Cranfield University study of Anti-scale magnetic treatment

What is magnetic water treatment?

The build up of scale deposits is a common and costly problem in many industrial processes using natural water supplies. In Britain alone the formation of scales in industrial process plant where water is heated or used as a coolant is estimated to cost £1 billion per year. Such costs can be attributed to cleaning (i.e. descaling) or the poor thermal conductivity of scaled surfaces; heat transfer is decreased by 95% by a $CaCO_3$ scale layer 25 mm thick whereas an SiO_2 scale layer 0.5 mm thick results in a 90 % decrease in heat transfer. Scale formation is the precipitation of sparingly soluble salts, most commonly calcium carbonate, which form an encrustation on susceptible surfaces. Most commonly this occurs as a result of temperature or pH changes, influencing the solubility of the scale former. Other common scale-forming compounds include calcium sulphate, barium sulphate, calcium phosphate, magnesium hydroxide, zinc phosphate, iron hydroxides and silica, all of which occur naturally in raw water supplies.

Traditional chemical methods of scale control or water softening involve either the pre-precipitation of the scale former with lime or soda ash, the addition of scale inhibiting reagents or the replacement of the scale former with soluble ions by ion exchange. All of these methods, though effective in scale control, substantially change the solution chemistry and can be prohibitively expensive.

Antiscale magnetic treatment (AMT) has a long and controversial history and has been reported as being effective in numerous instances (Baker and Judd, 1996). Its effect is to reduce scale deposition, remove existing scale or produce a softer and less tenacious scale. Many reports claim large savings in energy, cleaning (i.e. descaling) and process downtime costs from the installation of magnetic water conditioners in real systems. However, installed MTD's have also often proved ineffective in real installations though the precise reasons for their inefficacy are rarely examined in such cases.

Reported effects of magnetic conditioning of water have appeared in the literature since the late 1930's. These have usually related to AMT, though there is some evidence that magnetism interacts directly with microorganisms. Reported effects appear to vary widely, possibly reflecting variations in water quality, and the apparent lack of their reproducibility has tended to undermine the credibility of the process. The paucity of systematic studies of the phenomenon, independent of AMT device manufacturers, and the lack of recorded design criteria have prevented acceptance of the method by process designers and plant engineers. The scientific literature is still unable to explain confidentially why AMT works in some applications and not in others. Recent research at Cranfield has identified conditions under which magnetic treatment can lead to a maximum of 70% reduction in calcium carbonate scale formation. The degree to which scale formation is inhibited has been identified to be dependent on a number of physicochemical conditions such as temperature, pH, hardness and alkalinity. This work has also identified effects on pH, particle size, nucleation rate and crystal form.

The subject of AMT and other physical methods of scale suppression remain controversial and are still labelled as gadgetry in some scientific circles. The debate is understandable; for many years the positive effects well documented in trade literature resulting from industrial applications have been undermined by the apparent lack of good results from laboratory tests. In addition, some manufacturers continue to promote ineffective devices (with dubious literature) for applications where no real evidence exists, anecdotal or otherwise to show that they could ever, or have ever worked. However, many devices on the market have reasonably good track records, but even these have occasionally proven ineffective in certain situations. Many designs of commercial magnetic treatment devices (MTD's) are available; some use electromagnets whilst others use single or arrays of permanent magnets. Other MTD's are clamped on to the pipe, but these typically display lower field strengths than the 'plumbed in' variety. Other physical conditioners generate electric fields or alternating radiofrequency and often claim to be more effective that MTD's but on the basis of our literature work, we could find no hard evidence to substantiate this. Other conditioners subject the flowing water to an electrostatic charge (produced by a chemical potential difference) between two or more electrodes.

On reviewing the literature, we arrived at the conclusion that most reported successful applications of magnetic treatment devices (MTD's) have occurred in continuously recirculation systems enabling repeated treatment of the process water. The viability of AMT in certain applications can be emphasized by looking at the sales of CEPI-Co, Belgium, one of Europe's longest established manufacturers who have sold in excess of 700 000 units worldwide; current estimates are that 70% of sales are for industrial cooling circuits. In these instances operators often describe an accumulation of sedimented scale in low flow areas of the system and formation of a softer, less tenacious scale.

Encrusted scale has also been removed over periods of three to six months. It is fairly well agreed that the anti-scale effect results from changes in crystallization behaviour promoting bulk solution precipitation rather than formation of adherent scale. The magnetic effect also appears to be enhanced under conditions of super-saturation and a high ionic load of the process water. Credible laboratory studies have detailed increased solution precipitation rates, crystal size and morphology changes, enhanced and retarded coagulation and retention of the anti-scaling properties of the water for hours or days following treatment. In many of these studies, the results have only been apparent under dynamic magnetic treatment i.e. the solution moving sufficiently rapidly through the (predominantly orthogonal) field.

Many mechanisms for the anti-scaling effect have been proposed, some clearly ill informed such as magnetically induced changes in electron configuration (this would require a huge field). None however are fully comprehensive and can account for all of the observed effects. Early Russian work which claimed changes in the structure of water resulting from magnetic exposure has now been largely disproven by subsequent work. Other Russian workers have more recently proposed models to support the theory of enhanced nucleation in the bulk solution. However, on the basis of current crystallization theory European experts have concluded that any effects on heterogeneous nucleation would have a relaxation time of nanoseconds and any effects on homogeneous nucleation would be unlikely, even after exposure to a reasonably strong (5000 gauss) magnetic field.

Others believe that the reason for the ‘soft scale’ so often described results solely from magnetically induced changes in crystal habit i.e. calcite to aragonite, however, this is also unlikely since many other factors (specifically the presence of contaminants, heat or pressure) influence the preferred crystallizing form of calcium carbonate, in addition aragonite may prove to be a troublesome deposit because it will re-crystallize as calcite at low temperatures and pressures. Another school of thought involves the influence of contaminants (specifically Fe^{2+} or Zn^{2+}) introduced by magnetically induced corrosion or by slow release from the MTD. One thing is for sure - there is an interaction between a magnetic field and crystallizing matter which can, on occasions affect its scaling behaviour. As engineers we are primarily interested in deducing a satisfactory design basis and the conditions under which the process will repeatedly work, as scientists we want to know how it works.

What is needed is a complete analysis of all instances where AMT has worked effectively and more importantly - where it has not. In this way it may be possible to deduce which factors are crucial in terms of a successful application. In addition it can be seen that real results are realised after periods of months whereas most laboratory studies have tried to achieve results after hours or days using accelerated scaling techniques.

The results of current research into antiscale magnetic treatment at The School of Water Sciences:

Cranfield University investigated magnetic effects on the crystallization behaviour of Calcium Carbonate in once through systems.

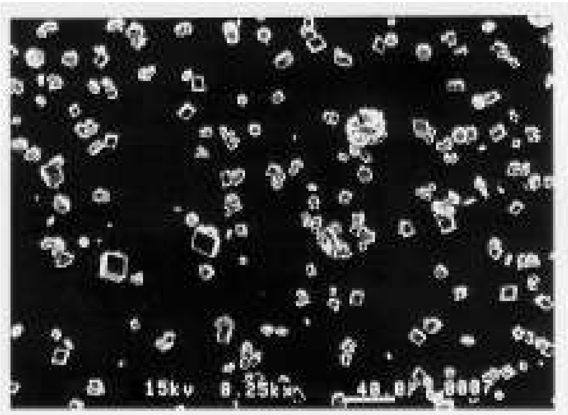

Figure 1 Sedimented CaCO3 scale produced from high-purity supersaturated solution in a once through system.

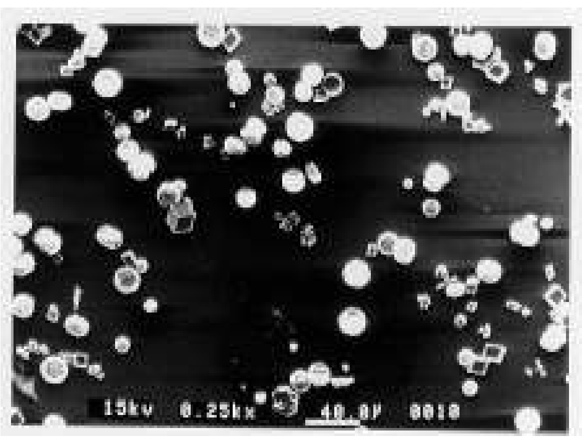

Figure 2 Sedimented scale formed from the same solution after placing the flow path into an 8000 gauss magnetic field. These effects were only apparent with a sufficient flow velocity through the field.

For more information:

Useful consumer fact sheets
www.britishwater.co.uk/consumer/Factsheet_Index/factsheet_index.html#index

Recent papers on scaling and corrosion including physical conditioner papers.
www.iwaponline.com/wst/04902/02/default.htm

For recent Cranfield University publications please visit our Scale and Corrosion research pages.

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