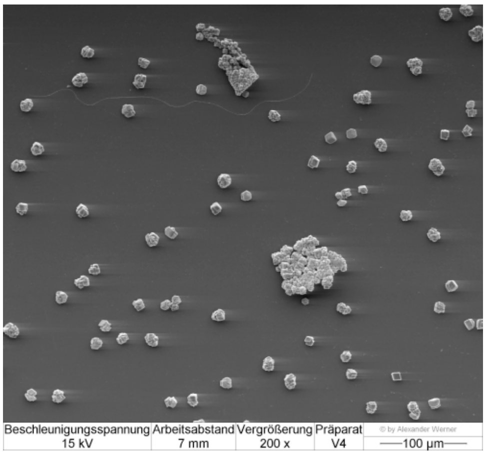

Figure 11: *Series 4, sample 4/3 (30 minutes circulation of Aquabion), magnified 200x times*

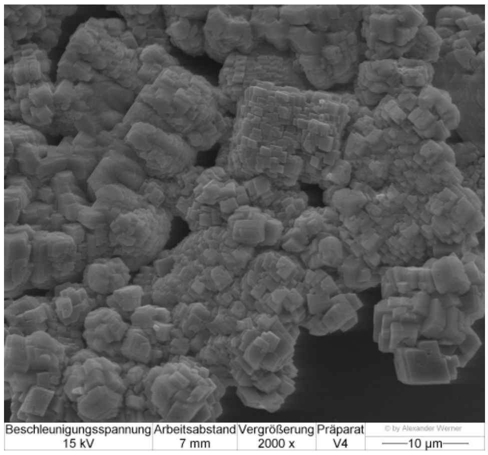

Figure 12: *Series 4, sample 4/3 (30 minutes circulation of Aquabion), magnified 2000x times*

In place of many smaller aggregates, there are now many small aggregates as well as some particularly large calcium carbonate crystal aggregates, which have a diameter of almost 100µm. With larger magnification it can be clearly seen that the aggregate consists of very many individual crystals and has a very irregular structure. These characteristics suggest that the effects described by ION Germany GmbH have taken place, first of all, and secondly, that they could be favourable for the abrasive effect in the pipeline. [6]

Discussion

Finally, it can be concluded that both the electro-magnetic scale converter and the active anode system affect the crystallisation of calcium hydro-carbonate to calcium carbonate. However, the mere evidence of the effect can barely be used as proof of the actual effectiveness in practical use, since there are other factors that also have a contributory effect. These include, amongst others, the water temperature, the speed of flow and the calcium carbonate content of the water itself.

Owing to the experimental character of the investigations carried out under discretionary conditions, it is, thus, inappropriate to make a generally valid statement regarding the effectiveness of the physical softening of the water.

However, since the active anode system AQUABION ® has already been successfully used a number of times and is also fitted by established installation engineers and companies, it can be assumed that this system provides protection not only against corrosion but actually also prevents the deposit of scale in pipeline systems.