By Jan de Baat Doelman

Controlling Scale Deposition and Industrial Fouling

Treatment options for limescale build-up include inhibitor chemicals, descalers, ion exchange, physical cleaning, magnets and electronic devices.

Look at the heating element of a washing machine or dishwasher in a hard water area and you will see a white encrustation containing hardness salts. This is commonly referred to as limescale and is an example of domestic fouling. The limescale (calcium carbonate) that deposits on the heating element will, if untreated, reduce the efficiency of the machine, induce corrosion of the element and ultimately lead to appliance failure.

Industrial fouling poses a far greater problem than in the domestic sector. This is because huge volumes of fluids are handled and the systems that contain the fluids can become fouled. The quality of water streams used by industry varies widely and causes many fouling problems.

Types of Fouling

Mineral scale deposition occurs as a result of heat transfer or pressure changes. For example, calcium carbonate scaling comes from hard water, while calcium phosphate and oxalate formation occurs in sugar refineries. Other types of fouling include the growth of algae and bacteria (bio-fouling), the consolidation of loose particles (particulate fouling, [e.g., corrosion by products]) and the accumulation of "coke" like deposits (chemical reaction fouling).

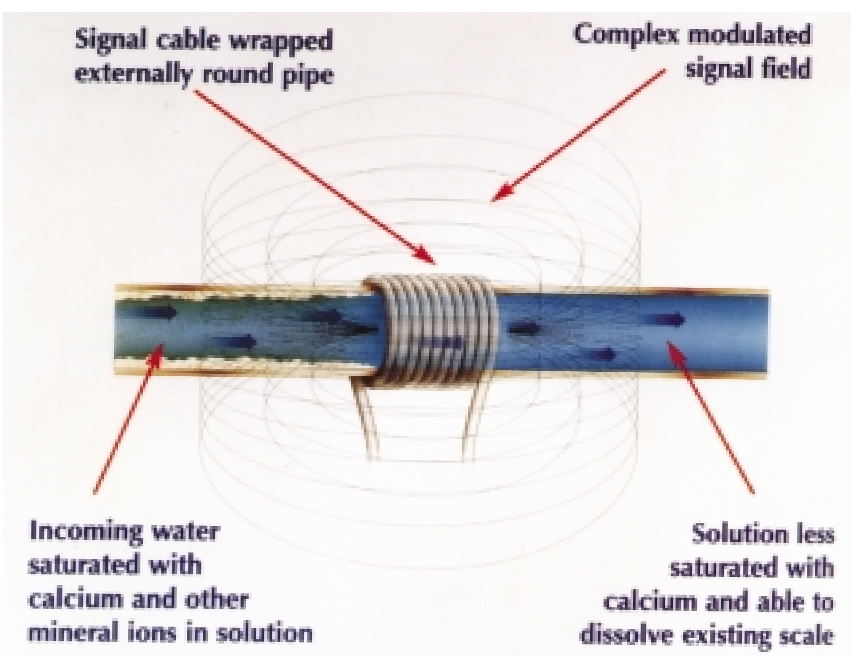
What Can Go Wrong?

Process managers should be concerned about fouling. Deposits are an insulating layer on heat transfer surfaces. These deposits lead to more power being consumed or to the installation of heavier duty, more expensive heat exchangers to compensate. It is estimated that 40 percent more energy is needed to heat water in a system fouled with 0.25″ of calcium carbonate scale. Scaled boiler tubes mechanically fail as a result of overheating, and cooling tower plates can collapse due to the weight of scale deposits. Erosion damage can occur as a result of scale particles breaking loose and then subsequently impinging on other surfaces.

Pipework scale reduces the available cross-section area, and fluids are affected by increased pipewall friction. A larger, more power-consuming pump will be required to maintain throughput volumes but this is only a temporary solution to the problem. A plant that needs to be shut down for cleaning costs money.

The formation of a thin uniform layer of scale or wax can temporarily reduce the steel corrosivity, but eventually stagnant conditions develop under the deposit and electrochemical reactions will corrode the steel surfaces. The result can be fluid leaks and equipment failure, which is potentially very dangerous. In the food industry, the incorporation of even trace amounts of undesirable particulates can lead to off-flavors or off-colors, reducing shelf-life or even making the product unsaleable.

Not only is plant and product integrity at risk but also personnel health and safety may be compromised. Safety valves or emergency process sensors that are fouled may not operate in an emergency. Overheated boilers have been known to explode. Failure to control bacterial growth in cooling water can create conditions hazardous to health (e.g., production of *legionella pneumophilia*). In anaerobic conditions, it may allow the production of toxic hydrogen sulfide from sulphate reducing bacteria.



Magnetic and electronic descaling systems alter the shape of the crystals to reduce the adherence and build-up of deposits on the pipewall.

Recognizing Fouling

Since scales and other deposits generally form inside closed systems, it is not always evident that deposition is occurring. However, some clues can provide the evidence that is necessary. It is useful to try to answer the following questions.

- Do energy/heating bills reduce immediately after cleaning the plant?
- Is it necessary to arrange significant planned and/or unplanned downtime?
- Are heat exchangers performing below design?
- Is corrosion a problem in the plant?
- Are there signs of unexpected deposit formation within the system?

The more times that the answer is "yes" then the more likely it is that there is fouling. If fouling can be controlled, there is potential to save energy, prevent equipment failure and reduce maintenance. Furthermore, a successful treatment strategy will maintain fluid flow, reduce corrosion effects and provide a safer environment. Finally, it will save money.

Solving the Problem

A process audit would identify the extent of the current problem, the point in the system corresponding to initial fouling and, most useful, why there is a problem. From the evidence collated, it may be possible to suggest a solution without the need for expensive external control measures. Minor changes in the process temperature, pressure, pH or fluids composition could significantly reduce the fouling potential at practically no cost.

Treatment options include inhibitor chemicals, descalers, ion exchange, physical cleaning such as pipeline pigging, or the installation of permanent magnets or electronic devices.

Although it usually is possible to find a chemical solution to a fouling problem, environmental and safety pressures are demanding that chemical consumption be reduced when possible. Increasingly, restrictions are being applied regarding the use of chemicals.

Physical Methods

A range of physical methods can be used to remove fouling deposits. Water jetting, sand or plastic-bead blasting can be used in accessible locations. Such methods are expensive and can cause the abrasion of surfaces.

Table 1: Scale Prevention with the Lorenz Force

Electronic Scale Control: $F = q(E + v \times B)$
Magnet: $F = q.v \times B$ Newton
Alloys: $F = q.E$ Newton

F: Lorenz Force on particle or dissolved mineral ion in the liquid, measured in Newtons.
q: Charge of particle or dissolved ion, measured in Coulombs.
E: Electric field generated by alternation magnetic field measured in V/m (Volts/meter).
v: Velocity of water measured in m/s (meters/second).

Magnetic and Electronic Descaling

Unlike other preventative techniques, these devices do not stop precipitation but alter the shape of the crystals to reduce the adherence and build up of deposits on the pipewall. These devices also can affect descaling downstream of the point of installation. A softening and loosening of existing scale is commonly reported several weeks after installation.

To understand the mechanism, some knowledge of mineral scale precipitation is necessary. In order for a scale deposit to form; three conditions must be met.

- The solution must be supersaturated.
- Nucleation sites must be available at the pipe surface.
- Contact /residence time must be adequate.

In order to prevent scale it is necessary to remove at least one of these pre-conditions. Clearly contact time is not an alterable factor. Therefore, any successful device must affect either the supersaturation value or the nucleation process.

The direct effect of electronic devices is on the nucleation process and in particular to enhance initial nucleation through the creation of new nucleation sites within the bulk fluid flow. Crystal growth then occurs at these points of nucleation and not at the pipewall. It has been observed that suspended solids increase with a corresponding drop in the level of supersaturation. The localized pH increase near the pipewall caused by hydroxyl radicals formed by electromechanical interactions is one mechanism that drives the changed nucleation characteristics.

A Lorenz force (F) is experienced by charged particles that flow through a field: $F = qE + q(V \times B)$ where q is the charge on the particle, E is the electric field vector, V is the particle velocity and B the magnetic field vector. Electronic devices operate at very small residual magnetic fields whereas magnets need high field strength (>1,000 gauss) for optimum performance. The flow dependency of magnetic devices is explained by the velocity parameter, (V) and $E = 0$. The flow non-dependency of electronic devices is explained by the fact that the magnetic component approaches zero, but the electric component is essentially constant. This suggests that the key performance parameter is the total value of the Lorenz force acting on the charged particles, rather than the individual magnetic and electric field vectors. The equations for various devices using the Lorenz Force are shown in Table 1.

Electronic devices are not flow-rate dependent and can be built to fit pipe diameters up to at least 60″. The units are lightweight and easy to install, can be retrofitted and produce no significant magnetic field. They usually are effective on calcium carbonate, are claimed to reduce iron fouling and appear to prevent fouling by various other substances.

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