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Non Chemical Devices: Thirty Years of Myth Busting

By Timothy Keister, FAIC, CWT

Non chemical devices (NCDs) have been marketed for control of scale, corrosion, deposition and biological growth in boiler and cooling tower systems for over 50 years. During this time, numerous NCDs based upon various magnetic, electromagnetic, electrostatic, catalytic and mechanical theories of operation have been proposed and installed in a great variety of water systems, with generally unacceptable results.

Types of devices on the market

Looking at either the supplier literature or actual devices in the field, we have observed the following general construction of five basic types of NCDs.

Magnetic. Devices of this type generally employ one or more permanent magnet(s) mounted either on the outside or inside of the pipe containing the water to be treated. No other equipment or input power is supplied and the magnets are stated to be 'permanent'.

Electromagnetic. These devices commonly have a low-power, low-voltage (step-down transformer) based power supply providing alternating (or in some cases, direct) current to one or more coils wound around the outside of the pipe through which the water to be treated flows.

Electrostatic. Such units generally consist of a low-amperage, high-voltage DC power supply and a capacitor-like cell where the water to be treated flows between two insulated plates which are typically charged to between 10,000 and 30,000 Vdc. Operating like a capacitor, there is very low power usage.

Catalytic. These devices appear to be nothing more than sealed metal cylinders filled with 'powered metal' or metal shapes of varied composition, inserted into either a tank or a pipe in the water system to be treated. The chemical composition of the 'catalyst' is reported to vary widely, but is often claimed to include transition and precious metals.

Mechanical. The mechanical devices being marketed appear to be modified centrifugal pumps that provide for recirculation of the pressurized water.

How do they work?

Review of NCD supplier literature shows many common explanations for their operation, one theory often covering several types. However, we do note a certain amount of disagreement between some suppliers having the same basic type of unit. In order to address the many varied theories of operation, the clearest explanations found in the literature are summarized below and examined against known scientific principals.

1. Device operation causes calcium carbonate to precipitate as aragonite, not calcite, generally as a bulk precipitation; also causes any existing calcite in the system to re-crystallize to aragonite.

To date, all controlled studies of devices claiming this ability have shown that the calcium carbonate continues to crystallize as calcite, not aragonite. In cases where the water pH has not increased by cycling, calcite does not bulk precipitate, forming instead a typical scale.

Bulk precipitation has been noted in many NCD-treated, high-cycle systems, but is a function of pH, not operation of the NCD. Not addressing effects within the device itself, it is difficult to picture any downstream mechanism which could cause calcite to change to aragonite, as calcite is the stable crystal phase of calcium carbonate. In fact, aragonite is the low temperature stable phase of calcium carbonate with a reported transition temperature of 128°C (262.4°F) to calcite. Some reversion is reported in the literature, at a temperature of -60°C (-76°F).

We would note that this ability is claimed (or inferred) by many of the NCD suppliers for their devices with claims such as, 'scale forming minerals change their ionic construction,' or, 'dissolved solids precipitate as a loose, powdery dust.' While it all sounds scientific, aragonite will form in place of calcite only under well-defined temperature and pressure conditions. Note should be made that the primary factor in dictat-

ing the crystal structure adopted is geometry of the ions; i.e., their size. Thus, at low temperatures and high pressures, aragonite forms a denser structure than calcite and is thus the preferred phase. Exposure to electrical and/or magnetic fields has never been shown to affect the size of ions in solution. In addition, aragonite forms scales that are as hard and tough as calcite, so there would appear to be no good reason for preference of one crystal structure over the other.

2. Particles or molecules are charged or their static charge is altered by operation of the NCD in such a way that they repel each other, preventing formation of scale.

Cooling water is quite conductive and as a result, any charge placed on particles or molecules within the liquid as a result of NDC operation would immediately short to ground.

We also note that calcium and carbonate exist in water solution as dissolved ions, thus they are not in a particle form. Exposure of these ions to the low-level magnetic, electrical or mechanical forces produced by the NCD reviewed will not alter their ionic state.

3. NCD operation alters the behavior of molecules or particles in the water by aligning their polarities to neutralize the adhesion required to form scale.

Not considering any effects within the device, any such polarity alignment would be immediately destroyed in the operating water system by simple Brownian motion.

4. Mechanically alters the Langelier Saturation Index (LSI) by stripping out carbon dioxide and oxygen; forces calcium carbonate to form a non-sticking solid. Kinetically breaks scale mineral chemical bonds.

Removal of free carbon dioxide and oxygen from water has minimal effects on the LSI and no effect on the crystal form that calcium carbonate will take upon precipitation.

Due to the high energy levels needed, it is extremely unlikely that scale mineral bonds can be affected by mechanical devices. We also note that as calcium and carbonate are typically present as ions in cooling water, there would be no crystal 'bonds' to be broken by passage of the water through the NCD.

5. High shear produced by operation of mechanical NCDs is reported to 'crush and kill' microorganisms.

Interesting comment that may have some truth to it; but as the major problem in cooling water systems is sessile microorganisms, not planktonic ones, it is irrelevant to obtaining good microbiological control in cooling water systems.

Testimonials versus science

The vast majority of NCD marketing is based on the use of testimonials on device performance. Rarely is any scientific data (such as corrosion coupon results or system mass balance analyticals) provided. In most cases, the testimonials are provided by people with no technical knowledge and little idea of what constitutes acceptable performance for a water treatment program.

To date, every testimonial we have had the opportunity to investigate has shown cause(s) other than operation of an NCD to be responsible for the performance cited. The most common causes behind successful testimonials are reviewed below.

No treatment needed

We have all experienced the untreated cooling system operated at low cycles, using a low hardness makeup water, where there is no scale formation and corrosion rates are running at two or three mils/yr. While a chemical program can often improve on these results, they are acceptable to many people and installation of an NCD into such a situation will

always result in 'success'. In general, a good field test is to simply unplug the NCD and see if anything changes, while a complete analytical workup on the makeup and cycled water will tell the truth about any real benefits.

Reduction of cycles

Operation of treated cooling systems at excessive cycles is fairly common due to faulty (or no) blowdown controls and/or a poor chemical treatment program. This commonly results in system scaling and substantial operating problems.

Many suppliers of NCD also supply conductivity-based blowdown controls with their device. Installation of an NCD with a new blowdown control, set to maintain lower cycles, will often result in prevention of new scale and removal of existing scale, regardless of whether or not the NCD is really doing anything at all.

Bulk precipitation

Several NCD suppliers actually claim that their devices force or cause bulk precipitation and thus prevent scale formation. Our investigations into many such NCD installations show that they are typically operated at very high cycles, with resultant high cooling water pH values.

Under these conditions, any calcium introduced into the cooling system in the makeup will immediately precipitate as calcium carbonate in the bulk water, with or without the aid of an NCD. This process is, of course, the basis for the well known 'carbonate cycle' boiler treatment chemistry. We have confirmed, in a full-scale experiment, that operation of a cooling tower under such conditions will prevent scale formation in the condenser tubes of a chiller. However, you do have to shovel the calcium carbonate sludge out of the cooling tower basin on a routine basis and plugging of fill can be a problem.

Bio control via bulk precipitation

Some of the more recent NCD literature actually cites removal of planktonic microorganisms via the bulk precipitation process. We agree that this is a viable process and note that it is used in thousands of potable water treatment plants every day, but it is worthless in getting at the sessile microorganisms, which are the real troublemakers in cooling water systems. In any event, as already noted, this effect can be obtained without an NCD, by simple adjustment of cycles or addition of caustic soda to obtain the pH needed for bulk calcium precipitation.

Bio control via high pH operation

In our own cooling water management programs, we have noted a substantial reduction in the amount of biocide needed to obtain biological control when operating at cooling water pH values above 9.0. Since many NCD installations are operated at high cycles to take advantage of bulk calcium carbonate precipitation for scale control, they are also getting the benefit of reduced biological activity due to the resultant high pH. Again, the results obtained actually have nothing to do with operation of the NCD.

Deposition control

NCD suppliers commonly specify hydrocyclones and media filters as part of their installations, which certainly help prevent deposition and resulting problems within cooling water systems. Of course, the same benefits could be obtained without use of the NCD. It is interesting to note that those suppliers of NCDs who acknowledge the bulk precipitation process also typically recommend filters or hydrocyclones as part of their installations.

Corrosion control

The high pH, high LSI and 'controlled' scale formation cited by many NCD suppliers as the theory for corrosion control by their device are all actually familiar chemical methods used for many years to reduce corrosion in cooling towers. It should come as no surprise that many suppliers of NCDs recognize these methods and use them to obtain lower corrosion rates by judicious selection of operating cycles. Again, operation of an NCD is not required to obtain results, just careful selection of cycles.

Drivers of NCD market acceptance

With thousands of failed installations, not a single controlled study showing positive results and no creditable operating theory, why are large numbers of NCDs still sold each year? This is a very interesting question, with a multi-part answer.

Proprietary nature of the water treatment business

Unlike many other science-based fields, such as civil engineering, the provision of water management programs is dominated by proprietary technology. There are no open sources where one can acquire the knowledge to separate 'snake oil' and marketing hype from the real thing. In addition, the water treatment

business has had (and still has) more than its fair share of marketing hype sales activity, as well as just plain incompetent people.

General lack of scientific knowledge

In spite of it being politically incorrect, the plain fact is that many people in engineering, specification and purchasing positions do not have the basic scientific knowledge to properly evaluate the many claims made in regard to water treatment. While this is partially due to the proprietary nature of the water treatment business, a good part of it is due to a general de-emphasis on scientific subjects in the education system. Included in this area are the various licensed professional engineers, who should know better than to practice outside of their field. Six credits of chemistry 20 years ago does not qualify someone to evaluate the merits of an NCD versus generally accepted chemical practices.

Green marketing and chemo-phobia

Many suppliers of NCDs are marketing their devices as green and safe alternatives to 'chemicals' which are automatically assumed by many people to be environmentally bad and hazardous to health. While this was sometimes the case with pre-US EPA programs (such as chromates), modern chemical treatment programs produce a lower environmental impact than many NCD installations, due to the lower corrosion rates of system metals of construction obtained. In addition, green is only good when the technology actually works.

Cost reduction (getting something for nothing)

Many people decide to install an NCD due to the substantial cost reductions claimed over chemical treatment programs. In some cases, the existing chemical program is very costly due to 'snake oil' sales or incompetence, making a cost reduction easy to show. In several recently reviewed cases, the NCD supplier had assumed completely unrealistic costs for chemical programs to ensure that their technology would appear cost competitive. The desire for reduced costs must be balanced with sufficient knowledge for an independent evaluation of claims made.

About the author

♦ *Timothy Keister holds a B.Sc. in ceramic science from Penn State University. After 13 years as Section Head, Water/Wastewater at Brockway Glass Company and 11 years as President of Brockway Analytical, Inc., a water/wastewater analytical laboratory, he founded ProChemTech in 1987 (a water management program supplier) and is presently the President and Chief Chemist. His professional activities have included election as a Fellow of the American Institute of Chemists; Senior Member of the American Institute of Chemical Engineers and memberships in the American Chemical Society, Water Environment Federation, Cooling Technology Institute and Association of Water Technologies. Certificates and licenses include Certified Water Technologist (CWT) and wastewater operators licenses in New Jersey, Pennsylvania and Indiana. Keister also serves as Vice Chairman of the Brockway Area Sewerage Authority and is Technical Director of the Toby Creek Watershed Association. He has investigated non-chemical devices since 1974 by testing actual devices and through critical examination of numerous NCD installations.*