No Salt Softeners
Fact, Fiction or Fantasy

By Jonny Seccombe

Introduction

Fact, fiction or fantasy—all these adjectives, in different measure, can be applied to those water treatment devices sometimes described as 'no salt softeners'. These devices are occasionally claimed to be the Holy Grail for the treatment of hard water; but on the opposite side, in the opinion of many water treatment specialists, there is no lower form of life than those who promote them. They are treated with contempt and disdain by many. Here we'll look at the facts, explore the science and see what is really happening in this peripheral section of the water treatment market.

First of all, let's define the product sector. A more agreeable descriptive term for the so-called 'no salt softener' is a physical water conditioner (PWC). PWC devices inhibit scale encrustation without the use of salt or the addition of any chemicals to the water supply. The word *encrustation* is significant because scale still forms since calcium is still present, but it forms in such a way that it no longer sticks to surfaces but stays in suspension and is carried away in the flow of water.

The chemistry

Hard water contains many different dissolved salts but the one that causes the most problems is calcium bicarbonate $(CaHCO^{3})^{2}$. This compound converts by precipitation to calcium carbonate $(CaCO^{3})$, known as lime scale, with by-products of carbon dioxide and water. The main problem with hard water is that calcium bicarbonate reacts badly with soap, reducing lathering and increasing scum, while lime scale, when it precipitates, encrusts surfaces. To soften water it is necessary either to reduce the calcium or to reduce the bicarbonate. Conventional water softeners replace calcium with sodium, but what does a PWC do?

It is important to emphasize that PWCs don't stop scale from forming. What they do is make it form in such a way that it doesn't stick to surfaces of heater elements and pipes. Scale always precipitates onto something; it won't easily form naturally on its own in a liquid. It has to find a surface or a nucleation seed to form onto. What a PWC does is to present the precipitating scale with numerous nucleation seeds in suspension in the water onto which it can form, in preference to a surface, such as a heating element, which it would normally encrust.

Once the scale is formed as a particle in suspension it will not normally revert to its dissolved form, calcium bicarbonate. Instead, it gets carried away with the flow of water and is pretty harmless. Where the water later evaporates on a surface, such as a glass shower screen, the particles will be deposited and will spot the glass but it should not be in an encrusting form so should be easy to wipe away.

PWCs come in many forms, some weird and wonderful and their manufacturer's literature can be equally varied and fanciful. But what scientific evidence is there for the way in which they work and what are the mechanisms that they employ? There are three prevalent mechanisms on the market today: magnetic/electrolytic, cathodic and electronic/electromagnetic. Each of these makes use of a different material for creating the all-important nucleation seed.

Magnetic/electrolytic

There are numerous such in-line devices; many manufacturers claim these have some kind of magnetic effect on the water or on the dissolved salts. There is little or no scientific evidence to support these claims and quite a lot that contradicts it.[1] The evidence points to zinc dosing being the mechanism employed. Zinc released into hard water converts to zinc carbonate which has a similar crystal structure to scale and therefore acts as a seed upon which the scale forms in suspension in the water.[2] Most of the more effective in-line magnetic PWCs incorporate a zinc anode which corrodes into the water. As water passes through the magnetic field it generates a DC current releasing the zinc from the anode. Similarly, electrolytic systems incorporate dissimilar metals that create an electric current, but without the water flow.

Dr. W. Abi Aoun, an acknowledged expert in the field, has summarized the process as follows:

There are many publications (US, France, UK, Israel, The Netherlands, Denmark) that investigate the fundamental *mechanisms governing the performance of physical devices; other published work is based on case studies where physical devices were fitted in domestic and commercial situations and their efficiency evaluated: Some results indicate that physical conditioning devices are very effective at removing and preventing scale formation whilst others contradicted this conclusion.*

A comprehensive fundamental research work was undertaken and published by Professor K, Busch.[3] His research showed that the anti-scale effect is due to the electric field induced by the ionic species crossing the magnetic flux lines. The electric field creates anodic and cathodic zones within the magnet itself or the magnet housing and consequently galvanic corrosion. Busch suggests that corrosion by-products are leached in the water and act as nucleation seeds for calcium carbonate to precipitate upon in the body of the solution instead of precipitating on heating elements and other surfaces. This model explains why in some instances (both in the laboratory and in real applications) the results were negative: for example, if the magnets were coated with some epoxy material and the magnet housing is in plastic, or if the magnet is clamped on a plastic pipe, galvanic corrosion cannot occur; if the corrosion by-products were prevented from reaching the heat exchanger (if they were trapped by some filters or adsorbed on some surfaces or coated by organic substances dissolved in the water, or settled in a break tank) then scale encrustation would still be observed and the magnets will be perceived to be ineffective. Researchers have tried adding corrosion by-products to calcium carbonate rich solutions to check Busch's theory[4] and found that various ferric hydroxides do not induce heterogeneous nucleation, but that ferric and ferrous ions can sometimes act as scale inhibitors. More recently, it was shown that zinc released from magnets can also act as a scale inhibitor.[5] So in conclusion, it seems that magnets operate by leaching particulate or dissolved scale inhibitors species directly or indirectly into the water stream. As this process is very dependent on flow rates, various hydraulic parameters, the age of the magnets and the concentration of dissolved organic and inorganic species, the rate of success is very random and this is reflected in the results obtained in laboratories and in field studies.

Such in-line units can be effective in preventing scale. They can be very cheap and are simple to fit. The problem is that they perform inconsistently and generally suffer from having a relatively short life. The rate of corrosion is uncontrolled so, whereas the amount of zinc dosing should preferably be related to the hardness and flow rate of the water, the preferred dosing rate is seldom achieved.

A further problem is the life of the unit. Ultimately, the zinc anode will be exhausted and need to be changed—few devices have such facility, but the biggest problem is the onset of passivity. This occurs when a surface barrier builds up on the anode reducing its ability to corrode further. Depending on water quality, this passivity can occur quite quickly. Such PWCs therefore generally have a relatively short life (two or three years, maybe more) before the performance falls off and scaling of the heating system recurs.

Externally applied magnets are less reliable than in-line systems as they rely for their functionality on finding a source of zinc within the existing system. This may take the form of a zinc anode in a water heater or some other source. Without such a zinc source their effectiveness is unreliable at best and non-existent at worst.

Cathodic

A German performance standard for PWCs was introduced in 1996 known as DVGW W-512 (W-512). Very few products have passed this test and those that have done so appear to make use of a common mechanism, described as cathodic. W-512 is a tough test and just because a product fails, it does not mean that it is not effective. It is safe to conclude, however, that a product that passes W512 is a very good product indeed.

One example of a W-512 graduate is a well-known biostat device which passes an electric current through the water contained in a chamber. The anode is a non-corroding, iridium-coated titanium wire mesh and the cathode is a stainless steel wire brush. At the cathode, a very high pH occurs in the water and calcium carbonate precipitates on and around the cathode. Any particles precipitated on the wire brush are mechanically removed; these and other particles of scale go on to act as nucleation seeds when the water is later heated. Scale nucleation seeds are the most effective of all seeding materials, which explains the high degree of effectiveness of these devices. The drawback is that they tend to be expensive and require regular maintenance and/or replacement of cartridges or other components.

Electronic/electromagnetic

The third main class of PWCs are described variously as electromagnetic or electronic systems. They are often erroneously confused with magnetic devices, but it is clear that the mechanism they employ is very different. Generally these are powered by electricity and transmit a signal into the water (either by wires wrapped around the outside of a pipe) by a ferrite ring or by using powerful electromagnets or internal copper coils over which the water is forced to flow at 90 degrees to the field.

One example of the electronic genre is currently the subject of research at Oxford University*. A brief report by Professor Peter Dobson and Alexandra Kay, University of Oxford, Dept. of Engineering Science, dated March 2006 says in part:

The device differs from most available non-chemical water conditioning devices because it applies an electric field to water inside the pipes rather than a magnetic field. The electrodes are fixed to the outside of the water pipes and they comprise of two coils of insulated wire, the coils being merely for convenience of attachment, they do not provide for any magnetic field production. A rectangular pulsed voltage is applied between the two coils and this induces an electric field inside the water pipe. The electric field will penetrate any normal water pipe and even for a copper pipe there is a transient short electric field pulse induced in the water.

The electric field induces movement of ions or charged nanoparticles that are naturally present in the water. The pulsed nature of the field will ensure that there is some transient dissociation of the counter-ion charge cloud surrounding the ions or particles which permit a chemical reaction to occur that would not occur under normal steady-state conditions. It is this chemistry without adding extra chemicals that we believe is responsible for the action in the unit.

The normal scale that builds up in hard water areas is calcite, often mixed with some magnesium carbonate. This forms a tenacious scale that reduces water flow and reduces effective heat transfer in boilers. Application of the device to a system produces an increase in suspended nanoparticles which tend to have a higher percentage of aragonite present and these particles tend to flocculate rather than build scale and form a fine sludge that is flushed away. There is also evidence that application to an existing installation brings about a removal of scale. The presence of traces of iron in the water also appears to enhance the device's effectiveness, probably by enhancing the electrical charge on the suspended nanoparticles.

What is clear from this work and other experience in the field is that location is critical for these devices. Whatever process occurs seems to be reversible and the closer the device is fitted to where the scale is going to form, the more effective the devices are. Tests have shown that they are far more effective when located downstream of cold water storage cisterns. Equally, pumps have a very negative effect on performance.

Test results

A unique feature of the unit Oxford tested is that it is proven to have a softening effect on hot water. The number of nucleation seeds generated will often cause more precipitation to take place than would otherwise occur, with the result that there is less dissolved calcium in the form of calcium bicarbonate in the hot water. This softer water has the effect of improving lathering and providing other benefits of partially softened water. The device can be truthfully described as a no-salt softener.

A further effect of some electronic devices is that they remove existing scale. Over a relatively short period of time, old scale will exfoliate from the surfaces where it is attached and break down in the plumbing system, sometimes into fine sand-like particles. So far, there is no acceptable scientific explanation for this phenomena, but it is clear from field studies that it can be a dramatic and rapid event, especially where iron is present in the scale.

In the hard water areas of England (roughly half the country) PWCs of some kind are installed as a matter of course in both domestic and non-domestic locations. Recently adopted building regulations require new and refurbished domestic premises to have some kind of scale reducer fitted where total hardness exceeds 200 ppm and most heating engineers specify them for non-domestic properties as well.

Conclusion

Experience in the UK has shown that an active market, with the positive promotion of PWCs, has actually increased the market for conventional softeners. Even at their best, PWCs can never deliver the equivalent performance of a properly maintained salt softener. Experience shows that for the majority of people, the low cost, convenience and lack of maintenance is a sufficient incentive to look at the PWC alternative. The level of performance can never be guaranteed; however, most people's expectations match the delivery that they get from their PWC and they remain happy customers. Those whose expectations exceed the performance will generally convert to conventional softening.

The research currently being conducted at Oxford University and elsewhere will lead to a better understanding of the performance of these devices and will in due course be able to define their performance parameters and will lead to product development. Current knowledge is enough to give grounds for confidence—the threat is that technical ignorance will continue to result in bad experiences among customers.

Footnotes

1. The Influence of Magnetic Fields on Calcium Carbonate Precipitation. Rebecca Barrett and S. A. Parsons. *Water Research* Vol. 32, No. 3, pp. 609-612 1998

2. Calcium carbonate scale control, effect of material and inhibitors. J. Macadam and S. A. Parsons. *Water Science and Technology*, Vol. 49, No. 2, pp 153-159 © IWA Publishing 2004

3. Busch, K., et al. Evaluation of the principles of magnetic water treatment. *API Report 960, Report by the American Petroleum Institute, Washington DC.* 1985

4. Katz, J. L. and Parsiegla, K.L. Calcite growth inhibition by iron. (*Paper J* 96, *Corrosion* 94, *The Annual Conference and Corrosion Show Sponsored by NACE International*, 1994)

5. Coetzee, et al. The role of zinc in magnetic and other physical water treatment methods for the prevention of scale. *Water SA* Vol.22, No 4, October 1996

References

1. *DVGW W-512* http://www.waterking.co.uk/Pdf%20Files/DVGW-W512.pdf

2. *Softer water and the data that proves it* http://www.waterking.co.uk/Pdf%20Files/Softerwater1.pdf

* The cathodic device referred to is the Judo Biostat www.judo-online.de.

About the author

♦ *Jonny Seccombe is Managing Director of Lifescience Products Ltd. He has worked in the water treatment industry for 14 years, specializing in hard water treatment without the use of chemicals. Seccombe is accredited by the Chartered Institute of Building Services Engineers, the Society of Public Health Engineers and the Institute of Plumbing and Heating Engineering as a provider of Continuing Professional Development. He is also a lecturer to Consultants and Engineers in the UK on a regular basis. A graduate of Oxford University, Seccombe is also a pilot and a tobogganist. Contact him at: sales@waterking.co.uk*

About the company

♦ *Lifescience Products Ltd. supplies water treatment products worldwide from the corporation's base in Abingdon, Oxfordshire, England. The firm was founded 13 years ago to develop and exploit environmentally-friendly technology in the water treatment field. Lifescience has a technology partnering agreement with Oxford University Science Department and a consultancy agreement with Dr. Abi Aoun, who specializes in the field of physical water treatment. The firm takes pride in offering excellent product support from design through installation stages, offering an unconditional no-quibble money back guarantee. Its range of water treatment products covers the latest technology for water conditioners, UV sterilizers, backwash and water filters.*

About the product

♦ *The electronic device being tested at Oxford University is the Water King, a non-intrusive water conditioner that inhibits scale formation, removes existing scale deposits and partially softens hot water. It requires no plumbing and there is no need for ongoing maintenance or service. The Water-King range of electromagnetic water conditioners is manufactured in Manchester, England. One of the most powerful devices of its kind, the units are extensively specified.*