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Keeping Cool and Clean this Summer

By David Daniels

Ahh, the smells of summer: frying burgers, fresh cut grass, and chlorine at the local swimming pool. Chlorine, or more properly, sodium hypochlorite is the most common disinfecting and biological control chemical in use in the US. Besides the local swimming pool, it is also commonly used in a variety of industrial open recirculating cooling loops to keep biofouling in check. Biofouling can have profound effects on the efficiency of heat transfer and corrosion in your cooling water. Even a thin layer of biofilm on the condenser can result in increased back pressure and causing load restrictions in the heat of the summer, just when you are trying to get every MW they can out of the system.

Bacteria are ubiquitous in an open cooling system. The can enter with the makeup water or as spores in the air, entrained by the cooling tower fans. It is important to remember that single free-swimming or planktonic bacteria do not cause microbiological fouling or corrosion. It is only when bacteria become fixed in one place or sessile, that they become a significant fouling or corrosion issue. As bacteria settle on surfaces, they begin to form colonies; joined together by a gelatinous substance they manufacture called exopolysaccaride or EPS. The bacteria and EPS form a protective layer called a biofilm. Inside a biofilm, bacteria are shielded from changes in the bulk water conditions and, to a remarkable degree, attack from many common biocides. The biofilm creates its own environments including areas that are oxygen deficient and areas of high and low pH. In an established biofilm there are many different species of bacteria, all finding or creating conditions that are optimum for their survival. The stickiness of the EPS also works to trap various nutrients and silt from the water. Biofilms may also take an active role in the formation of calcium carbonate and other inorganic deposits by providing a stable area for crystals to grow.

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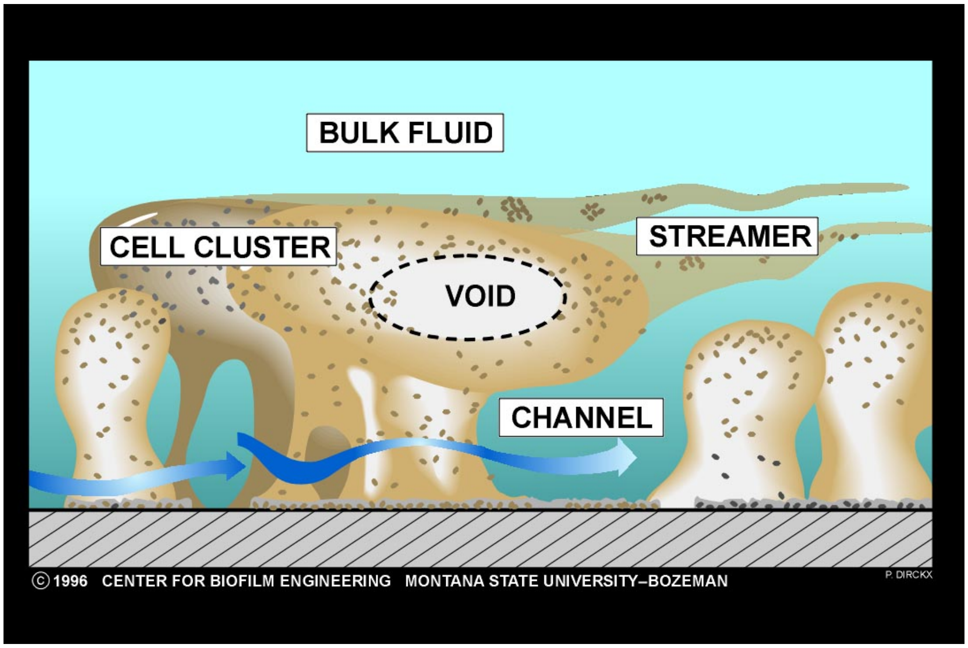

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Figure 1. Structure of a Biofilm

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Even if you could sterilize the system for a few minutes with a super high dose of biocide, it wouldn't last long. Bacteria will find a way to enter a system and survive. The goal of adding a biocide is to keep the bug population from thriving, to the point where they create operational problems. The biggest problems usually occur when there is a lapse in the program—either not enough biocide to keep the system clean, or problems that prevent the system from being treated at all for a even a few days. Biofilms are designed to protect the bacteria inside it. Once biofilms get firmly entrenched, it can be very difficult to clean up. Cooling towers with film fill provide more surface area for increased cooling efficiency, but also increase the surface area for biological growth. (Figure 2)

Biocides can be divided into two major groups, oxidizing and non-oxidizing. Oxidizing biocides include chlorine, bromine, BCDMH, chlorine dioxide, hydrogen peroxide, and ozone. Common non-oxidizing biocides include gluteraldehyde, isothiazalone, DBNPA, and methyl bis-isocyanate.

Oxidizing Biocides

As noted above, chlorine is still the most commonly used oxidizing biocide, however, many power plants in the US have abandoned their economical gaseous chlorine systems in favor of bleach or bleach/ bromide combinations. Though more expensive, the regulatory and potential PR issues associated with one-ton chlorine cylinders were too much for most plants to bear.

When chlorine gas is added to water it reacts to create hydrochloric acid and hypochlorous acid in equal proportions. Bleach reacts in a similar fashion forming the hypochlorous acid as it reacts with water. The hypochlorous acid penetrates the cell membrane and is thought to interfere with the enzyme system of the cell, destroying it. The hypochlorite ion, on the other hand, is not nearly as effective as the acid in killing bacteria. The difference in the cooling water pH from 7 to 8 means the percentage of hypochlorous acid in chlorinated water drops from 80% to 20 % with a proportional decrease in biocide effectiveness. This drop in effectiveness is not measured when testing for Free Available Chlorine, as the FAC test reduces the pH of the water being tested. Therefore, a 1 ppm Free Available Chlorine in cooling water with pH 8 has the effectiveness of 0.25 ppm Free Available Chlorine at pH 7.

Chlorine or bleach is indiscriminant—it will oxidize anything. Besides bacteria, chlorine will react with other organic and inorganic compounds. It also significantly increases the corrosion rate for iron in the cooling system and can destroy chemicals such as TTA, designed to protect copper components from corrosion.

The elimination of corrosion inhibitors such as zinc chromate resulted in treatments that required the pH of the cooling water be increased to between 8-9. While better for corrosion, it made chlorination almost ineffective. The solution was to switch to bromine or more correctly, hypobromous acid. Hypobromous acid typically formed by combining bleach with a source of bromine, typically sodium bromide. While as effective a biocide as hypochlorous acid, the hypobromous acid remains an active biocide at higher pH conditions.

Figure 2. Film fill is an excellent surface area for biofilm accumulation and can be difficult to keep clean.

Bromochlorodimethylhydantoin or BCDMH is an organic compound that can function as a bromine/chlorine donor similar to the chlorine/bromide mixtures, with the exception that it is a single solid chemical. This ease-of-use is very important to some plants and outweighs the additional cost of the chemical.

Chlorine dioxide is a very powerful oxidizer that is popular in industrial wastewater treatment, pulp and paper mills. Typically created by the reaction of sodium chlorite with chlorine gas or with bleach and hydrochloric acid, chorine dioxide is an extremely powerful oxidizing biocide and it is not affected by the pH of the cooling water. The more complex handling of additional wet and dry chemicals, some of which can react violently, has limited its widespread use in cooling water at utilities.

Non-halogen options

For those who need to get away from halogenated compounds altogether, there are oxygen-based oxidizing biocides such as hydrogen peroxide, peracetic acid and ozone. All have a history of use in other industries such as drinking water or pulp and paper manufacturing and may have application in specific instances in cooling water. These compounds disperse very quickly and leave no environmental legacy. They tend to be very powerful but also very localized. Ozone has very little solubility in warm water, which limits its applicability in most cooling systems.

Hydrogen peroxide has been injected into individual cells in a cooling tower to clean high efficiency film fill with excellent results where chlorine just can't keep up or is an environmental liability.

Non-oxidizing Biocides

There are also a number of chemicals that control biofouling by acting as a "poison" to the bacteria. Unlike chlorine and bromine the do not oxidize, so typically have very little effect on corrosion of iron piping. They also are not typically pH sensitive. However, they are much more expensive to use than chlorine. For this reason, on larger cooling tower systems, they tend to be used as supplements to an existing oxidizing biocide program instead of a complete replacement.

Occasional treatments with a non-oxidizing biocide in a system that is routinely treated with chlorine or bromine, can act as a one-two punch, the non-oxidizing biocide hitting bacteria that the oxidizing biocide has weakened. Non-oxidizing biocides can be tuned to a particular problem, such as blue-green algae, or macrofouling issues such as clams. There are no firm rules on which non-oxidizing biocides work best in a particular application, so finding the right one is sort of hit and miss. Nor does it pay just to stick to one, since a tolerance can be developed.

There is a whole alphabet-soup of non-oxidizing biocides including such tongue-twisters as BHAP, DBNPA, and TKHPS. They tend to be complex organic molecules that have the ability to get in, kill the bacteria, then biodegrade or breakdown such that they don't become harmful to higher organisms like fish and people.

Two of the more common non-oxidizing biocides are glutaraldehyde and isothiazolone. Glutaraldehyde is a good bactericide and has good penetrating ability, which makes it effective against biofilms. It acts quickly, typically in a few hours, and is effective over a wide pH range and compatible with chlorine. Glutaraldehyde is also biodegradable.

Isothiazolone is a organo-sulfur compound that is also effective the pH range of most cooling towers. It is a good, wide-spectrum bactericide and algaecide that has been an industry standard. Isothiazolone require very careful handling due to severe skin and eye irritant properties.

Failure Modes for High Energy Piping

By Ron Munson

One of the most "feared" failures at a power plant is the rupture in the piping system carrying high-energy steam or pressurized elevated-temperature water. While boiler failures and turbine failures are more common they are for the most part contained by the boiler casing or the turbine shell; risks to personnel are minimal. Piping failure are much more dangerous in that the piping normally is located in open areas of the plant where foot-traffic and work areas are located.

Longitudinal Failures

The longitudinal ruptures of high-energy systems are catastrophic. Because of the physics involved, these failures tend not to leak, but rupture suddenly and cause considerable damage. Minute cracks leading up to these ruptures are progressive in nature and grow from an embedded flaw. The ruptures tend to initiate mid-wall or on the I.D. surface, which makes early detection very difficult. The pipes affected tend to be seamed piping made by bending plate into a cylinder, then fusing the plate ends by submerged arc welding, forming a long seam weld. Damage often occurs within the analytically predicted useful life of the piping and is unexpected.

The mechanism for failure is almost always creep. Creep is a time-temperature-stress dependent failure mode. The resistance to creep is related among other things, to the degree of alloying. Fortunately, for each alloy there is a minimum temperature below which creep damage will not occur. The following table approximates the minimum creep temperatures for common alloys in high-energy piping.

These values are conservative lower estimates.

It is suggested that power plants that have piping made of these alloys operating above the temperatures perform a more rigorous evaluation. If operating temperatures are below these temperatures this equipment should not have a creep problem.

Material	Minimum Temperature for Creep to Occur
Carbon Steel	700°F
1 ¼ Cr- ½ Mo Steel	850°F
2 ¼ Cr- 1 Mo Steel	900°F
½ Mo – Carbon Steel	800°F

Circumferential Failures

Circumferential failures of piping systems are far more common than longitudinal failures. Fortunately, these failures are usually far less catastrophic in that the pipes usually leak before they rupture and the time between leaking and rupture is much slower. Most circumferential failures are related to externally applied loads and have very little microstructural influence. While creep failures are possible in high temperature systems, fatigue or fatigue-assisted cracking is the dominant circumferential failure mode.

The circumferential failures are usually O.D. surface initiated at highly stress locations, thus conventional surface inspection such as magnetic particle or penetrant testing will usually detect the failures at an early stage.

Sectional Failures

A much rarer failure mode in high-energy piping is sectional failure. In this mode, a section of the pipe "blows out" leaving a fairly large window. There are two predominant causes for this type of failure, both are related to in-service aging. One cause is that a significant area of pipe wall is thinned by either internal or external corrosion or corrosion-assisted erosion. Two-phase flow, for example, a steam/water mixture, is the common cause for this thinning. Another significant cause for window rupture is pipe graphitization that is observed in carbon steel or carbon/molybdenum piping which is operating above 750°F. This graphitization is an alteration of the microstructure that can occur locally, creating local weak spot in the pipe wall. Carbon steels and carbon-molybdenum steels will all graphitize given the appropriate temperature exposure and time. If the graphitization is random and well distributed; general pipe strength loss will occur but it is not a major failure concern. The problem exists when the graphite aligns along a metallurgical feature such as a heat-affected zone. The resultant plane of weakness can lead to catastrophic failure. Both guillotine and window ruptures are typical of graphitized materials. Erosion/corrosion failures can be prevented by periodic thickness measurements at suspect locations

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and timely replacement/repair when thicknesses approach the minimal allowable thickness. Graphitization failures are more difficult to detect but the phenomena is well understood and prediction of susceptibility is possible. Ultrasonic inspection especially ones employing attenuation decay are somewhat effective in detecting graphite formation, but boat sampling is still the best way to confirm graphite formation.

Calendar of Events

October 17-21
International Water Conference
Pittsburgh, PA
www.eswp.com

November 2-5
EPRI Conference on Boiler Tube and HRSG Tube Failures and Inspections
San Diego, CA
www.epri.com

November 31-Dec 1
HRSG Users Group Maintenance Workshop
Orlando, Florida
www.hrsgusers.org

April 11-13, 2005
HRSG Users Group Annual Meeting
Saddlebrook Resort
Tampa, Florida
www.hrsgusers.org

Hanger Basics for High-Energy Piping

By Jon McFarlen

With coal prices low and natural gas prices high there has been a recent interest in plant life extension programs on coal-fired units, and a commensurate increase in high energy piping inspections. This article should help de-mystify some of the basic elements and concepts of high energy piping inspections.

Piping Supports Basics

Piping supports can be divided into three basic categories including flexible hangers, rigid hangers, and rollers. Rigid hangers, such as rod hangers and stanchions, and rollers are fairly straightforward and easy to understand. Rigid hangers are used in piping systems to support the piping in areas where both vertical travel and horizontal travel are not needed. Similarly, rollers are used to support piping where only horizontal travel is needed for thermal expansion. However, when a pipeline expands vertically due to thermal expansion, flexible pipe supports are needed to adequately support the piping throughout expansion and contraction. This can be done using either constant support hangers or variable spring hangers. Compared to rigid hangers and rollers, variable supports are more complex in design and application, and are vulnerable to degradation that can limit or arrest their functionality.

The Basics of Flexible Hangers

Constant support hangers provide a "relatively" constant supporting force of the piping throughout the full range of vertical thermal expansion and contraction. Constant support hangers do this by using a helical coil spring attached to a pivot lever (See Figure 1). These hangers are mostly used in critical piping systems or critical areas of piping

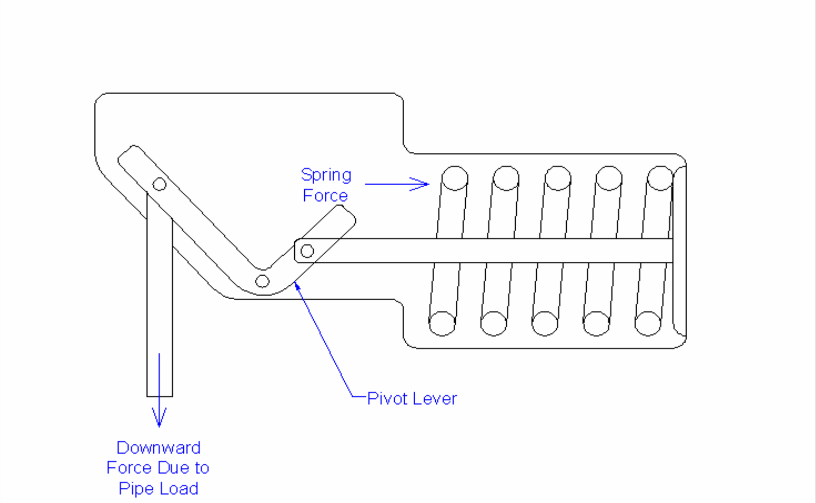

Figure 1. Cross-Sectional View of Constant Support Hanger

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systems such as boiler terminations and turbine terminations.

Variable spring hangers are basically used in circumstances where constant supports are not required – making the primary benefit of variable spring hangers the cost saving advantage. With a variable spring hanger, the supporting force varies with spring deflection due to the non-linearity of spring coils. Since the piping weight is a constant, the variation in the hanger support due to thermal excursions can create excessive stress in some areas. This is a problem when placing a variable spring hanger adjacent to critical equipment. Consequently, variable spring hangers are not used where large vertical displacements due to thermal expansion are expected. Figure 2 shows a simplified view of how a variable spring hanger is constructed.

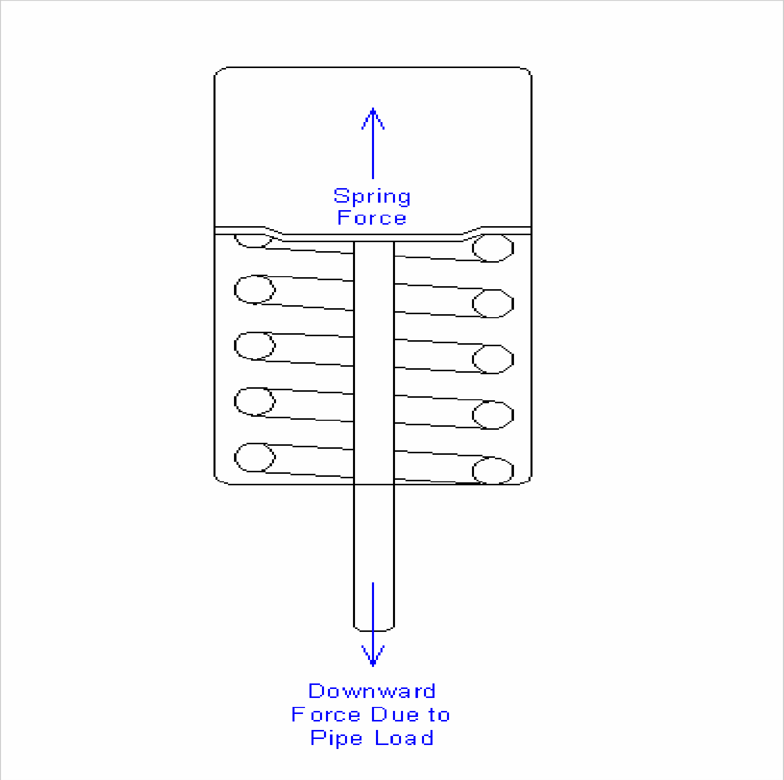

Figure 2. Cross-Sectional View of Variable Spring Hanger

Problems Encountered with Pipe Supports

Due to the strict design rules and load ratings governing flexible supports, the supports themselves are generally over-designed. Because of this, the general mindset is to ignore the supports once they have been installed making inspection and maintenance internals infrequent. As a result, malfunctioning supports causing problematic piping areas often go unnoticed.

Although flexible supports are generally reliable, they can be prone to internal mechanical problems such as lack of lubrication, contamination by fly ash or coal dust, corrosion, or even nesting birds. Piping systems close to seawater or in paper mills are particularly prone to corrosion due to chloride-containing mists.

Corroded or broken supports can result in excessive loads that overload adjacent hangers or equipment connections, increase pipe stresses, or promote pipe deformation and cause low points.

Mitigating Potential Problems

The first step to determine the condition of the piping system and supports is to perform systematic visual inspections. The visual inspection should include hot and cold walk downs of the system in which the hanger positions are recorded and areas of uplift or sag are identified. Also note the physical conditions of the hangers in regard to corrosion or bent components. The hanger readings in the hot and cold positions will determine the amount of vertical travel due to thermal expansion. A good check is to compare the actual hanger travel to the designed hanger travel.

Depending on the observations during the hot and cold walk downs, a stress analysis of the system may be required. With the assistance of computer aided pipe stress analyses software, a stress analysis can be performed efficiently and affordably. Additionally, the stress analysis can identified areas of high stress.

Areas of high stress and areas known to be problematic by industry experience should be further evaluated by non-destructive testing. Additionally, potentially problematic hangers should be load tested. Following these two exercises, corrective measures such as hanger replacement or more dramatic piping modifications can be performed. The last step in ensuring a reliable piping system is routine monitoring.

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