PLANNING TO FAIL - COMPREHENSIVE WATER TREATMENT SPECIFICATIONS ARE A MUST!

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INTRODUCTION

In recent years, there have been a large number of catastrophic corrosion-based failures of system water piping associated with HVAC systems in mid-rise and high-rise buildings. Systems designed to provide long term service life are failing due to leaks and obstruction incident to severe pitting attack, corrosion and massive tuberculation in both galvanized and un-galvanized carbon steel and copper piping. It is not uncommon to encounter systems where complete penetration has occurred within a few years after initial commissioning. There are a number of reasons for the increased incidence of failures.

Prior to the late 1980's and early 1990's (EPA-2000, a ban on the use of chromate in cooling water systems) the use of chromate for corrosion control in all sorts of aqueous environments was commonplace. A few hundred parts per million of hexavalent chromium could maintain a corrosion-free, well passivated system even in stagnant water within mild steel pipe and mixed metal systems. It is little wonder that the phenomenon of exacerbated piping corrosion that we see today was relatively rare prior to the late 1900's. Today, treaters are restricted to the use of inhibitors composed of phosphate, carbon, sulfur and nitrogen containing material - all relatively non-toxic, biodegradable compositions. While the benefits of less dangerous chemistry are obvious, so too are the higher product costs and the system damages that are occurring at an alarming frequency.

It is becoming a far too commonplace occurrence for aggressive early onset corrosion to develop in HVAC piping and equipment installed in new commercial buildings. In severe instances, this corrosion presents in the form of water leakage into finished interior spaces within a few years after the building is first occupied. Frequently, this results in occupants being constructively evicted, with the attendant inconvenience, damage to personal property and business assets, and loss of domicile and/or business for the occupants. When significant amounts of corrosion products accumulate in the piping, an ideal environment is created for the proliferation of various anaerobic bacteria. The attendant biomass attracts opportunistic pathogens such as Legionella sp., and other undesirable organisms. Once this process has progressed, it becomes very difficult for chemical treatment and/or cleaning products to penetrate these accumulated deposits and reach the metal surface without the use of strong acids and mechanical intervention. The damaged parties expect to be compensated for resultant damage including human disease, loss of assets, loss of revenue, and inconvenience.

COMPLEX "HIGH STAKES" LITIGATION

Regardless of whether the building is used primarily as residential space, office space, for manufacturing, research, data storage, retail, education or healthcare, the costs begin to soar, patience runs short, and legal counsel is ultimately engaged to recover damages and to compensate for inconvenience.

Anyone involved in the design, construction, installation, commissioning, start-up and maintenance of these systems may find themselves in the crosshairs of a lawsuit. The building owner and/or the building management company are often targeted by the occupants and the insurance carriers are quickly drawn into the fray. The building architect, the design engineering firm, the specifying engineer, the general contractor, the mechanical sub-contractor, and all other sub-contractors who installed the piping and equipment, or who are assumed to have rendered services to prevent this scenario, are likewise usually implicated. This typically involves the water treatment supplier, the party that conducts the required hydrotesting, the party that provides post construction piping cleaning and passivation services, and frequently the suppliers of HVAC equipment, piping, and treatment and control equipment. All of these parties can be recipients of multi-million dollar demands.

Attempts to determine responsibility and to seek compensation for these failures, result in considerable legal expense, as well as business disruption that may last for years. Moreover, the scope of a defendant's potential liability may far exceed the amount they were paid for their services, as it may include not only the damages incident to the repair and replacement of the water system and its attendant equipment, but also to any surrounding structures and improvements, the expenses incident to constructive eviction of the building tenants who are displaced while such repairs or replacements are performed and, in some cases, the prevailing party's attorneys' fees and costs.

The lawyers for both the plaintiffs and various defendants will hire experts and investigators with a range of experience and skills to help them determine the root cause of the issues. Months of expensive work ensues as the parties, their lawyers, and their experts develop their positions and prepare for extensive document-based written discovery, site inspections, party and non-party depositions, hearings, court-ordered mediations and ultimately, trial.

These scenarios can be especially sever, inconvenient, and costly when a high-rise structure is involved, with multiple large diameter steel riser pipes that extend from the basement to the rooftop. These risers usually supply a larger number of small diameter horizontal piping which services the various entities and spaces on the many floors of the building. Over the past decade, the authors of this publication have been involved in high-cost litigation of these matters on a national scale. Experience dictates that the damages in these disputes ranges from $10,000,000 to $30,000,000 and the corresponding litigation invariably takes years to resolve.

In some of these matters, sub-standard piping quality was a significant factor that was identified, while in others design issues contributed to the corrosion. In all of these instances it was found that vague and/or non-existent specifications resulted in failure to detect sub-standard materials, inadequate flow due to design issues, failure to provide adequate cleaning of piping and equipment, failure to treat the system water adequately to minimize the corrosion, and in failure to manage the progression of the process of moving from initiating construction through hydrotesting, post hydrotest cleaning and passivation, and in continuously maintaining the corrosion control process from hydrotest through cleaning and passivation to HVAC system startup, occupancy, and turn-over of the property to the owner/operators.

Strict adherence to well-prepared specifications may help reverse this trend. In this document we offer recommendations for use in formulating comprehensive engineering specifications to help minimize these instances.

COORDINATE NOW OR LITIGATE LATER

The process of taking a complex structure from the architect's design to a finished facility, ready to turn over to the owner/operator is inherently complex. This process is interdisciplinary and involves coordination with a wide array of various trades. Despite this fact, research and experience reveal no true comprehensive domestic industry standards to outline the process of ensuring that the HVAC piping and equipment is preserved and protected from corrosion during and after the construction process.

Without some generally accepted domestic standard that deals with the necessary procedures and practices required to ensure the owner that the property has been properly constructed, inspected, treated and tested, we are completely dependent on the engineering specifications and the experience and integrity of the various disciplines involved. Comprehensive engineering specifications are vital to ensure that the new facility can be started up and occupied without suffering severe corrosion damage along the way.

Without an industry standard to ensure that correct practices are required by all parties and are understood by those responsible for executing them, the entire process can easily spiral into an unregulated bidding war with final cost as the only consideration. The corrosion control and inspection process necessary to protect the HVAC piping and equipment involves a relatively small expense for products and equipment, but potentially a large amount of labor. Unless there is some means of insuring that only highly motivated and well-trained personnel are supervised by someone with appropriate experience and qualifications, "cutting corners" may result in a very attractive quoted bid price, followed by very disappointing results down the road.

Those who may be ultimately liable are the very people with the training and experience for the architects and engineers to enlist to ensure that all bases are covered. Corrosion consultants, corrosion engineers, plumbing experts, chemical cleaning experts and water treatment experts should be enlisted by the specifying engineer early in the conception and design of the facility and remain involved with the various contractors until the facility is built, turned over and occupied.

HVAC CONSTRUCTION MILESTONES

As it relates to corrosion prevention, there are several milestone moments in the life of an HVAC system from commissioning to start-up. They include but are not limited to: (1) Specification Preparation; (2) Bidding; (3) Materials Procurement, Shipment and Inventory; (4) Piping Construction; (5) HVAC Equipment Installation; (6) Hydrostatic Pressure Testing; (7) Piping & Equipment Passivation; (8) Piping & Equipment Cleaning; (9) Piping & Equipment Passivation; (10) On-Going Corrosion Protection of Completed Construction; (11) HVAC Equipment Start-Up and Operation Pre-Turnover; and 12) Commissioning and Turnover of the Property.

As reflected in the list, there is a series of related activities conducted in a sequential fashion, often by different sub-contractors, involving many different trades. To ensure that the project is completed in a manner that results in one or more well-built HVAC systems being turned over to the owner/operator with only minimal and appropriate time-related general corrosion of metallic components evident, it is necessary to consider this entire multi-stage process as an on-going continuous process from the corrosion control view point.

A single subcontractor could ideally be hired to manage the completion of corrosion protection during each construction step, as well as during any intervening time delays between steps. This subcontractor must coordinate closely with the general contractor and the mechanical subcontractor, who will need to ensure that the activities of the corrosion control sub and those of other subs and trades are coordinated to insure a desirable outcome. The mechanical subcontractor must ensure that all needed utilities and appropriate utility services are available for the duration of the appropriate step. The corrosion subcontractor may either supply all needed chemicals, equipment, and services required to accomplish the corrosion control steps needed, or he may work with the appropriate party designated by the mechanical subcontractor to provide any needed equipment, chemicals, and services.

The corrosion control subcontractor could be found from a variety of sources, including a corrosion consultant or a qualified representative of a water treatment company. The corrosion control subcontractor may ensure that inspection of piping and equipment is conducted and documented before each step, as well as at its completion. This subcontractor may provide detailed written instructions for the completion of each step, and either supply all needed equipment, chemicals, and services, or work with a designated supplier to insure smooth completion of each step in the process.

The equipment required may include recirculating pumps, inspection equipment, testing stations and equipment, safety equipment, and chemical feed and control equipment. This equipment may be purchased for the project or rented/leased for use on this project. Any needed chemicals must be supplied by the corrosion control subcontractor, or by his designee, along with any needed labor to apply it, complete instructions for its safe use and disposal, and with any needed equipment and products in the event of an unintentional spill.

During each construction step different environments may be present, requiring different chemistries and equipment to permit successful corrosion control during the step at issue, as well as during any transition period between steps. An examination of the corrosion subcontractor's involvement at the respective steps is listed below.

Specification Preparation: A corrosion consultant may work closely with the specifying engineer for the project to provide the specification author with detailed information on what is required in terms of services, functions, experience and resources, and to provide specific specification language and requirements for the ensuing steps. It is important that provision for proper utilities be incorporated into the specifications and the attendant construction process. For instance, in order to properly hydrotest, clean, and passivate the piping, a safe and reliable power supply and lighting must be installed at each location where pumps and mixers will be employed. The water supply must be readily available in sufficient volumes and pressures to accomplish these tasks. Advance provision may need to be made with appropriate municipal utilities for the safe disposal of spent hydrotest, cleaning, and passivation solutions as appropriate. Recirculation pumps of sufficient capacity and pressure should be available to accomplish these tasks.

Bidding: A corrosion consultant may be employed to work with the specifying engineer, the construction manager, with the appropriate contractor, and his bid coordinator, to review the bids and ensure that the specification is being met before a contract is awarded.

Materials Procurement, Shipment & Inventory: It is well known that substandard piping and materials find their way into many projects. A corrosion consultant may work with purchasing to review the bids and conduct appropriate inspections to ensure that the piping, equipment, and materials to be provided will meet the specifications. The corrosion consultant may review the proposed shipping methods to make sure that the supplied items will be adequately protected from in-transit corrosion damage. The corrosion consultant may review proposed piping and equipment, as well as any on-site inventory facilities and methods in order to make sure that they are appropriate to prevent damage and deterioration during on-site storage.

A quality control procedure may be established to require a corrosion consultant and/or metallurgist to examine representative piping from each shipment received on site just before the material is used in the project. Specifically, the consultant/metallurgist may look for the correct material identification, weld integrity, and any evidence of inappropriate corrosion, especially pitting and tuberculation.

Piping Construction: The corrosion consultant and/or the corrosion sub-contractor may coordinate with the mechanical sub-contractor before the project starts to make sure that the proposed construction methods and sequences will incorporate adequate corrosion control provisions to ensure that the piping and equipment is not deteriorated during construction due to corrosion. Corrosion coupons fabricated with system metals may be installed in multiple locations, along with removable pipe spools fabricated with the same grade of piping, so that the corrosion rates and piping surface conditions can be followed during the idle period prior to start-up. In addition to pipe spools fabricated from new piping, the use of polished nipples may be considered if periodic pit depth measurements during the construction period are desired. The locations of such devices should be carefully specified by the specifying engineer in consultation with the corrosion consultant.

An example of how such damage might occur is instructive. In some cases, the piping construction may be conducted "stepwise", with the piping risers constructed one or more floors at a time, with hydrotesting scheduled to be completed as each set of floors is completed. If this practice is used, the piping must be protected during the hydrotest with appropriate corrosion inhibitors and microbicides added to the hydrotest water. At the conclusion of the hydrotest, the piping must then be cleaned and passivated to remove construction dirt and debris along with cutting oils, welding slag, corrosion products, etc. Depending on the chemistry and metallurgy involved, hydrotesting and cleaning may be done consecutively, or this may require draining and re-filling the piping before cleaning. Following the cleaning process the piping must be immediately inspected to ensure complete removal of foreign materials and corrosion products, and to ensure freedom from unexpected corrosion damage.

The piping must then be chemically passivated to resist corrosion for the balance of the construction phase. Passivation may involve treating and protecting the piping with the piping full of water containing the corrosion inhibitor, or the piping may be drained, air dried, and treated with a vapor phase inhibitor. If the subsequent stepwise construction likewise involves hydrotesting of the successive series of floors, then the sections that have been previously hydrotested, cleaned, and passivated must be isolated before proceeding. Unless this newly constructed, cleaned, and passivated segment is isolated from the preceding segments, each successive hydrotest will contaminate the previously cleaned and passivated segments. This makes construction stepwise with intervening hydrotesting a very questionable practice unless each segment is isolated from the preceding segments with isolation valves, blinds, caps, or some other temporary mechanisms to ensure that cross contamination does not occur.

HVAC Equipment Installation: Specific components, such as cooling towers, evaporative condensers or fluid coolers, chillers, heat exchangers, water cooled process equipment, pumps, filters, compressors, generators, and others frequently require separate hydrotesting, cleaning, passivation, and inspection after the involved piping has been installed. Conditions such as special metallurgy, special coatings, and difficult geometry, with very narrow fluid passages may impose special manufacturer-imposed cleaning and passivation requirements, and failure to observe these may result in voiding any warranties. Such conditions may also require that the equipment be isolated from the main piping system prior to conducting these procedures. The corrosion consultant or corrosion subcontractor would be well served to review manufacturer's installation, operation, and maintenance manuals, and if need be, consult separately with equipment suppliers in order to make sure that all pertinent conditions are met.

Hydrotesting: The purpose of hydrotesting is to ensure that the piping is free of leaks and weak joints prior to finishing equipment addition and prior to installing walls and finishing out the interior space. The process of hydrotesting involves filling the constructed skeleton piping or piping section with water, excluding air pockets, and then pressurizing the filled piping segment to a specified pressure greater than ambient, and holding that pressure for a specified period while leak checking is conducted. The newly constructed pipe segment may be inspected by the corrosion subcontractor or his designee, and the condition of the piping may be verified with an inspection report accompanied by photographs, videos, and recorded data such as eddy current tests, pit depth readings, or reading of general corrosion or deposition, as applicable. Any deposits should be sampled, analyzed, and removed. This information may be entered into the construction records.

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The water used for hydrotesting should be clean water, free of dirt, debris, corrosion products, and other contaminants. The chemistry of the water used for hydrotesting should be specified, tested, and recorded in the construction records. This can become problematic, as frequently the source of the hydrotest water is temporary piping, or from fire hoses. In some instances, the water must be hauled in by tank truck. If there is any question about the integrity, chemistry, or cleanliness of the hydrotest water, then it should be tested and if necessary, externally treated to remove contaminants.

To minimize corrosion of the new piping due to the presence of water, a corrosion inhibitor that has been approved by the corrosion consultant or corrosion subcontractor should be added to the hydrotest water at the specified concentration. The treated hydrotest water should be recirculated until the composition is uniform and the water should be sampled and tested to verify proper chemistry and proper inhibitor concentration. At the end of the hydrotest, the water may again be tested to again verify proper inhibitor concentration and freedom from excess suspended and dissolved corrosion products. If this water is dirty, discolored, or contains obvious contaminants, the system should be drained and flushed prior to chemical cleaning. This information, along with all test data, should also be entered in the construction documentation.

Depending on the inhibitor selected for the hydrotest, it may or may not be appropriate to add cleaning chemicals directly to the inhibited hydrotest water for subsequent cleaning of the piping without intermediate draining and flushing. This should be cleared by the corrosion consultant or corrosion subcontractor. It is important to not allow the hydrotest water to stand stagnant in the piping at the completion of the hydrotest. The selection of the hydrotest corrosion inhibitor composition and dosage is dependent on the construction materials involved, as well as on the chemistry of the water selected. This may all be specified by the corrosion consultant. Typically, the hydrotest corrosion inhibitor may incorporate some or all of the following list of ingredients: phosphates, nitrites, nitrates, borates, molybdate, phosphonates, filming amines, azoles, zinc, surfactants, antifoams, microbial control agents, and dispersants.

Following the hydrotest period, depending on the need for subsequent draining between hydrotest and cleaning, provisions should be made for the appropriate storage, treatment, and safe disposal of the hydrotest water. This may be specified in advance by the corrosion consultant in accordance with local disposal regulations and requirements. It is important that there be no delays between the completion of the hydrotest and the cleaning and passivation steps.

The hydrotest treatment chemicals should be pumped into the hydrotest water as it is being added to the piping at the recommended dosage, and then the solution should be recirculated to ensure good mixing and a uniform solution. The corrosion subcontractor may provide appropriate tanks, pumps, and dissolving equipment and specify needed injection fittings, sampling nozzles, test equipment, and locations. The hydrotest water may be sampled and analyzed prior to removing it and the final analysis should be compared with the initial analysis, and both tests may be entered into the construction record.

Piping & Equipment Cleaning: It is common to find some corrosion products firmly attached to the piping interior surfaces by the time that the pipe is incorporated into the building risers and laterals. In addition, depending on shipment and storage methods, the pipe frequently contains dust, dirt, mud, and other types of loose deposits. Inspection is prior to construction may detect these conditions. If present, they must be addressed in the cleaning process. In addition, it is common to find materials such as cutting oils, welding slag, and construction debris in the newly constructed piping.

This piping segment will contain mild steel piping. It may also contain galvanized steel, copper, copper alloys, stainless steel, and possibly aluminum alloys. The materials present will dictate the cleaning chemistry and procedures. This may be specified by the corrosion consultant coordinating with the specifying engineer and the mechanical subcontractor.

If any HVAC or process equipment is incorporated into the piping prior to cleaning, it may impact the cleaning chemistry and procedures to be specified. The corrosion subcontractor would be well served to familiarize himself with the materials present, as well as with manufacturer's requirements regarding cleaning chemicals and procedures. The cleaning chemistry may be acceptable to add directly to the hydrotest water after hydrotesting is complete, or it may require draining and refilling the piping. This again may be specified by the corrosion consultant and/or the corrosion subcontractor.

The corrosion subcontractor may provide all required equipment to apply the cleaning chemistry, including tanks, pumps, mixers, safety equipment, sampling and testing equipment, and inspection equipment. The piping segment should be inspected and photographed prior to cleaning. This inspection will dictate specifics of the cleaning process, including ingredients, dosage, recirculation velocities, cleaning times, and cleaning chemistry. The results of this inspection (report and photos) may be recorded in the construction documentation.

The cleaning chemicals may be added by chemical injection pump through specified fittings while the system water is being added and/or recirculated. The cleaning solution may be sampled and tested before and after recirculation. The chemical concentration, solution chemistry, and recirculation time may be specified by the corrosion subcontractor depending on the inspection results. Corrosion coupons and/or pipe spools may be incorporated into the piping before the cleaning process. After cleaning is complete, the piping may be inspected and photographed again. Depending on the starting conditions, one or more cleaning cycles may be required. This process may be repeated until it can be verified by inspection that the piping and equipment to be cleaned is actually clean.

Following the cleaning and inspection period, depending on the need for subsequent draining and/or chemical additions between cleaning and passivation, provisions must be made for the appropriate storage, treatment, and safe disposal of the spent cleaning water. This must be specified in advance by the corrosion consultant or corrosion sub-contractor in accordance with local disposal regulations and requirements. The spent cleaning solution may be sampled and analyzed, the cleaned equipment inspected, and these records may be entered into the construction documents.

Piping & Equipment Passivation: Depending on what has been hydrotested and cleaned, and depending on equipment manufacturers instructions, the cleaning solution may be appropriately drained, the piping flushed, and a passivating corrosion inhibitor added to fresh clean water immediately upon completion of the cleaning. The composition and dosage of the passivating inhibitor is again site specific and depends on metallurgy and equipment manufacturer instructions.

Typically, the passivating treatment chemical may contain nitrite, nitrate, borate, azole, silicate, molybdate, surfactants, antifoams, phosphates, phosphonates, zinc, filming amines, microbicides, and dispersants. Depending on site conditions, metallurgy, water chemistry, piping design, and manufacturer's requirements, the passivating formulation, required dosage, and required application time and method may be determined by the corrosion consultant and/or the corrosion subcontractor. Again, the passivating chemical should be added by injection pump as the system is being filled with water. The corrosion subcontractor may provide all required equipment, chemicals, testing materials, and labor necessary to get the job done properly. In recent years, new non-fouling amine chemistry has been developed that may be applicable either when used in a flooded piping system, or when applied as a vaporized or steam distilled material to clean dry piping.

Ongoing Corrosion Protection of Completed Construction: The period of time between passivation of the piping and equipment and HVAC system start-up can be highly variable due to a variety of factors. It is not uncommon for the completed and passivated piping and equipment to sit idle for a period of months. Without proper on-going corrosion monitoring and control, the best efforts of the earlier steps can be quickly defeated if piping and equipment is allowed to stand idle without treatment and attention.

Historically, the completed piping and equipment is maintained completely full of clean water with corrosion inhibitors and microbicides added. Depending on the site conditions it may be appropriate to cap the passivated piping and equipment with a low-pressure dry nitrogen cap to exclude oxygen from the passivated system. In recent years, the treatment chemistry of choice has been a high-level nitrite formulation. Typically, such products contain nitrite, nitrate, borate, and often silicate and/or azole. In some cases, a mixture of nitrite and molybdate has been successfully used. In addition, these formulations are frequently supplemented with a non-oxidizing microbicide such as Glutaraldehyde or Isothiazolin.

If such chemistry is to be successfully employed, it is important to maintain the equipment fully flooded with high quality water, and it is important to exclude air. In addition, it is vitally important to provide for recirculation of this treated water periodically while the system is maintained in idle condition. If the water is allowed to stand stagnant for extended time periods, the inhibitor may become locally depleted, leading to aggravated pitting attack at these sites. The nitrite level should generally be maintained at approximately 500 mg/l, as NO2 if the water is continuously recirculated at ambient temperature and a linear water velocity of at least 3 ft/sec. If only periodic recirculation is possible, or if recirculation will result in much lower flow velocities, then higher dosages should be considered. The system should be recirculated weekly for a time period sufficient to accomplish several system volume turnovers, and sufficient to maintain uniform nitrite levels throughout the system.

If periodic recirculation is employed, the nitrite level should be maintained at a higher level, preferably between 1,000 and 3,000 ppm as NO2, depending on recirculation frequency and velocity. The details of dosage and recirculation rate and time should be specified by the specifying engineer in conjunction with the corrosion consultant.
The new filming amine formulations have been successfully used as an alternative to traditional nitrite-based programs. If amines are to be used, their use parameters must be specified by a corrosion consultant with specific experience with these materials in these applications. Notably, the U.S. military has had very good success using amine chemistry lay-up of military equipment that is stored idle for extended time periods.

Regardless of the method and dosage employed, the idle period corrosion protection should be verified using regular testing of the system water supplemented with the previously discussed corrosion coupons, pipe spools, and possible with electronic corrosion probes. Testing of idle solution chemistry should be preceded by recirculation of the water and should involve traditional parameters, including pH, conductivity, hardness, alkalinity, chloride, sulfate, silica, and system metals concentrations, as well as microbial testing for microbial proliferation due to aerobic and anaerobic bacteria, algae, fungi, and mold. The inhibitor chemistry must be specifically tested. While this publication does not address water borne pathogens, specific testing for infectious organisms such as Legionella is advisable. All such information should be maintained in the form of testing reports and corrosion monitoring reports with photos in the construction documents. If the idle period extends beyond two months, it is advisable to supplement this information with periodic fiber optic piping inspections with photos.

The corrosion subcontractor may participate in the commissioning and start-up of the HVAC system to ensure that adequate provision is made for chemical treatment and control to protect the system from startup until the owner/operator takes responsibility for the system operation. This period frequently involves only periodic operation of the system and can require special treatment provisions and periodic recirculation to prevent standby damage and deterioration during any periods of low flow or stagnant conditions.

Depending on the specific site location and the intended purpose of the building, federal, state, & local regulations may require complete system sterilization at specific timing prior to occupancy.

Commissioning & Turnover: It is advised that the mechanical subcontractor and the corrosion control subcontractor meet with owner representatives well in advance of turnover to ensure continuous maintenance of the treatment, control, and monitoring of the HVAC treatment program during the transition. This transition may or may not involve the use of different water treatment contractors.

CONCLUSION

There are a large number of industry prepared guidelines and standards governing the manufacture of piping for various purposes. There is also a wealth of individual equipment manufacturer information that is somewhat relevant with respect to installing, protecting, and maintaining their mechanical equipment, such as cooling towers, evaporative coolers, chillers, compressors, generators, and pumps used in an HVAC system. There is likewise a fair amount of industry information produced by ASHRAE, ASME, NACE, CTI, AWT, and others, regarding proper water treatment practices relating to routinely operating HVAC and industrial cooling water and heating systems. In addition, some of the large domestic and international property management firms have developed water treatment specifications for internal use, and some of the water treatment firms and consulting companies have likewise produced literature, including specifications for use by their customers in the treatment of normally operating systems.

In contrast, research has revealed no North American guidelines or standards pertaining to the practices of surrounding the preservation of HVAC piping system asset value during the complex, multi-step, and frequently delayed construction, commissioning, and turn-over process. Investigation has revealed a document published by the British Iron & Steel Research Association (BISRA) entitled, "A BISRA Guide, Pre-commission Cleaning of Pipework Systems" (2nd edition) by Chris Parsloe. Perhaps this British publication can serve as a starting point to allow one of the appropriate industry trade associations or technical societies to develop an industry standard that can serve as the basis for establishing accepted minimum requirements for those who prepare the mechanical specifications as well as those who implement these specifications during the construction process, extending until occupancy by the owner.

In the absence of specific guidelines and standards pertaining to these construction issues it is vitally important for the project specifying engineer to provide comprehensive specifications governing the conduct of the functions described earlier in this paper.