NUMBER 7 | VACUUM FURNACE REFERENCE SERIES

IMPORTANT CONSIDERATIONS
When Selecting a Vacuum Furnace Cooling System

SOLAR

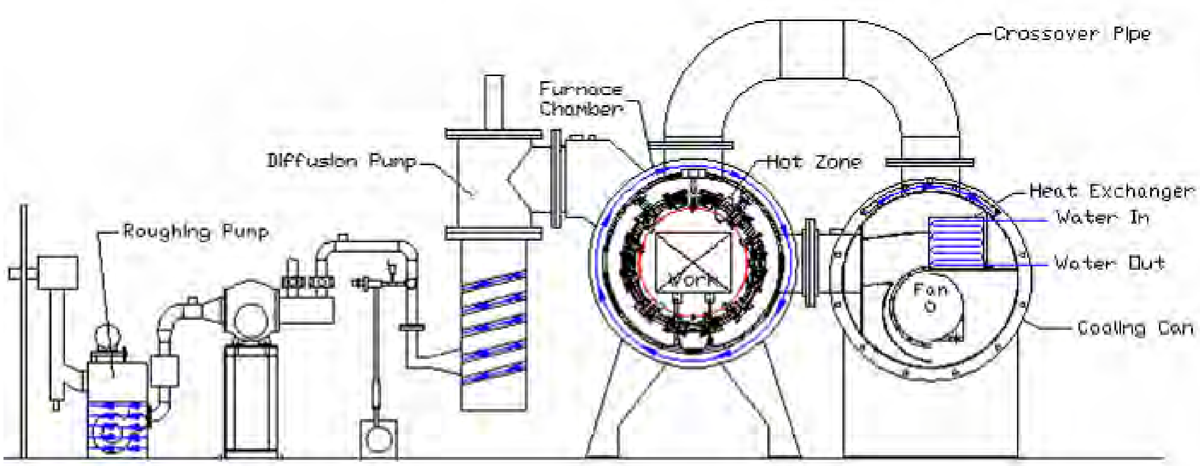
Important Considerations In Selecting A Vacuum Furnace Cooling System

The proper selection of a water cooing system to support all aspects of vacuum furnace operation is a critical decision. This booklet highlights the advantages and disadvantages of various systems to help you determine which one will best suit your specific requirements.

A vacuum furnace has many components that require water cooling for proper operation and performance:

- Mechanical Roughing Pump – where the oil reservoir is cooled to maintain proper oil temperature.
- Diffusion Pump – where coils around the pump require water to provide wall cooling for proper oil condensation and operation.
- Gas Cooling Heat Exchanger – necessary to cool the tubes passing through the heat exchanger removing the heat from the attached fins.
- Vacuum Chamber Walls – with the double wall construction, water re-circulates between the walls to maintain a safe outer wall temperature on the outside surface and on “O” ring seals.
- Other furnace components such as power terminals, cables, etc.

The following schematic illustrates a typical vacuum furnace and these components with the blue areas highlighting some of the cooling lines.



Several of the areas defined above have small cross-section tubing in which clogging can potenitally occur if proper precautions are not taken. In the chamber structure, flow must occur through and around several structural features where stagnation is always possible.

Types of Cooling Water Systems Available

There are three different types of water systems used to cool vacuum furnace components:

1) ***Once-through System***

2) ***Open Recirculating System***

3) ***Closed Recirculating System***

Once-through System

These cooling systems use the water's cooling capacity a single time through the equipment being cooled. They use large volumes of water and then typically discharge the water directly. Due to the large volume needed, once-through systems often use water from rivers, lakes or other city supplies.

The only external treatment generally applied to a once-through system would be mechanical screening or filtering on the inlet side to protect downstream equipment from serious damage due to foreign material intrusion. Since evaporation is negligible, no significant change in water chemistry occurs.

Since very few production facilities have large, once-through volumes of water available, these systems are not the norm for most vacuum furnace installations. If used, concerns relating to corrosion, scaling and biological fouling must be considered as well as environmental problems relating to the water discharge . A typical schematic of a direct in-and-out system is shown below in Figure 1.

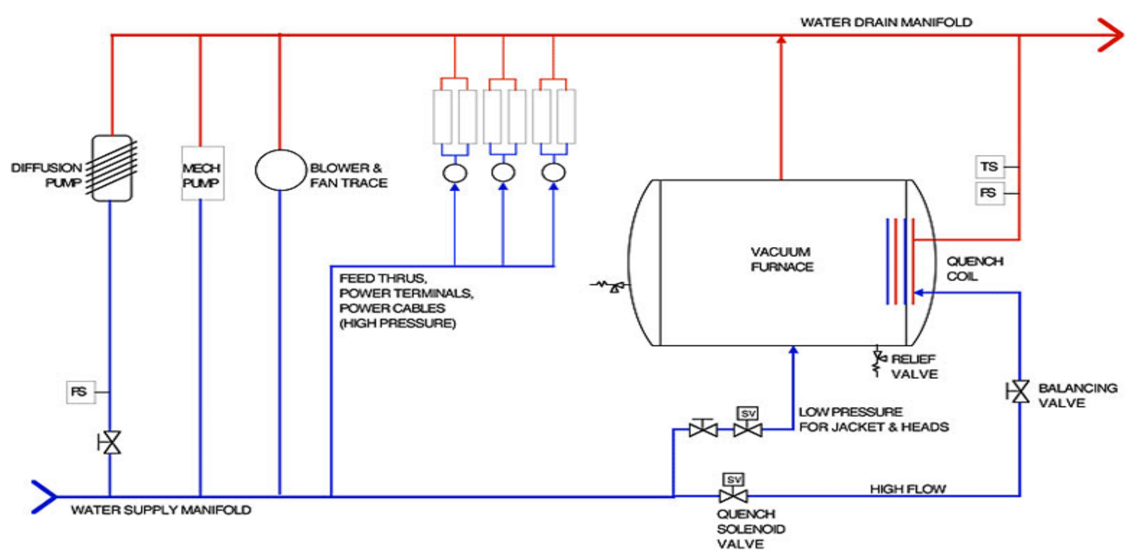


Figure 1 - Typical Once-through System

Areas Of Concern For Once-through Systems

Problems associated with once-through systems can be grouped into three categories:

- Corrosion
- Scale or deposition
- Biological fouling

Corrosion can be described as the wastage or loss of base metal in a system. Various types of corrosion can occur in once-through systems. However in all cases, base metal loss is encountered and corrosion products enter the bulk water stream as troublesome suspended solids. In addition to the detrimental impact of suspended solids, serious process contamination or discharge problems can result from active corrosion.

Scale or deposition can be grouped into two general types:

- Inorganic mineral deposits
- Sludge (when suspended solids settle)

The deposits insulate the metal surface from the cooling water, restricting heat transfer. "Under-deposit corrosion" can also occur. If the deposit formation is severe, restrictions to flow may further impact the cooling system's ability to carry heat away from the process.

Biological concerns can be categorized as either microbiological or macrobiological. The proliferation of biological organisms in a cooling system results in many of the same problems caused by corrosion. Significant microbiological growth causes equipment fouling, heat transfer impediment, microbiologically induced corrosion and possible flow restrictions

Open Recirculating Type System

Open Tower-Open Reservoir

An open recirculating water system uses the same water repeatedly to cool the furnace system. With this type of system, water recirculates from a large reservoir tank, back through the furnace, and back to the tank. Heat absorbed by the reservoir tank must be dissipated to allow for re-use of the water. This is accomplished by continually cooling the water through a secondary circuit that recirculates the water through an evaporative tower. Open recirculating systems

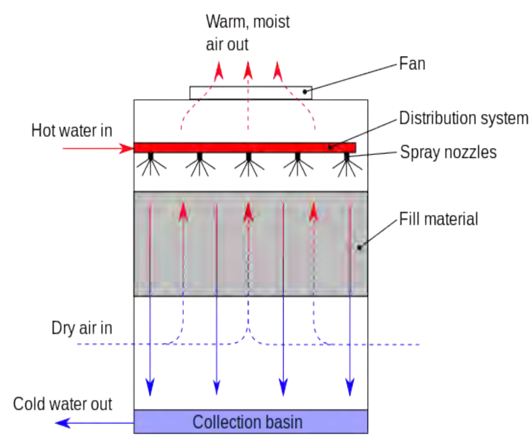


Figure 2 - Open Type Tower

save a tremendous amount of water when compared to once-through systems. The quantity of water discharged is minimized and chemical treatment is much more economical. However, the following concerns must be addressed:

- Cooling by evaporation increases the dissolved solids concentration in the water, raising corrosion and deposition.
- The relatively higher temperatures increase corrosion potential.
- The longer retention time and warmer water tend to increase the tendency for biological growth.
- Airborne gasses, especially oxygen, can be absorbed from the air, causing higher corrosion rates.
- Microorganisms and potential foulants can also be absorbed into the water across the tower.

An evaporative cooling tower is the most common type of tower used on these water systems. They are designed to provide intimate air/water contact. Heat rejection is primarily by evaporation of the cooling water. Make-up water, as a result, can be as much as 10%.

A typical open tower is shown in Figure 2 where the water enters at the top of the tower and is air cooled as it is sprayed to the lower part of the tower.

Closed Reservoir Tank – Open Tower – Interface Heat Exchanger

In this design, the water recirculating to the furnace system is part of a closed circuit. This is shown in the following schematic in Figure 3.

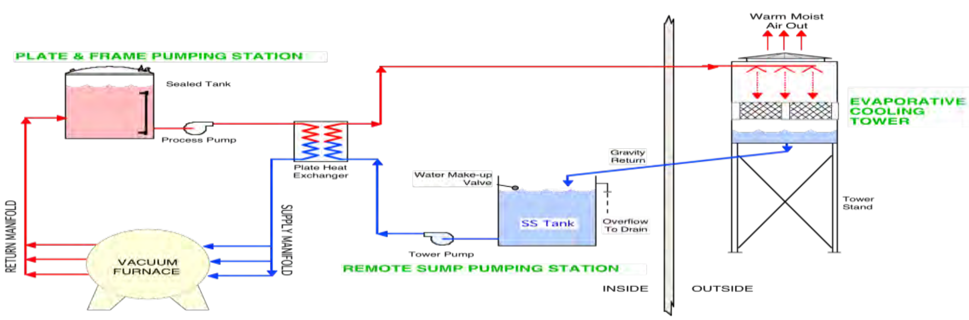


Figure 3 - Closed Reservoir - Open Tower

However, this type of system requires a secondary tank and an interface heat exchanger which adds to the overall installation cost. Also, with the same open tower as that shown above, similar concerns regarding dissolved solids, corrosion and bacterial growth must be addressed.

Areas Of Concern In Open Recirculating Systems

Cooling towers are the most common method used to dissipate heat in open recirculating systems. They are designed to provide intimate air/water contact. Heat rejection is primarily by evaporation of part of the cooling water. Cooling towers can be:

- Natural Draft Type – because of their distinctive shape they function as chimneys and do not require fans.
- Mechanical Draft Type – these towers use fans to move air through the tower with air normally entering at the bottom of the tower.
- Counterflow Type – in these towers, air moves upward directly opposed to the downward flow of the water.
- Crossflow Type – in this design, air flows horizontally across the downward flow of the water. The crossflow design provides an easier path for air, thus increasing airflow for a given fan horsepower.

Especially in cooling towers, there are many contaminants in cooling water that contribute to deposit problems. The three major types of contaminants are scaling, general fouling and biological fouling.

Scaling can usually be controlled by chemical addition to prevent deposition of pH sensitive species, softening the water to reduce calcium, or using scale inhibitors to allow operation under supersaturated conditions.

Regarding general fouling, species that do not form scale (iron, mud, silt, etc.) can also cause deposition problems. Because these materials are composed of solid particles, their deposition is often more flow-related than heat related. Suspended solids tend to drop out in low flow areas, such as the tower sump and the vacuum chamber.

An open recirculating cooling system provides a favorable environment for biological growth. If this growth is not controlled, severe biological fouling and accelerated corrosion can occur. Corrosion inhibitors and deposit control agents cannot function effectively in the presence of biological accumulations.

Several additional factors must also be considered:

- Without a proper water system and proper treatment, the life of the chamber could be reduced to as little as 5 years.

- Operating temperature of the chamber should always be at least 10^{o}F higher than ambient temperature in order to avoid condensation within the chamber.
- ***Water systems using evaporative towers will be more expensive to operate because of make-up water costs, etc.***

Closed Recirculating Water Systems

In a closed water system, the water circulates in a closed cycle and is subject to alternate cooling without air contact. This can either be accomplished through a closed circuit evaporative tower or with air-cooled heat exchangers.

Closed recirculating systems have many advantages. They provide better control of temperature and their smaller makeup water requirement greatly simplifies control of overall water associated problems. Makeup water is needed only when leakage has occurred or when water has been drained for system repair or maintenance. Little, if any, evaporation occurs. Therefore, high quality water can usually be used for makeup, and as a result scale deposits are not a problem. Closed systems are also less susceptible to biological fouling from slime and algae deposits than are open systems.

Closed systems also drastically reduce corrosion problems because the recirculating water is not continually saturated with oxygen, as in an open system. With the small amount of makeup water required, adequate treatment can virtually eliminate corrosion and the accumulation of corrosion products.

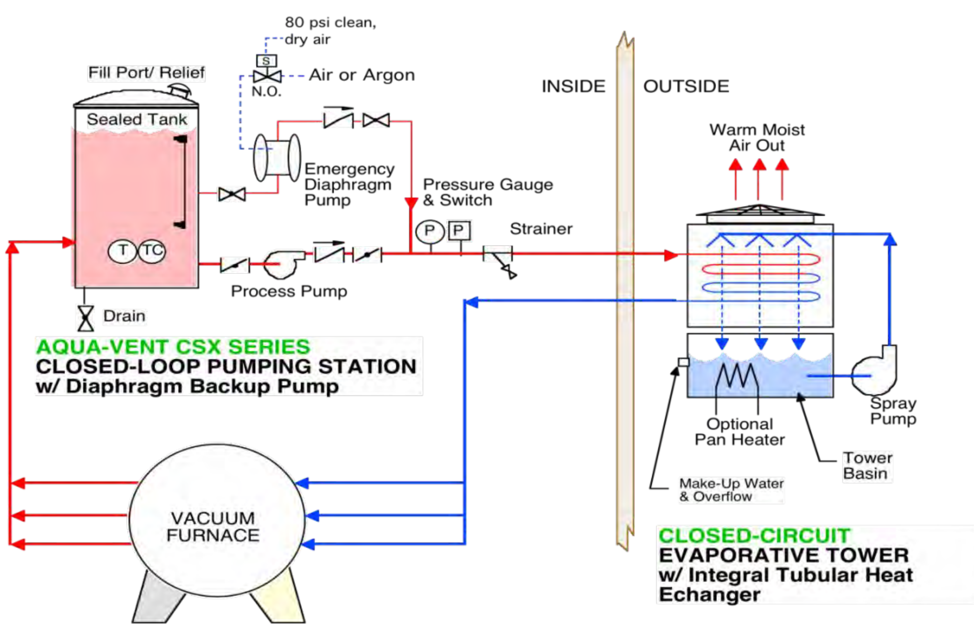


Figure 4 -Closed System with Closed Evaporative Tower

Closed System – Closed Evaporative Tower

Figure 4 above illustrates a typical arrangement of a closed system incorporating a closed evaporative tower. With this design the cooling water processing through the system is not open to the air, thus eliminating other problems associated with the open tower system.

One disadvantage with this system is the re-circulating water in the tower that sprays the water used to cool the heat exchanger coils that circulate the water feeding the connections to the furnace. Various contaminants can accumulate within the tower system and could eventually become serious problems in the long term. This situation, however, is typical of most water tower arrangements.

Depending on the area of the country where the installation occurs, the tower will often be equipped with a type of heater system to control water flow under cold conditions.

Closed System – Air-Cooled Heat Exchanger

Another type of closed water cooling system is one in which the evaporative tower is replaced by a large air cooled heat exchanger. The furnace water recirculates from the reservoir tank and is then cooled by a large air-cooled heat exchanger normally located outside the building. Figure 5 below illustrates this type of installation.

These cooling systems are typically less expensive to operate because of fewer pumps required and much less make-up water needed.

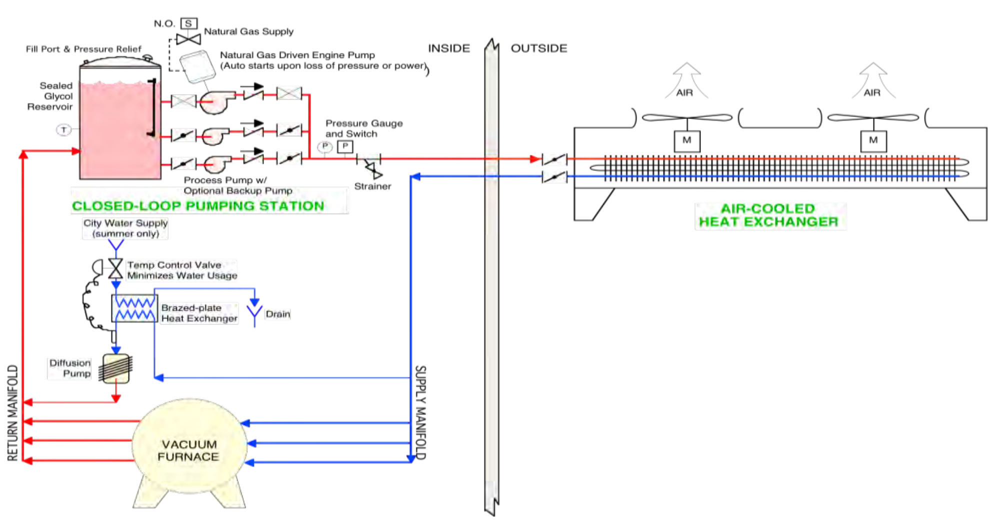


Figure 5 - Closed Air Cooled Heat Exchanger System

Some Concerns With Closed Systems

Because no concentration of dissolved solids occurs, fairly hard make-up water may be used with little danger of scale formation. However, in vacuum furnace cooling, the higher temperature of the water from the chamber- wall cooling and the gas-quenching heat exchanger water may increase the tendency for deposit scale. Over a long period, the addition of even a small amount of hard make-up water causes a gradual build-up of scale.

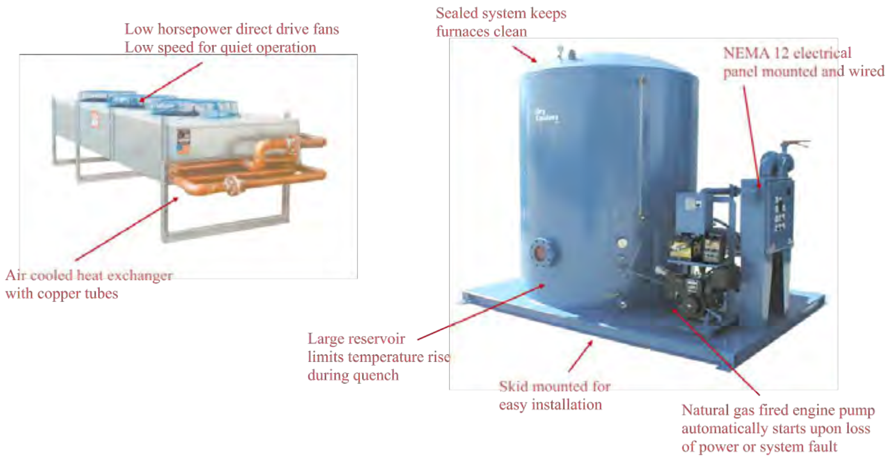


Figure 6 - Typical Components of a Closed Air Cooled System

Untreated systems can suffer serious corrosion damage from oxygen pitting, galvanic action, and crevice attack. Closed systems that are shut down periodically are subjected to water temperatures that may vary. During shutdown, oxygen can enter the water until its saturation limit is reached. Therefore, water cooling systems should never be shut down unless absolutely necessary. When the system is returned to high-temperature operation, oxygen solubility drops and the released oxygen attacks metal surfaces.

Fabrication of all types of cooling water systems might include materials such as steel, copper., copper alloys, and aluminum as well as various solders. Nonmetallic components such as rubber, asbestos, and carbon may also be used. If bimetallic components are present, galvanic corrosion may develop.

The three most reliable corrosion inhibitors for closed cooling water systems are chromate, molybdate and nitrite materials. Generally, the chromate and molybdate types have proven to be superior treatments. However, for systems with mixed metallurgical systems, the molybdate inhibitors provide the best corrosion protection. The level of concentration of these various inhibitors is a direct function of the system component materials and the typical maximum operating temperature of the cooling water.

Closed systems often require the addition of a suitable antifreeze. Non-chromate inhibitors are compatible with typical antifreeze compounds. Chromate may be used with alcohol antifreeze, but the pH of the circulating water should be maintained above 7.0 to prevent chromate reduction. Since glycol antifreezes are not compatible with chromate-based treatments, non-chromate inhibitors should be used.

Pretreatment of Cooling Water Systems

Pretreatment of cooling water systems is necessary to maximize the equipment. Usually, pretreatment consists of two phases:

- Pre-cleaning, to remove the accumulation of foreign matter.
- Pre-filming, to promote the rapid formation of an inhibiting film (also known as "passivation" for the surface enhancement of steel).

Pre-cleaning is important because it prepares the surface for the pre-filming phase. After the surface has been cleaned, pre-filming minimizes the initial corrosion which occurs at start-up and allows the most efficient application of a corrosion inhibitor program.

Pre-cleaning

All new water systems should be pre-cleaned to remove grease, oil, corrosion products, mill scale and dirt. Clean surfaces enable corrosion inhibitors to promote a uniform protective film. Failure to pre-clean can result in increased corrosion and fouling, leading to reduced heat transfer, premature failures, and high maintenance costs.

Pre-cleaning should be conducted just prior to start-up, followed by proper passivation of all surfaces. Normally, a solution of polyphosphate, surfactant, and antifoam is circulated through the cooling system. The polyphosphate and surfactant help remove light rust and other materials left by manufacturing and construction.

Typically, cleaning is conducted over a period of 8-24 hours.

Pre-filming

Most methods of corrosion control involve the formation of a film to act as a barrier to corrosion. The effectiveness of the treatment depends largely on the rate at which the barrier film is formed.

Pre-filming permits the rapid formation of a uniform film that immediately stifles the corrosion reaction. Once the film has been established, it can be maintained through continuous low treatment levels to deter the accumulation of corrosion products.

Pre-filming of water cooling systems is recommended immediately following pre-cleaning. Phosphate and zinc are used on most pre-filming applications. With copper alloys involved, azoles are also used.

Polyphosphates are most important because they effectively remove undesirable corrosion products as they form, while developing a protective oxide film. Generally, these materials are circulated through the system at concentration ranges of 300-600 ppm phosphate and 30-60 ppm zinc.

Pre-treatment is critical for any water cooling system containing steel components because of the higher corrosion rates that occur.

In general, pre-treatment followed by ongoing treatment programs minimizes corrosion for improved heat transfer, longer service life, and reduced plant maintenance.

Solar Manufacturing And Solar Atmospheres Background, Problems, Recommendations On Water Systems

As stated previously, a well-established and maintained process cooling water system is critical to the function and long term service life of water-cooled vacuum furnaces. The first criterion in establishing a foundation for long term, low maintenance furnace life is to purchase a furnace from a company with sound engineering awareness of proper design and construction of the furnace. Next, the furnace cooling chamber should be kept as clean as is practical during construction and be blown out with high pressure dry gas prior to exposing it to water. It is imperative that the water first exposed to the chamber is clean and "chemically treated," as discussed above in pre-cleaning, to provide the all-important initial corrosion- resisting surface enhancement of the steel, termed "passivation" or prefilming.

Once commissioned, the heat treat facility's cooling water system must maintain the "passive" nature of the steel and copper surfaces throughout a furnace's entire life. Doing so can provide reliable service indefinitely. Conversely, case histories have shown that not doing so can lead to corrosion and maintenance issues within three to five years of a furnace entering service. Typical chamber material is made from structural grade steel, while gas and water cooling heat exchangers are commonly fabricated with copper tubing. Corrosion protection needs to address the fact that different metals of different galvanic potential are exposed to the same cooling water.

Additionally, one cannot overlook the fact that if a new chamber is put into service on an existing cooling system, the new furnace potentially has the ability to seriously tax the corrosion inhibiting capability of the cooling water, particularly if it is a larger size furnace (large surface area). Adding a furnace to a cooling system requires vigilant and more regular monitoring and maintenance of the water chemistry until equilibrium is established.

As examples of what might occur, following are incidents of corrosion problems experienced by our sister company Solar Atmospheres, that were related in one or more ways to the design, construction, and commissioning, and/or the production facility's water system treatment, monitoring and maintenance program. These examples are offered to inform the heat treating community of the critical importance of understanding cooling water systems and their relationship to the low maintenance longevity of vacuum furnace service life.

Please note that this paper relates to closed-loop type cooling systems installed at Solar Atmospheres which are considered the best solution to vacuum furnace cooling. Similar or even more severe problems can occur on open type water cooling systems.

Solar Atmospheres Water Cooling System

Solar Atmospheres' vacuum heat treating facilities operate what is best described as a "quasi" or "semi" closed loop, process cooling water system. That is, the systems are not truly closed to the complete exclusion of air (oxygen). They are closed loop from furnace to furnace and to and from the reservoir tank, but the reservoir tank itself has non-sealed covers on top that can allow for some air infiltration, albeit minimal. The non-sealed nature of the reservoir tank also allows for minor evaporation of the cooling water that is replenished from a city water supply. Figure 7 below shows a typical water system schematic.

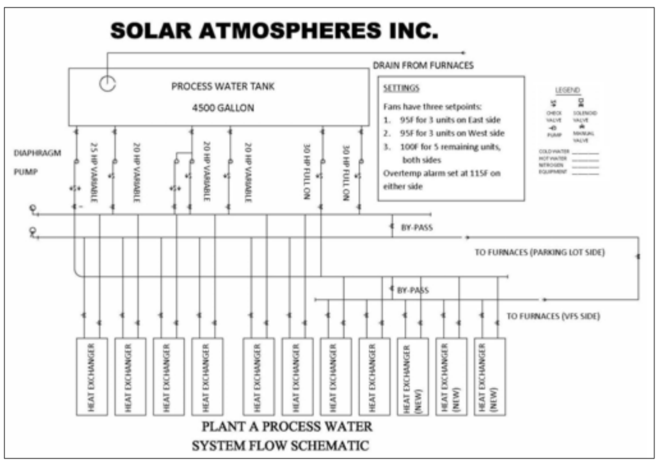


Figure 7 - Water Cooling Schematic

It is considered that domestic water refilling process likely adds comparable amounts of dissolved oxygen (approximately 7ppm) to the system as air infiltration.

Interestingly, oxygen is required for corrosion to occur but it is also needed for the initial passivation of steel surfaces to prevent further corrosion. So in layman's terms, a little oxygen is good but above a certain threshold it is detrimental. Additionally, and although a bit confusing, the absence of oxygen can be detrimental as well. The most common phenomenon exhibited by the latter situation is termed "under-deposit corrosion," where there is no available oxygen for passivation under a deposit. Corrosion occurs under sediment deposits in cooling systems where the "sediment" is, in part or wholly, corrosion products (rust) from an improperly treated water system and/or construction remnants that settle out in low flow areas of the system. The differential in oxygen concentration from outside the deposit to under it establishes a "corrosion cell".

A corrosion cell also can be related to design-generated "low flow zones" which are to be avoided, not only to prevent sediment deposition, but also to ensure that all areas in the system get exposed to the water treatment protective chemicals. Another design rule, which is applicable to construction as well, is to avoid cavities. Cavities can experience the same differential oxygen concentration cell corrosion as under deposit corrosion. Not all crevices can be avoided in construction, such as fillet welds in through-wall penetrations. But the penetration conduit can be designed to be significantly more robust if made from drilled bar stock instead of from standard pipe. Examples would be Power Feed-Through ports, T/C ports and Gas-Backfill ports.

Figure 8 - Solar Atmospheres External Cooling Components

Figure 6 is a schematic representation of a cooling water system layout shown for one of Solar Atmospheres' heat treating facilities. This particular system services eleven varying sized vacuum furnaces from a 4,500 gallon reservoir tank located just outside the building's back wall, Figure 8. The semi-closed looped system cools all eleven steel constructed furnaces and their copper heat exchangers used for quench gas cooling. The amount of water actively in the system is roughly another 2,500 gallons in addition to that in the reservoir tank.

Heat is released through eleven 5' x 15' copper tube and aluminum fin water-to-ambient air heat exchangers (no open air-cooling tower or chillers). It is important to note that there is a fair amount of copper exposure to the water system in addition to steel. Further, copper is "noble" compared to steel and can galvanically accelerate corrosion of adjacent steel surfaces (as in a battery cell) if the water system is not properly treated.

Corrosion inhibitor chemicals are added to cooling water systems to, as the word implies, "inhibit" corrosion. More specifically, they act to interfere with the electrochemical nature of corrosion by impeding the cathodic or anodic reaction or both. So there are cathodic, anodic, and mixed inhibitors. Further, the inhibitor may be reactive, precipitating, or film forming. The chemicals that provide this wide variety of functions may be organic or inorganic. The common list includes: orthophosphate polyphosphates, phosphonates, molybdate, silicates, nitrates, azoles, and zinc. Most inhibitors are not used singularly, but are combined to provide a synergistic effect both for chemical and economic benefits. With so much involved in cooling water chemistry and the critical influence it has on long term, low-maintenance serviceability of equipment, it is highly recommended to contract with a water treatment service company for regular cooling water testing and treatment.

Solar Case Histories of Typical Problems

Prior to contracting with a new water treatment company, Solar Atmospheres had experienced several instances of under-deposit corrosion and cavity corrosion problems on several different furnaces. The most prevalent were at thermocouple feed-through penetrations and some power feed-through penetrations. These both have been attributable to cavities created during fillet welding and rust sediment deposits from improper waste treatment maintenance.

Figure 9 - Typical Pipe Leakage

Early furnace designs used pipe as the through-wall conduit, with the ultimate path of leakage being through the pipe wall. Current furnace designs use drilled bar stock as the conduit for thermocouple penetrations as does any replacement conduit that has leaked. Figures 9-10 show examples of pipe conduit leaks associated with welds.

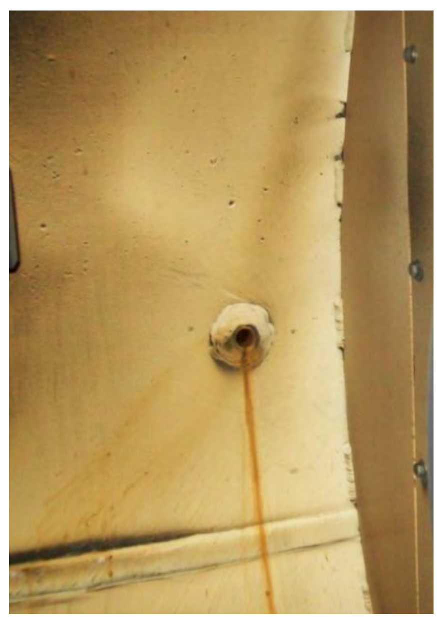


Figure 10 - Pipe Leakage Expanded From Figure 9

Exterior through-wallpitting leaks have occurred on at least four furnaces owing to under-deposit corrosion from rust sediment settling on structural support ribs between the double walls of a chamber and along seam welds at areas of low flow. Figure 11 shows external leakage that occurred at a seam weld.

Figure 11 - Seam Weld Problem

Figure 12 shows a section of plate excised from the side of a very large car bottom furnace with a 1⁄8” diameter exterior hole. The location of the water jacket side of the plate was directly above a structural support rib (used because of the size of the furnace). A substantial amount of muck had built-up on the support rib, which in turn led to under deposit corrosion of the 3⁄16” thick plate surface above it. The area of plate affected was almost 3” square with the leak occurring at the near center of it, Figure 13.

Figure 12 - Plate Section

It is noteworthy to share that the “muck” associated with the corrosion shown in Figure 13 was biochemically tested for bacteria, because microbiologically influenced corrosion (MIC) is a real corrosion phenomenon that can and does occur in all types of water systems. The bacterial count was negligible, indicating that the through-wall corrosion was attributable to classical under-deposit corrosion (differential oxygen concentration cell). If bacteria are found to be present in corrosion product, biocides can be added to the system. But these make the water chemistry very complex because of their interaction with the corrosion-inhibiting chemicals. Normally, a system would need a

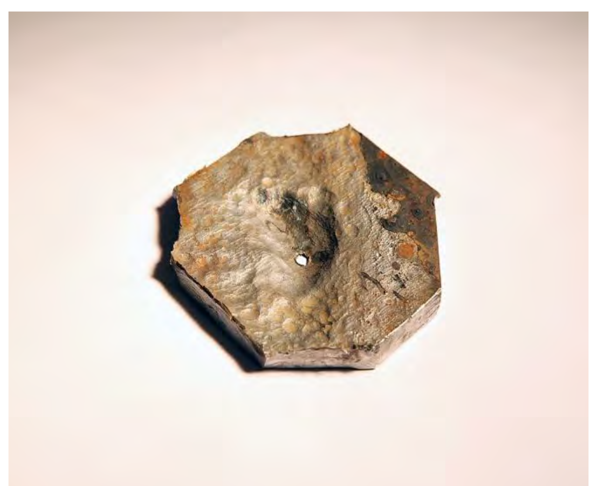


Figure 13 - Underside of Plate

considerable period of time to "clean up" after adding biocides and the preferred approach is to completely flush the system when MIC is conclusively determined. Equally daunting, too much biocide could "feed" certain types of bacteria if its exact nature is not known.

Even without the presence of MIC in Solar's water systems, the amount of muck found in some furnaces was alarming and recommendations were made to consider flushing the system. In lieu of flushing the entire system containing thousands of gallons of chemically treated water, Solar decided to "back-flush" specific furnaces. Normal furnace cooling water enters the furnace at the bottom and exits at the top. This flow was reversed for 24 hours at a slightly increased pressure (5-10 lbs) for the back-flush. Additionally, a chemical dispersant was added with the intention of "suspending" disrupted solids in the fluid flow. Then 25 micron bag filters were installed to collect the suspended solids.

Using this approach initially resulted in the collection of a great amount of sediment and the approach was considered a success. Eventually, the filter size was incrementally reduced all the way to 1 micron where it is maintained today and changed normally between a four to six week span when a 10-15 pound pressure differential across the filter is reached.

Figure 14 - Typical Pin Hole

Inside chamber wall leaks have been a much more rare occurrence, but then the interior plate is heavier gage than the exterior plate. One water leak occurred on the inside wall of a 2 bar furnace at the end of a hot zone support channel that was associated with plastic deformation (bowing away from the wall) from weld cooling strain. The root cause of the leak was under deposit corrosion from low water flow, which was exacerbated by high residual stress in the steel plate from welding (stress enhances and accelerates corrosion). The inside chamber leak appear as a pinhole, Figure 14, but grinding for weld repair preparation required removal of a 1" x 2" segment of steel before "sound" metal for weld repair was obtained, Figures 15.

Sediment in cooling water systems not only can cause corrosion issues but can clog furnace inlet and outlet water couplings, Figures 15. This creates undesirable hot spots which potentially can lead to precipitation of certain minerals in the water. These precipitants can be very tenacious and obviously can lead to under- deposit corrosion same as other sediments. The first and easiest evaluation of the cooling system is a visual check; the water should look visibly clear both in the reservoir tank and in any ball float, flow indicators in the furnace

Figure 15 -Expanded Leak Hole

inlet/outlet water manifolds. A sampling pipe line and valve should be installed at the furthest location in the cooling loop from the reservoir tank to sample water for clarity and other periodic tests performed for preventive maintenance.

Figure 16 - Sediment Illustration

Figure 17 - Water Pipe Sediment

It cannot be overstressed that passivation of steel is considerably enhanced by the use of non-acidic cooling water with minimal suspended solids. "Clean" water significantly enhances the effectiveness of all chemical treatments. Chemicals are added to keep the pH generally in the range of 8-10 (slightly above neutral to basic region), which is good for both steel and copper passivation. Moreover, passivation is augmented by heat, so it is of great importance to use treated water in newly constructed furnaces when conducting initial performance testing. Figure 16 shows a water pipe segment used in the cooling system of newly constructed furnaces before a rigorous high pressure gas, chamber blow-down procedure and water treatment system were instituted.

Solar Atmospheres' cooling system presently uses three different chemicals for corrosion protection. Two different organic nitrogen inhibitors are added to suppress both steel and copper corrosion. Nitrite is a strong anodic reactive inhibitor (similar to the now banned chromate). It reacts directly with steel surfaces in the absence of oxygen to form a protective passive oxide of magnetite. There are three oxides of iron and magnetite is the desired one for corrosion protection. It is thin, uniform, and highly tenacious. Because copper is quite prominent in the cooling water system and the availability of oxygen is low (for passivation), the use of an azole is required to provide protection to copper base alloys. Azoles are reactive inhibitors that form a very stable and tenacious reacted film over copper surfaces. The azole is part of the formulation of one of the nitrogen base inhibitors, which also reduces the influence of copper on the galvanic accelerated corrosion of nearby steel.

A second nitrogen inhibitor is defined as a "quadrasperse quadpolymer" which basically means its principle function is to keep suspended solids dispersed, thus acting as a deposit control agent. The third chemical in the system is an inorganic anodic precipitating inhibitor, molybdat. Molybdate is an oxidizing agent that forms a precipitated film over steel surfaces of ferric molybdate for corrosion protection. Molybdate is relatively expensive compared to nitrate, but when the two are blended the total amount of chemical required to keep the system passive is considerably reduced. A significant benefit of molybdate is that it is an excellent "tracer," meaning that it can be tested for easily and provides valuable information as to the quality of the system, and indicating the need for chemical additions.

Solar Atmospheres weekly tests for molybdate, pH, clarity, conductivity, water level, and filter conditions. The contracted water treatment service conducts more detailed tests quarterly and corroborates Solar's most recent test results.

Summary & Conclusions

Process cooling water chemistry is of such importance that equipment can last a lifetime or be scrap metal within several years. It is our experience that controlling water chemistry is more easily accomplished in closed-type water cooling systems. In open or once-through systems, corrosion is insidious and out of sight. Water chemistry formulation to inhibit corrosion is a science, and as such is diverse and complex. Rarely are two systems treated in the same manner unless they are in a local community with a common water supply. As such, it is best to contract with a water treatment service company to evaluate the existing condition of a process cooling water system and then to service it properly.

- Whenever possible, a closed loop type water system should be selected.The furnace water system should include flow indicators to show proper flow to critical areas.
- Proper water temperature control within the cooling system during external temperature variations will help to control future potential problems.
- When purchasing a water system, work with contractors who understand the requirements of cooling all aspects of a vacuum furnace.
- Water treatment is not an exact science and is best left to experts to recommend proper solution to each specific problem.

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