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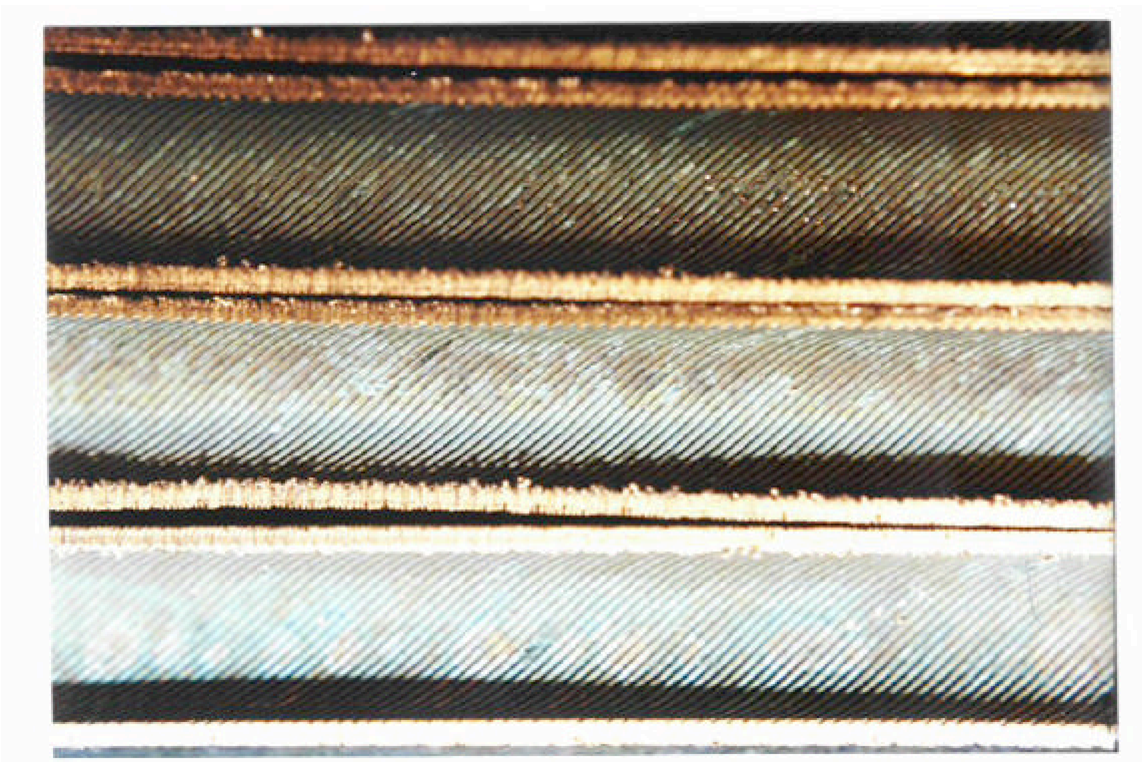
Guidelines for Treatment of Systems Containing Enhanced and Super-Enhanced Tubes

Association of Water Technologies (AWT)



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Forward

The Association of Water Technologies (AWT) is an international trade association founded to serve the interests of regional water treatment companies and to advance the technologies of safe, sound and responsible water treatment practice. AWT is a non-profit organization which provides education and training, public awareness, networking, research, industry standards and resource support. These association activities serve to benefit members, as well as advance the arts and sciences of the water treatment industry. Moreover, AWT makes a commitment to the public as a Responsible Care® Partner Association.

Guidelines for Treatment of Systems Containing Enhanced and Super-Enhanced Tubes

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Abstract

As cooling water usage continued to increase by orders of magnitude in the early twentieth century, the demand for efficient heat transfer systems increased. During the mid to late 1900s, the rising cost of energy forced the industry to develop new technical methods to reduce utility costs. The concept of utilizing enhanced tube technology to reduce energy consumption thereby reducing utility costs has been in use for over 20 years. The most recent breakthrough in heat transfer tube technology has been the use of a combination of internal rifling with roll-worked external enhancements to increase heat transfer. This practice has resulted in a significant reduction in energy consumption. As this new technology expanded into different areas of industry, new challenges had to be overcome. New designs such as enhanced and super-enhanced tubes require that the heat transfer medium (i.e. water) be of a higher quality than ever before. These changes demand exceptional water treatment control programs. This paper is written as a supplemental guide for the owners and operators of these new technology heat transfer systems and for water treatment professionals. It is intended to aid in the design of water treatment programs, in the development of correct treatment and operational practices, and in the instruction of proper maintenance techniques for systems that incorporate enhanced and super-enhanced tube technologies.

Introduction

In today's world of increased energy demand and utility costs, the focus of the equipment manufacturer is on conservation. In the consumer market, we have been inundated with yellow tags on appliances and equipment stating the new item's Energy Efficiency Ratio (EER). In the commercial and process market, we have seen changes in equipment to make heat transfer technology more efficient. One of these changes has been in shell and tube heat exchangers. To increase energy efficiency and to provide cooling / heating equipment vendors a commercial advantage over older equipment, new heat exchange surface designs or profile geometries for the tubular heat exchanger surfaces have been developed. The common term for these new surface designs is enhanced or super-enhanced tubes. Their function is to enable a high efficiency of heat exchange which permits use of smaller or less expensive equipment and many other energy efficient benefits that can reduce capital and operating cost.

As water treatment professionals, our goal is to keep these heat exchanger surfaces clean and free of deposition and fouling. This in turn prevents corrosion of the heat exchange surfaces so the end-user experiences the improved heat transfer rates provided by these new heat exchanger geometries while achieving maximum life expectancy. To accomplish these goals, the nature of these tubes must be understood as well as what water quality characteristics can hinder their performance and what operational practices are required to keep them at their peak performance. The intent of this paper is to document this information in a logical way so that the owner, operator and water treatment professional can be more successful in preventing damage to systems utilizing enhanced and super-enhanced tubed heat exchangers.

Background – Enhanced Tubes, What are they?

The design of heat exchangers has been studied as early as the mid 1800s. Enhancing the tubes to increase heat transfer rates has been promoted since the 1970s, mostly based on a few mechanical engineering principles:

1. Making a thinner wall with structural integrity can provide more efficient overall heat transfer by reducing the resistance through the tube wall.
2. Increasing turbulence of flow close to the heat exchanger surface can turn over the fluid faster, providing increased heat transfer.
3. Increasing the surface area on either side of the heat transfer surface will provide increased heat transfer.

The first enhancements of straight bore (or smooth bore) tubes came with the insertion of internal vanes or differential flow directing devices to improve flow characteristics. These design modifications were only moderately successful in increasing heat transfer efficiency and these devices were more prone to fouling which decreased their functionality.

The next generation of enhanced tubes was a rifled barrel effect with fins both on the outer and inner tube surfaces. The fins, depending on the manufacturer, varied in height, width, numbers per inch, and change in pitch. These factors changed the velocity profile of the water on the interior surface of the tube. Most of these tubes had a decreased wall thickness (up to 50%). Their increased surface area over the straight bore tube (by about 50% to 70%) resulted in improvements in energy efficiency up to 40% claimed.

The most recent generation of tubes (super-enhanced) have a rifled barrel effect with fins on the internal part of the tube and a waffled-type structural effect (roll-worked external enhancement) on the outside. [1,2] This external structure has been referred to as external fins or external enhancements. The fins on the inside vary in height, width and number per inch, while the waffling effect provides an even greater surface area and reduces the wall thickness in some areas by up to 70% from the straight bore tubes.

Advantages of Using Enhanced Tube Technology

The most obvious advantage of using enhanced tubes is the ability to reduce the cost of heat transfer. Energy costs have always been a major part of cooling's operational costs. With the utilization of enhanced tube technology, a greater amount of heat is transferred per unit of energy consumed. [3, 4, 5, 6, 7] This enhanced heat transfer has resulted in energy reduction from 10% to as high as 40% in some cases. [6, 8, 9] These savings in utility costs ultimately reduce operating costs for the heat exchangers.

Since the greater surface area in enhanced tubes results in higher heat transfer rates, the same work can be accomplished using heat exchangers of smaller physical dimensions.[3,10] The result is a much smaller footprint for the enhanced tubed heat exchanger than for the conventional straight bore tubed heat exchanger. Lower capital costs [11,12] in new buildings and in older building retrofits can be attributed to this space reduction.

Disadvantages of Using Enhanced Tube Technology

One representative of a major chiller manufacturer indicated his major concerns were with water quality. He stated that a side-by-side

Source: Hoffman & Feige Metallurgists

Internal riflings of enhanced tube are shown with some pitting.

comparison of a system with enhanced tubes to a system with straight bored tubes would show a significant difference in the amount of heat transfer efficiency lost due to a thin layer of scale in the enhanced tubes only. The straight bore tubed system may lose about 10-15% heat transfer efficiency whereas the enhanced tubed system could lose as much as 20-30% heat transfer efficiency. Because of this greater susceptibility to scaling in the enhanced tubes, water quality and the associated water treatment program must be first rate. If not, the efficiency gained from the purchase of the enhanced tube system will be lost in a few months.

The other disadvantage of the enhanced tube technology is that their thinner walls and rifling patterns make preventing loss of tube wall thickness from corrosion the main priority of the water treatment professional. Scale, fouling, deposition, and incorrect biocide use can all lead to corrosion of the tubes.[13] With the thinner tube wall, this corrosion attack will penetrate the tube wall more quickly, thus causing loss of refrigerant or intermingling of an open water system with a closed water system. There are other secondary effects that can lead directly to the replacement of the tube. In older style straight bore tubes, a minor amount of scaling or fouling eventually would lead to loss of heat transfer and possibly some corrosion. The thicker tubes in such equipment allowed water treatment professionals a lead-time to identify incipient problems and to take proactive steps to prevent any catastrophic failures. However, the thinner walled enhanced and super-enhanced tubes are significantly less forgiving and are more prone to failure due to wall penetrating corrosion.[14, 15]

Another side of these enhanced tube geometries result from the small crevices that are created in the rifling of the tubes. Even though the greater flow turbulence will ultimately aid in the increasing heat transfer and minimize fouling at velocities above 3 ft/sec,[10] the small crevices that are introduced to the inner tube surface are ideal spots for deposition to occur when tube velocities fall below 3 ft/sec. These small, pocket-type, areas also make it more likely for the deposition to occur. It is important for the water treatment professional to recognize these potential problems and to take appropriate steps in the development of an appropriate water treatment program.

Source: Hoffman & Feige Metallurgists

Internal rifling of an enhanced tube is shown with damage to right side of tube.

Practical Water Management Applications

When dealing with enhanced tubes the water treatment and monitoring programs are critical. This section addresses how to design a proper water treatment program and the associated monitoring, troubleshooting, and other operational considerations that must be addressed by the water treatment professional.

Design of a Water Treatment Program

A water treatment program is based on the incoming water quality, [16] mechanical design of the system, materials of construction of the systems components, environmental conditions and discharge requirements. For enhanced tubes, these design considerations are the same as those for any typical water treatment program. The following factors however, must be considered:

1. Makeup Water Quality – Is the source of the water used in the cooling circuit a surface supply, well, pretreated, brackish or reused wastewater from another process? Surface waters can contain high levels of suspended solids that may have been tolerated by straight bore tubed heat exchangers in the past. With enhanced tubes, pretreatment to remove these solids has to be considered. Well waters can have high hardness and iron that have an impact on how well dispersants work. This situation may require increasing the particle dispersant levels to keep solids from settling in the fins. Brackish or waste water may contain other components such as high chlorides that could enhance corrosion in other areas of the system. These corrosion products could be transported back to the tubes causing deposition. A system with a high microbiological loading in the incoming water may need a biodispersant in addition to a biocidal program to ensure that biological fouling does not occur. Does the incoming water quality have other treatments from the pretreatment program that can interfere with the performance of the planned program – aluminum salts, phosphate, DADMAC, etc? Water sources must be evaluated by the water treatment professional to insure that the program that is being designed will work. For these reasons, getting a full water analysis is an important first step.

2. System Design and Operating Factors - Knowledge about the design and operational parameters of the system is essential. Is transfer piping flooded or prone to wet/dry cycling? Wet/dry cycling can greatly increase the corrosion and deposition potential of a system. Intermittent operation, such as secondary applications, thermal storage, and

comfort cooling during office hours only can expose wetted areas of piping to extensive corrosion patterns and can lead to a strain on normal corrosion inhibitors. This may require higher dosages of corrosion inhibitors; a vapor phase corrosion inhibitor may have to be added for protection during idle periods.

3. Corrosion products can be transported back to the tubes possibly requiring additional dispersant protection. Is the heat exchanger at the lowest end of the loop where solids can settle during downtime? Are flows restricted in any way or are the design flows limited or outside the boundaries of equipment manufacturer's design flows? These conditions can lead to deposition, scale formation and fouling and have to be recognized before the program is designed. What are the surface temperatures of the heat exchangers? Are they within the water treatment program's limits? Higher surface temperatures mean stressed conditions. Can the designed program tolerate these conditions? Does the operation include cycling which shuts down flow periodically or whenever ambient temperature demands are met? Intermittent operation during seasonal transitions (spring/summer and summer/fall) can lead to shut down periods of several days to as long as a week or two. Stagnant water can cause biological and corrosion problems. Does the cooling tower, sump or heat exchanger have an epoxy coating that is being degraded or is tower fill being degraded? Coating chips or pieces of tower fill can make it past strainers and become lodged in the rifling patterns of the tubes. Likewise, tower fill that is thin can degrade and break up sending pieces past strainers and into tubes. These are just a few of the design and operational ramifications that must be considered before designing the water treatment program.

4. Knowledge of the metals used in all system components is necessary. Dissimilar metals in direct contact can lead to galvanic corrosion of the more anodic metals. This could increase deposition and the loading of corrosion products in the system. Corrosion inhibitors may have to be adjusted or changed based on the metallurgical composition of the system. Since most of these tubes are copper or copper-nickel, copper inhibitor levels may have to be enhanced to ensure that copper corrosion is kept in check. Copper corrosion rates should be maintained below 0.1 mpy. No pitting corrosion should be allowed in any of the metallic system components. Poor copper corrosion control not only leads to problems in these tubes from direct corrosion but indirectly from more anodic metals corroding and again transporting their by-products back to the tubes.

Sacrificial anodes and epoxy coatings may have to be used on tube sheets and in other areas that are prone to corrosion attack. Deposition or corrosion on tube sheets can create changing flow patterns that can lead to more deposition, fouling or microbiological growth in the tubes.

5. Environmental conditions have to be examined. Can conditions near and around the tower increase suspended solids and biological growth, change chemical nature of the water, or add organics or other compounds that can interfere with the water treatment program's performance? Do weather conditions such as drought, rain, wind, etc. change operational parameters? All outside sources that can affect the operation of the cooling water system must be identified and corrective actions must be implemented.

6. Proper biocidal selection is critical to the performance of these tubes. Biocides prevent MIC (Microbiologically Influenced Corrosion), biofilm formation, algae blooms, anerobic growth and other microbiological excursions. Biocide selection must not negatively impact the tubes. It must address metallurgy and chemical compatibility issues. Overfeeding of some biocides such as chlorine, other oxidizers, carbamates, etc. may interfere with deposition or corrosion control parameters. Shock dosing the system with strong oxidizers, carbamates or other biocides can cause corrosion in the system if proper levels of corrosion inhibiting additives are not maintained. Overfeeding of other biocides can also contribute to corrosion. A professional must examine where the biocides are fed. Are they introduced directly to the heat exchanger or are they being placed in the tower sump? A reaction can occur between biocides and solids in the sump causing them to be transported throughout the system. A professional must examine how often biocides are fed (feed times). Are biocides being fed at night when system water flows can be disrupted? What forms of biocides are being implemented? Some dry biocides improperly fed may not always dissolve completely and thus send concentrated particulates of biocide into the tubes or other areas where they may enhance deposition or corrosion. Industry professionals must remember that biological control is important in controlling the growth of Legionella that can add to slime formation. *(See AWT Legionella Position Paper – June 2003 – William E. Pearson II.)*

All of the above must be examined to complete the design of an overall balanced treatment program that will not interfere with the performance of the enhanced tubes.

System Surveying, Monitoring and Troubleshooting

Water treatment professionals must know the type of tube that is in the equipment before they can design a water treatment program.[17] Many operators may not be aware of the type of tubes in their system. Professionals can obtain heat exchanger or chiller part serial numbers and contact the equipment manufacturer as the first step in determining if their system has enhanced tubes.

Source: Hoffman & Feige Metallurgists

Enhanced tube is shown with deposition products in crevasses.

Do not rely on the mechanical contractor or mechanical service technician to provide the tube-type information. Contact the equipment manufacturer when in doubt. (Note: There are times when the manufacturer's engineering department may not know so internal inspection becomes your second option.)

Once the type of tube has been established professionals should inspect the present condition of the tubes. There are two basic non-destructive test procedures: Eddy Current and Fiberoptic Scoping.

Eddy Current Testing (ECT) has been in use for many years and is widely employed to determine the condition of tubes by mechanical contractors.[18] It is very important to use experienced and certified technicians to conduct this type of testing in order to distinguish between pitting and deposit formations in the tubes. ECT has several appealing features such as the ability to do a rapid internal and external tube surface and wall thickness inspection. Its sensitivity is a direct function of the calibration of the equipment and the identical nature of the calibration standards used by the ECT operator. The disadvantage of using ECT is that it cannot determine the root cause of the imperfection in the tube surface. If a deposit is detected, this method cannot identify its origin. The same issues arises with a crack or pit. Why did it occur? Again a poor technician can misinterpret results and provide misinformation. The primary benefit of ECT is that it examines the entire thickness of the tube wall, not just the inner visual surface.

Fiberoptic Scoping (FS) is a modern technique of visual observation. Fiberoptic Scoping uses a small optical device with a light source attached to a video monitor via a fiberoptic cable. As with ECT, this procedure should be performed by someone who knows what they are viewing and has experience in doing so. This is a visual technique and because of magnification properties and examination of the internals via a one-dimensional monitor, sometimes misinterpretation is possible. Having different angle lenses and a proper light source is important to help identify problems. FS cannot quantify how deep pits or cracks are. However, some units claim that through digital depth measurement capabilities it is possible to measure the thickness of the deposit or the depth of a clean depression or pit. The advantage of FS is that it is a visual technique that sees color and can identify and distinguish between deposits, biofouling or other external material (such as epoxy coating, dirt or debris from the tower) that is providing heat transfer losses within the tubes.

Techniques such as Eddy Current and Fiberoptic Scoping should become part of a routine inspection procedure to verify how well the water treatment program is doing its job. These inspection techniques should be performed at least every other year unless other problems or operational conditions indicate the need for more frequent monitoring.

In addition to examining tube conditions, a thorough inspection of the tube sheet, attached piping and tower sumps or basins should be performed. Tube sheet or piping corrosion can allow a transfer of corrosion products to the tubes that can enhance deposition or under-deposit corrosion in the tubes. This situation can lead to pitting because of the rifling in the tubes. Tube sheet corrosion can also restrict water flow, which in turn, reduces flow velocity in the tubes. A direct consequence of this tube sheet corrosion is enhanced tube surface deposition, with the end result being the initiating corrosion. A clean non-corroded tube sheet is extremely important in maintaining enhanced tube condensers.

Sludge or large amounts of dirt and debris in cooling tower basins or sumps are another indication of potential problems during operation. Much of this material can be transferred throughout the system, especially to the enhanced tubes. Extraneous dirt and debris can settle into the internal rifling and cause fouling and differential corrosion cells, resulting in pitting of the tubes.

Source: Hoffman & Feige Metallurgists

Fiberoptic Scoping reveals severe deposition and corrosion.

If the tower basins, cooling tower fill or distribution decks show the presence of algae or other evidence of biological slime or fouling, these materials can be transferred to the tubes to cause additional corrosion attack. Likewise, any other external conditions such as deteriorating epoxy coatings or tower fill in towers or sumps, cottonwood seeds, etc., can lead to material being transported and deposited in the tubes. External inspections of the cooling tower, fill and basin should become a routine part of the water treatment professional's service visits.

Now that the water treatment professional has completed the inspections and design of the water treatment program, proper monitoring skills must be applied. Shortcuts are unacceptable when dealing with enhanced tubes.

Corrosion, scale and biofouling monitoring are all important. Corrosion coupons, Corrater® surveys and total dissolved metals analyses can provide the water treatment professional information about corrosion potential. It is important that professionals not rely on just one of these techniques. Cross-check verification must be done to verify that corrosion is not occurring.

Scaling indices and elemental mass balances that require complete water analyses can provide indicators of scaling or deposition. Deposit monitors can be used to verify that the water treatment program is working. When scale or deposits do form, analysis with Electron Dispersive X-ray (EDX) is important to determine where the water treatment program is failing or the root cause of the deposition.

Dip slides, BART (Biological Activity Reaction Test) testing, serial dilutions, and ATP (Adenosine Tri-phosphate) technology should all be utilized and cross-checked to verify that biofouling is not occurring. Additional testing using removable spool pieces and slime monitors is recommended to make sure there are no hidden biofilms. A water treatment professional cannot rely on one test to establish if there is a biological problem. Cross-checking any test with another is always helpful to verify if there are any operational problems.

These monitoring techniques should be standard tools for the water treatment professional and they must be used in their entirety to determine if typical water problems can pose serious issues for enhanced tubes.

Proper Water Treatment Procedures and Care

To maintain enhanced and super-enhanced tubes properly, care must be taken to design and control a consistent water treatment program that meets all the needs of the system. It is also important that owners and operators follow proper maintenance procedures to protect the tubes from fouling and corrosion. The following recommendations are an attempt to provide the owner, operator, and water treatment professional with mechanical, operational, and chemical procedures to keep the heat exchangers trouble free.

Mechanical Recommendations

Because cooling towers function to some degree as air scrubbers, particulate contamination of the recirculating water always occurs. Many enhanced tube failures occur due to particulates or debris contamination. To reduce debris and its potential settling in the tubes, the professional should consider the use of side stream filtration. It should always be considered where enhanced tubes are in use. Bag, cartridge or sand filtration can aid in removing particulate, old corrosion by-products, microbiological components, dirt and debris, etc. from the cooling water. The less particulate matter circulating the better the system will perform and the more effective the chemical treatment program.

The probability of galvanic corrosion on tube sheets can be controlled by installing sacrificial anodes on tube sheets to prevent corrosion attack on the tube sheet or water box metal. Alternatively, an epoxy coating, which acts as a barrier layer, could be used to limit corrosion on the tube sheet. (However, while a high quality epoxy coating can be beneficial to the system, a poor coating can be just as detrimental as corrosion by-products. Epoxy coatings require proper preparation of the tube sheet surface and precise and careful installation. Proper surface preparation guidelines, such as SSPC-5, which include achieving a clean metal surface and a minimum attachment profile should be adhered to or the coating will not be adherent enough to protect the surface of the tube sheet. Therefore, it is prudent to use a company experienced in supplying and installing epoxy coatings to handle the installation of the coating.)

Tubes should be cleaned on a scheduled frequency.[16] Mechanical brushing of the tubes can remove deposits or fouling before severe problems develop. All independent brushing systems and those used by the equipment manufacturers that installed these enhanced or super-enhanced tubes employ special procedures and special brushes that must be used for cleaning these types of tubes.[19] Using a straight tube brush can scratch the enhanced tube and lead to a more severe corrosion problem.[16] Many mechanical contractors require that these systems be cleaned on an annual basis as part of their service contracts. It is recommended that all units containing enhanced tubes be cleaned annually.

In some facilities, it is common practice to winterize certain water systems in the fall and clean them in the spring just before start-up. This can be very detrimental to enhanced tubes. The system should be drained, flushed, cleaned, and dried as soon as possible after circulation has been stopped so that no settling of solids in the rifling can occur.

Frequent cleaning of the tower basin or sump is also important. Removing heavy accumulations of settled dirt and debris before they get entrained in the water flow is critical to protecting the tubes. The water treatment program may have to be modified to increase the protection level for these systems just before shutdown and draining or layup.

Finally, it is important to make sure gas pockets do not form near the tubes. Oxygen bubbles can be very detrimental to the tubes as they promote corrosion. Vent cocks should be placed in the header box and they should be maintained regularly to remove any trapped air.

Operational Recommendations

One of the biggest operational issues is how to handle the off-line unit. Such off-line status could result from alternating operational units to achieve uniform service life patterns. In comfort cooling systems, special attention must be given to units that cycle off at night. An off-line unit, even when kept full, invites fouling and corrosion. In stagnant water, increased microbiological growth, settling of water borne solids, and entrainment of gas bubbles that get separated from the water and are trapped in the rifling of the tubes. These conditions can lead to localized corrosion of the tubes. Consideration should be given to lead/lag timing, recirculation with load, or draining and flushing.

Typically, if an exchanger is to be left full and not operating for more than two to three days, it should be recirculated every six hours for one hour to replace stagnant water. Others have recommended that if this condition is to exist for more than one week, the system should be drained, flushed and allowed to dry.[20]

One other means to prevent deposition and corrosion circumstances under stagnant conditions is to install a small re-circulation pump on the unit. This pump should be integrated into the system so it maintains flow when the unit is off-line. A small filter housing could be installed to allow addition of biocide and/or extra corrosion inhibitors or dispersants during down times. This arrangement would provide some flow, possible filtration and a means to restore protective levels of chemical inhibitors in the unit.

Another important operational parameter to determine and monitor is the heat transfer loads, resultant surface temperature and system temperature. Elevated loads or surface temperatures could put the system outside the water treatment program's operational limits.[21] Measurement of these temperatures is critical. Having an IR (Infrared Temperature) temperature sensor is an economical way to determine temperatures in a system. However, this does not determine the actual surface temperature where the heat transfer takes place. That is a difficult reading to obtain and requires more engineering knowledge.

<u>Water Treatment Recommendations</u>

The following recommendations will help prevent deposition and corrosion issues in an enhanced tubed systems:

- Increase the dosage or concentration of the particulate dispersive chemical additive, whether it be a biodispersant or polymeric dispersant, in order to keep dirt and debris from settling in the tubes. The most effective dirt / particulate dispersant available should be considered.
- Increase yellow metal corrosion inhibitor (azole) levels to minimize copper corrosion. Copper corrosion rates should be below 0.1 mpy, without any measurable pitting attack.
- Increase dosage/concentration of ferric corrosion inhibitors to prevent iron corrosion in other parts of the system and transport of corrosion products to the tube surface. Preventing any type of corrosion is the primary key to prolonged tube life. Mild steel corrosion rates should be below 2.0 mpy.
- Biocides must be selected properly and dosed accurately. Proper selection will minimize unwanted interactions with other water treatment compounds and with tube surfaces. Feeding equipment for biocides must be selected with care to insure accurate dosing. Do not take shortcuts by using makeshift devices to save money. Investing in proper

equipment will insure adequate biocide is fed within required dosage limits. The return will be a clean system with no accidental overfeeding resulting in severe corrosion issues.

- Make sure the chemical feed and control equipment is in good working order and that by-pass circulation loops are not clogged or providing false flows. Proper controlled chemical feed rates and complete blending of chemicals into the system water are important considerations.
- Make sure that off-line lay-up procedures are used. There should be both wet and dry procedures available from the equipment manufacturer. Make sure you use quality chemicals that provide corrosion protection even to wet/dry areas. Off-line corrosion product formation can cause serious problems when the system cycles to the "on" position.

Remember that any improperly designed or controlled water treatment program will cause different types of corrosion to occur within the tubes and surrounding areas of the system. Pitting corrosion can lead to rapid penetration of the thin tubes. Microbiological fouling can cause pitting. When the biocide type or dosage is inadequate to prevent the growth of biofilm on the tubes, a condition known as microbiologically influenced corrosion (MIC) can occur at the interface between the biofilm and the tube. Under-deposit corrosion can occur from anything within the system depositing on the tube surface whether it be a chemical scale formation or adhesion of contaminants carried in the water. Both pathways will initiate the corrosion cycle. The undesirable result can be managed by consistently evaluating the system and taking appropriate action before the situation has a chance to go downhill and turn deposition issues into more serious corrosion problems. However, even the best chemical treatment program available may not compensate for systems that are improperly designed and operated.

Summary/Conclusion

The use of enhanced tubes to increase heat transfer rates is an effective technology to reduce energy consumption and greatly benefits the user through significant operational cost reductions only if proper evaluation, water treatment, and system maintenance programs are followed.

These programs include:

- Use of suspended solids removal methodologies and side stream filtration whenever there are any indications of potential for suspended particulate solids circulating within the system.
- Proper epoxy coating to the tube sheets (as well as other areas prone to corrosion) and the use of sacrificial anodes are recommended to reduce corrosion potential. Epoxy coatings must be applied by qualified individuals to prevent delamination. Sacrificial anodes should prevent galvanic corrosion.
- The use rates of antiscalants, azoles for copper corrosion control, and microbiocides may have to be increased to assure that tube surfaces and other areas of the system are kept clean.[13, 22] Typical water treatment dosing programs utilized in straight bore tubed systems will not be enough to prevent severe corrosion circumstances from occurring with enhanced tubes systems.
- Proper maintenance including fiberoptic scooping (FS), eddy current testing (ECT),[18] and tube brushing must be performed routinely. The end user should utilize a specialist to perform eddy current testing or fiberoptic scoping on enhanced tubes. Brushing should be done at the end of the season before winterization of comfort cooling systems and followed by use of proper lay-up procedures.
- Mechanical changes and adjustments of cycle off-times must be performed to prevent wet/dry conditions.

The water treatment of enhanced tube systems creates a greater demand on water treatment resources. The end user must be willing to accept the cost for proper water treatment and system maintenance. The purchase of an enhanced tube heat exchanger will provide a healthy payback only if the water treatment and maintenance programs are upgraded consistent with the greater sensitivity of such equipment.

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Position Paper Review Quiz

The questions for the quiz may be answered by reading and understanding the AWT Guidelines for Treatment of Systems Containing Enhanced and Super-Enhanced Tubes. The correct answers are derived from that paper and any disputed answers will be referred back to that paper for justification. An 80% correct score must be achieved for Credit for this review.

1. The design of heat exchangers has been studied since:
   a) 1970's
   b) 1940's
   c) 2000's
   d) 1850's

2. The first enhancements of the straight-bore tubes was/were:
   a) Rifled barreling
   b) Internal vanes
   c) Riffled barreling with Internal and External vanes
   d) Modification that reduced wall thicknesses in some area's by 70%

3. The "next" generation of enhanced tubes was:
   a) Rifled barreling
   b) Internal vanes
   c) Riffled barreling with Internal and External vanes
   d) Modification that reduced wall thicknesses in some areas by 70%

4. The most recent generation of tubes (super-enhanced) have what?
   a) Rifled barreling
   b) Internal vanes
   c) Riffled barreling with Internal and External vanes
   d) Modification that reduced wall thicknesses in some area's by 70%

5. Enhanced Tube and Straight-bore machines show the same Loss of Efficiency due to a thin layer of scale?
   a) True
   b) False

6. If a thin layer of scale caused a straight-bore to lose 10-15% heat transfer efficiency, the enhanced-tube system could lose as much as?
   a) No efficiency would be lost
   b) 10-15%
   c) 20-30%
   d) The machine would fail to operate

7. What should be the main priority of the water treatment professional when treating systems with enhanced tube technology?
   a) Scale
   b) Fouling
   c) Deposition
   d) Corrosion

8. Which topic is not a problem with enhanced tubes?
   a) Increased heat transfer
   b) Fouling at flow rates of less than 3 ft/second
   c) Fouling at flow rates of more than 3 ft/second
   d) Thin walled tubes are less forgiving

9. Biocide selection is important. It must not…
   a) kill all biological growth
   b) have a negative impact on the tubes
   c) be fed at night
   d) be chlorine

10. Name the two types of Non-destructive test procedures mentioned in this paper:
    a) Corrosion Coupons and Eddy Current Testing
    b) Corrosion Coupons and Fiber-optic Scoping
    c) Eddy Current Testing and Fiber-optic Scoping
    d) Corrosion Coupons and Chemical Analysis

11. Eddy Current Testing inspects…
    a) the internals of the tubes
    b) the externals of the tubes
    c) both the internal and externals of the tubes
    d) types of deposits in tubes

12. Fiber-optic scopes allow one to…
    a) Measure the thickness of the tube
    b) Inspect the both sides of the tube at the same time
    c) Measure the depth of the crack
    d) See the color of and distinguish between deposits

13. Non-destructive Inspections should be performed at what time interval, unless other problems or operational conditions indicate additional needs?
    a) Twice per year
    b) Once per year
    c) Every other year
    d) Every five years

14. What testing technique does not provide a cross check that corrosion is being controlled?
    a) Corrosion Coupons
    b) Corrater surveys
    c) Total dissolved metal analysis
    d) Inhibitor levels

15. Deposit Monitors can be used to determine if the water treatment program is controlling the minerals in the water?
    a) True
    b) False

16. Which test method is not an indicator of a properly designed biocide program?
    a) Alkalinity
    b) BART
    c) ATP technology
    d) Dip slides

17. Many enhanced tube failures occur due to particulates in the recirculating water. To reduce this and its potential settling in the tubes, what must be considered?
    a) Soften the water
    b) Consider the use of side stream filters
    c) Decrease blow down
    d) Increase blow down

18. Mechanical brushing of the tubes can remove deposits and fouling before severe problems develop. How should this be accomplished?
    a) Brushing with a straight tube brush
    b) Employ special brushes and techniques as supplied by the manufacturer
    c) De-scale the units with special cleaners annually
    d) Cleaning the tubes will destroy the vanes

19. Offline units will…..
    a) Have fouling and corrosion tendencies
    b) Form scale
    c) Last many years
    d) Require no additional attention

20. Water Treatment programs should maintain corrosion rates below what levels?
    a) Copper below 1 mpy, Mild Steel below 5 mpy
    b) Copper below .1 mpy, Mild Steel below .5 mpy
    c) Copper below 1 mpy, Mild Steel below .2 mpy
    d) Copper below .1 mpy, Mild Steel below 2 mpy