Maintaining a satisfactory balance between microbiological control (especially *Legionella*) and metal wastage by corrosion in cooling water systems is not an art – it is cold-blooded science, with possible dire consequences if control of the balance is lost even for relatively short periods. The two processes are interactive – for example, some biocides are aggressive to metals commonly found in cooling systems - and corrosion product is a *Legionella* food source. On the other hand, and apart from *Legionella* control, Microbiologically Induced Corrosion (MIC) is to be avoided.

**Critical Risk Management**

Measuring the absolute values and assessing the trends of corrosion is not just a valuable tool in assessing the overall performance of a chemical supplier – nor is it just another Key Performance Indicator (KPI); it is a Critical Management Strategy (CMS) for assessing the average life expectancy of cooling water systems. Whilst being proactive with equipment performance it is also necessary to simultaneously provide a biologically safe working environment and surrounds.

**Heat Transfer Considerations**

Corrosion and corrosion product deposition profoundly affects equipment performance – especially heat transfer efficiency. Given that the relationship between the heat transferred (Q) through a chiller tube for example is the product of the Coefficient of Heat Transfer (U), the Heat Transfer Area (A) and the Temperature Difference (ΔT) across the heat transfer surface (Q = UAΔT) the only variable is U. Add a layer of corrosion product to the bare chiller tube wall and heat transfer efficiency suffers.

**Corrosion Monitoring**

Practical corrosion monitoring techniques are classified as either real-time measurement or retrospective over time, and each category offers pros and cons of cost verses expense, ease or otherwise of installation and maintenance of monitoring equipment – and relevance of data. Either way, the objective is to avoid un-necessary cooling system plant internal inspections. Rather, practical monitoring “flags” a developing problem long before pipe wall perforation, allowing an audit to be conducted and corrective action to be taken.

**Real Time Corrosion Measurement**

The linear polarization-resistance (LPR) technique utilizes electrode behaviour to rapidly indicate corrosion upsets. The most usual type has two electrodes – one being mild steel (anode), the other a copper based alloy (the cathode) between which is passed a very small voltage of 20mV. The resulting current generated from this applied potential difference gives a measure of the general corrosion rate in the vicinity of the electrode.
Retrospective Corrosion Measurement

Coupon corrosion studies are inexpensive and simple to perform. This is the most direct method, aside from inspection of the actual plant equipment, to determine the efficacy of the water treatment chemical program. Coupon evaluation allows simple comparison between different alloys which provide visual examination for localized attack, such as pitting, crevice attack, dealloying, or any other form of non-uniform attack, such as MIC.

Pre-weighed and surface prepared coupons are highly susceptible to corrosion. A corrosion coupon is not a heat transfer surface; cleaning the coupon to make it more susceptible to corrosion helps compensate for the fact that it is not a heat transfer surface operating at elevated skin temperatures. Exposing the corrosion coupon to a cooling water stream for a known length of time for usually 90 days, and by then calculating the difference between the initial and final weight it is possible to express average corrosion rate per year for that system. The time of exposure for corrosion coupons in cooling water must be considered in the evaluation of any results. In summary, the shorter the period of exposure, the higher the corrosion rate will be.

General Metal Loss and Pitting

The rate of corrosion represents an average metal penetration based on total weight loss and assumes 100% general attack. In many cases the type of attack or appearance of the coupon can provide more useful information than the actual corrosion rate obtained by weight loss. Even if the calculated average corrosion rate is low and all the attack is localised at one point on the coupon, the rate of penetration at that point could be 4 to 5 times the average rate of corrosion.

Deposits and Deposition

Heavy deposits and tuberculation are sure signs of unstable corrosive water, regardless of the corrosion rates. Furthermore, coupons covered with heavy deposits cannot reflect system corrosion rates, due to the deposit covering the coupon. Some types of deposits will cause an increase in corrosion while other types will form a protective coating.

Coupon Positioning, Orientation and Reynolds Numbers ($N_{Re}$)

For a corrosion coupon to provide useful data, it must be placed in a representative location in the system. The degradation of the coupon is dependent on many factors, including temperature, water velocity, the ratio of mild steel to copper metallurgy in the system, off periods, chemical treatment, chemical control etc. It is very difficult to locate a coupon in the highest critical area so locations are always seen as a compromise.

Water velocity over the coupon is critical and although “bucket-and-stop-watch” measurements suffice, it is useful to understand the type of water flow in the pipe – laminar, transitional or turbulent as measured by the Reynolds Number, $N_{Re}$. [$N_{Re} = \frac{DV\rho}{\mu}$ where $D$=pipe diameter, $V$=linear water velocity, $\rho$=density, $\mu$=viscosity]. A flow rate which is representative of system conditions is the only flow rate which will provide meaningful information.

Generally the best place is on the effluent stream of a critical heat exchanger (critical with respect to corrosion). Corrosion coupons installed on a common return line seldom are representative of critical system heat. It is important that the corrosion coupon rig flow rates correspond to the heat exchanger flow rates. Coupon rig exit flows that are high will usually result in cleaner coupons than the system metals. Excessive corrosion and fouling may result from low flow rates. Further, the orientation of the coupon in the rack is of little importance – after all, the pipe carrying the water of interest is circular and all surfaces are exposed to the effects of water velocity but only some to deposition of solids when the plant is off line – the base of the internal pipe.
Locating the corrosion coupon rack in the cooling tower pond recirculating loop means that the coldest water in the system is flowing over the coupons – this is not duplicating the “worst case” scenario taking place in the hottest part of the system. As a general rule, each 8°C increase in temperature doubles the rate of chemical reaction.

**Acceptable Corrosion Rates**

Corrosion coupons are a useful and meaningful evaluation tools which, when used on an ongoing basis and in combination with plant and equipment inspections will provide invaluable information on the chemical treatment programme and the level of protection that it offers. Coupons that indicate acceptable corrosion rates in a system which is experiencing severe corrosion are not properly installed or subjected to severe enough conditions. Coupons which reflect high corrosion rates in a corrosion free system are being subjected to too severe a condition assuming that the coupon environment is representative of the heat exchanger design parameters of flow and temperature.

Acceptable corrosion levels for mild steel should be less than 3mil and copper less than 0.5mil per year. Typical limits are mild steel 0.15mm, stainless steel 0.005mm (no pitting) and copper 0.005mm per year. (Imperial unit “mil”, one thousandth of an inch (1mil = 0.0254mm)

The ability to successfully control water quality in cooling towers depends on the monitoring and analysis of the system on a continuous basis.

**The Auditing Process**

The auditing process precedes corrective action and involves identifying the type and location of unacceptable metal loss and assessing the influence of all contributing variables, including:

- system operational information
- system metallurgy
- best estimates of mild steel and copper surface areas in contact with system water
- plant history
- biological loading
- corrosivity of make-up and system water
- seasonal variations in make-up water analyses
- system water soluble and total corrosion products content
- the lead-lag duty cycles if more than one cooling tower system is involved
- the calibre of water treatment provider service reports
- a review of any mechanical significant mechanical services performed, including tower cleans
- a review of biological sampling results
- a review of the chemical programs and control ranges
- a review of dosing and control equipment
- validation of any questionable data such as pH, free available halogen, cycles
- a review of the current and preceding Risk Management Plan and Audit

The auditing process should be a co-operative effort involving the key stakeholders – facility management, the water treatment provider, mechanical services – and the auditors. Generally, observations and recommendations indicate dynamic data is necessary and that involves:

- Installation and removal of corrosion coupons monthly for three consecutive months
- System water analyses monthly
- A review of identified critical factors and changes to the same (controller settings, inhibitor level maintenance, pH etc)
- Monthly reporting

Modern technology allows us the opportunity to see the inadequacies in past control methods and understand and realise what is really important in maintaining a successful water treatment
programme. What we now consider as the most important tools are reliable control, data recording of information and alarms to ensure benchmarks are maintained and confirmation that systems are treated proactively through a uniformed analysis of past performances. The selection and implementation of the correct control equipment with effective and professional management is pivotal to success.

Characteristics of such equipment should include:

- Linear Polarization corrosion of two metal monitoring, logs and alarms
- Automated velocity control to set point
- Conductivity measure and automated bleed control
- ORP measure using APL control, with time control if required
- pH measure using APL control
- Secondary biocide with pre-bleed and bleed lockout function
- Inhibitor dosage control via water meter or other mode selections
- Dispersant dosage control via water meter or other mode selections
- Water Usage including Makeup, bleed and Backwash
- 4-20mA input for external instrument with programmable ranging and alarms
- Data logging of all measures and outputs
- Remote control via GSM modem and Aquarius software
- 4-20mA output card for building computer connection of 8 measures and relay status
- Measure alarms, safety alarms with ORP and pH lockout alarm

Information plays a huge part in the total care used to provide both a safe, effective and efficient cooling system.

This allied with technologies that allow for a complete picture on a 24/7 basis using effective control methods and the monitoring of their affect on plant while introducing direct action capabilities through alarms and remote control coupled with professional management allow for a much improved and responsible management of treatment, water and energy.

Several things can occur in a cooling systems treatment which can jeopardise control without notice and include:

- Contamination via exterior source
- Equipment failure
- Water loss
- Empty chemical treatment tanks
- Changes in make-up water quality

Modern day property owners and managers are now recognising the need to better manage all parts of their business and are employing modern day technology to maximise performance and minimise costs.

Steve Powell is a Chemical Engineer specializing in industrial water treatment processes. He has held senior research and sales/marketing positions in multinational water treatment and speciality chemical companies operating within Australian and he brings considerable practical experience to address clients risk management security. Based in Melbourne he is currently Independent Monitoring Consultants (IMC) Victoria/South Australia Account Manager.

Steve says, “IMC is aware of all of the impairments to quality service and servicing. As a privately owned Australian company providing quality services since 1992, IMC was the first to introduce fully independent sampling and testing to help clients manage the control of Legionella, system corrosion, Risk Management, Audits, indoor air quality, OH&S and duty of care obligations. These securities are all important to international hotel chains, major shopping centres, hospitals, and key Property Managers and Owners. IMC was the first major microbiological laboratory in Malaysia. It was also the first to be accredited by Standards Malaysia for both sampling and testing of environmental waters, indoor air quality, and food.”
IMC technical expertise and proficiency has been perfected during the past 20 years through our national and international experience. With a combined total of more than 150 years of water treatment knowledge and experience in our senior staff IMC is the perfect partner.”