DEFINITIONS, ANALYSIS AND CORRECTIVE PROCEDURES REGARDING THE PROBLEM OF "SYSTEM AIR" IN CLOSED HOT WATER AND CHILLED WATER HVAC SYSTEMS

Chapter Three

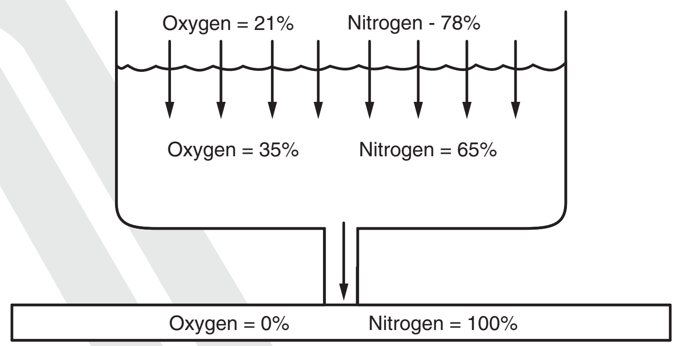
AIR ELIMINATION SOLVES THE PROBLEM OF OXYGEN CORROSION

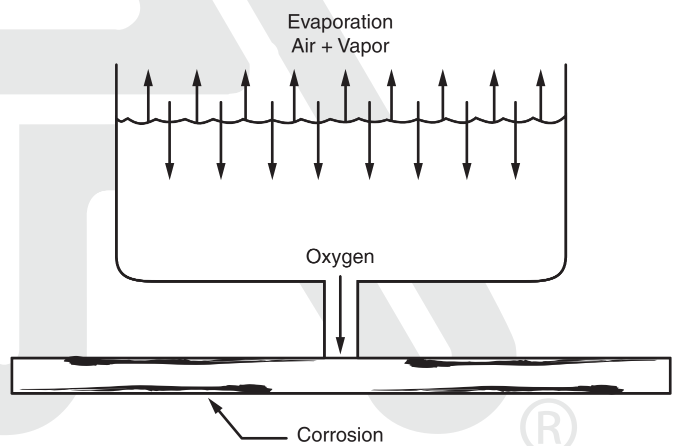
Oxygen Corrosion Potential is Extremely Serious with an Open Tank (Roof Top).

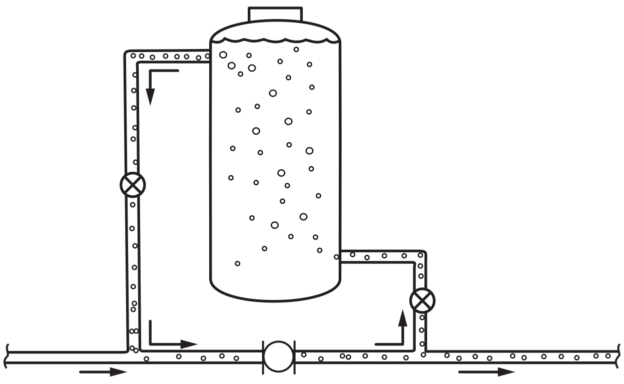
The open tank, or roof top, has several disadvantages over the closed tank (whether plain steel or diaphragm-type). In view of critical energy concern, the constant loss of vapor from the surface of the water (heating system) has become increasingly serious. The water loss through evaporation must be replaced by makeup water carrying more oxygen. In some installations, measures must be taken to prevent freezing – a further energy loss. Constant exposure to the atmosphere results in the introduction and concentration of chemicals, dirt and dust which cause sludge in system piping. Suspended solids cause erosion in piping, heat exchangers and valves. In spite of chemical treatment, deposits of dirt at the bottom of piping cause localized pitting.

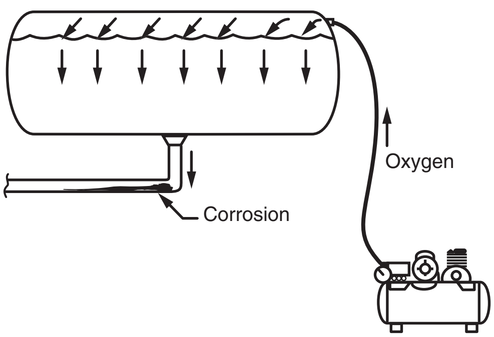
The most serious potential problem is oxygen corrosion. The water in the open tank is at all times in contact with air from the atmosphere. The air in the upper part of the tank is made up of 78% nitrogen and 21% oxygen. The absorbed air, in solution, in the water in the lower portion of the tank, is 65% nitrogen and 35% oxygen. Water has the characteristic of absorbing oxygen more readily than nitrogen. Not only the water at the surface, but also the entire amount of water in the tank must become saturated with oxygen.

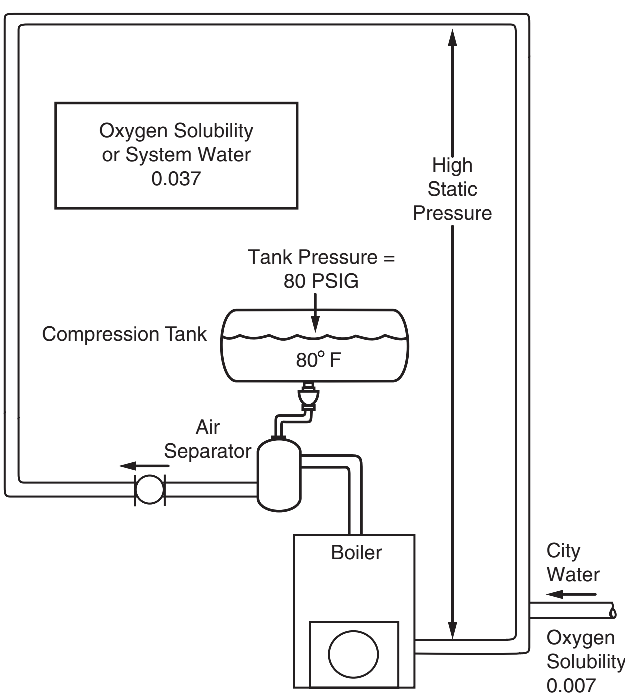
The oxygen in solution in system water is unstable, and unites with the metal components to form rust and corrosion. The amount of oxygen in the water in system piping is therefore always less than the amount that the water in system piping is capable of holding – in a sense, the water is oxygen "starved." In contrast, the water in the open tank, in direct contact with air from the atmosphere, is at, or close to, the saturation point. As long as the water in system piping contains less oxygen than its maximum capability, oxygen will migrate from the water in the tank to water in the piping by diffusion. The process of oxidation guarantees that water in system piping will always contain less than its maximum capability, therefore, the process of oxygen diffusion from the open tank to the system will be constant. This will occur even if there were no movement of water between tank and piping.











The constant movement of expanded water between tank and piping as system temperature fluctuates…expedites the migration of oxygen throughout the system. A drop in temperature results in contraction of the water volume and therefore flow of tank water, saturated with oxygen, into the system. An increase in temperature forces expanded water, always less than saturated with oxygen, into the tank. During each operating cycle, a quantity of oxygen is absorbed from the air and deposited in the steel piping in the form of rust – an oxygen pump.

Chemical treatment to reduce oxygen corrosion is essential in order to minimize maintenance and replacement problems. The anticipated cost of chemical treatment equipment and monitoring devices plus the cost of maintenance and replacement components should be made available to the owner in the evaluation of the life cycle cost for the building.

Oxygen Corrosion Potential with a Plain Steel Tank ("Closed" System) Would Seem to Be Less Than with an Open Tank

The plain steel tank in a "closed" system seemingly has an advantage over the open tank, in that the amount of oxygen available to the open tank is unlimited, whereas the amount of oxygen available to the plain steel tank is the amount in the tank at initial fill. However, the number of times that the tank must be re-charged with air, or in the case of the addition of an air compressor, provides, in essence, an open conduit to the atmosphere…truly an "oxygen pump".

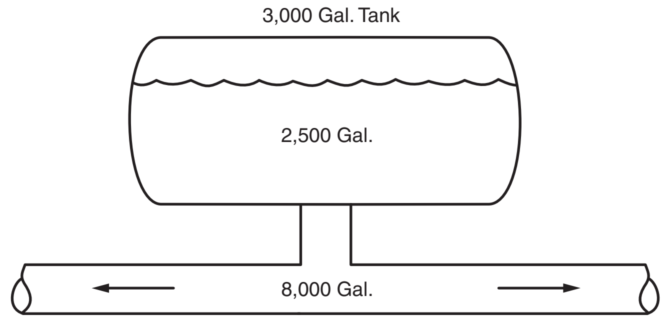
The plain steel tank installed at the bottom of the system, where the static pressure could be quite high and has the capability of holding a high amount of oxygen in solution. For example, in a heating system operating with a tank pressure of 80 psig and a temperature in the tank of 80°F, the oxygen solubility is 0.037, compared to the oxygen solubility in city water of roughly 0.007.

Just as the water flowing in system piping will absorb oxygen from the water in the open tank, it will absorb oxygen from the water in the closed tank. Whether or not there were actually movement of water from the tank or oxygen will migrate through the system, causing corrosion of piping and components.

Chilled Water Systems, at Lower Temperature, Have Higher Oxygen Solubility

In a chilled water system, the water flowing through the piping is at a much lower temperature and consequently can carry a much greater amount of oxygen. The solubility of water at 80 psig and 50°F is 0.0514 — the oxygen solubility of city water, 0.007. Makeup water is often cited as a source of corrosion, yet for every gallon of makeup water, only 0.007 gallons of oxygen enter the system. Every gallon of air originally in the plain steel expansion tank contained 0.21 gallons of oxygen — a ration of 1 to 30. For every gallon of air originally in the plain steel tank, 30 gallons of makeup water would be required to have the same corrosive effect. For example, chilled water system with a content of 8,000 gallons, a 3,000 gallon plain steel tank is installed. The 8,000 gallons of water from the city main required to fill the piping system and components contain 56 gallons of oxygen. The 2,500 gallons of water required to charge the tank to 80 psig minimum operating pressure contains 17.5 gallons of oxygen. The air originally in the tank contains 630 gallons of oxygen. Total oxygen of 703.5 gallons. 100,000 gallons of water would be required to have the same corrosive effects, a loss and makeup twelve times the system piping volume. It would appear that a reasonable amount of makeup water is not significant compared to the oxygen added to the system by draining and refilling a plain steel tank or charging with compressed air. The “closed” tank with a compressor is similar to an open tank in that it creates an efficient “oxygen pump.” In reality, the system is no longer “closed” but is “open.”

For years, engineers have agreed, that in a closed system with a plain steel tank (theoretically), there should be no corrosion problem. Yet, on countless installations, the abrasive action of the black iron oxide, Fe_3O_4, caused failure of mechanical pump seals and valves. Rust deposits formed in piping and components, reducing circulation and causing inefficient operation and wasted energy. In extreme cases, complete blockage of piping has occurred, necessitating reaming of the pipe or replacement.



8,000 Gal. – System Water

8,000 x 0.21 ÷ 30 = 56 Gal. Oxygen

2,500 Gal. – Tank Charge Water

2,500 x 0.21 ÷ 30 = 17.5 Gal. Oxygen

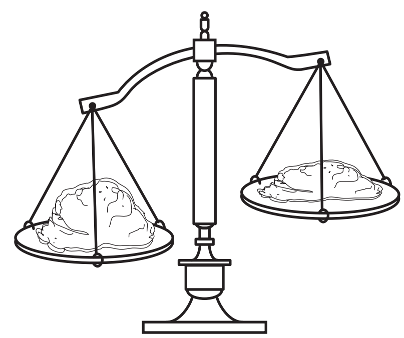
3,000 Gal. – Total Tank Volume

3,000 x 0.21 = 630 Gal. Oxygen

630 + 56 + 17.5 = 703.5 Gal. Total Oxygen

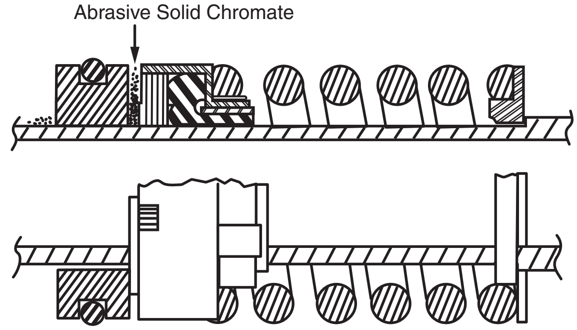
The Problems Resulting from Chemical Treatment Are Sometimes as Troublesome as Corrosion

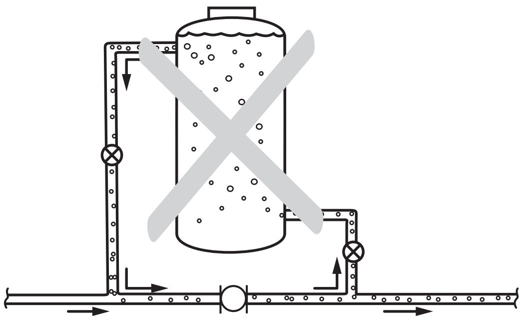
Because a “closed” system often becomes an “open” system, chemical treatment has become more common. But the problems resulting from chemical treatment are sometimes as troublesome as the original corrosion due to oxygen. Too small an amount of one chemical could cause pitting. Excessive amounts added intermittently cause problems which could be avoided by constant feeding based on monitored results. Automatic chemical feeders are costly, and many times introduce more oxygen into the system. Standard materials used for pump seals fail when exposed to high concentrations of certain chemicals. Even a low percentage of chromate in system water can cause seal failures. Absorbed in system water, it travels across the mechanical seal face, from the system to the atmosphere. When the water evaporates into the atmosphere, the chromate remains as an abrasive solid, causing seal wear and eventual failure.

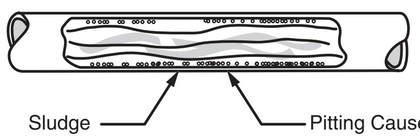


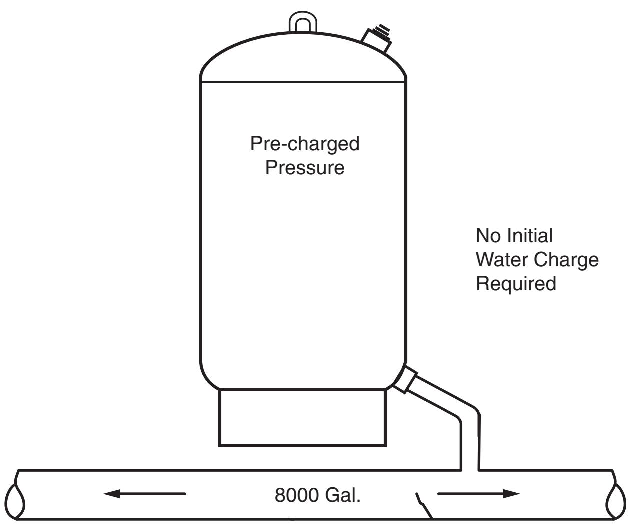
Chemical Imbalance Causes Problems in Chemical Treatment

Pump Seal Failure Caused By Abrasive Solid Chromate









8,000 Gal. - Volume System Water
8,000 x 0.21÷30 = 56 Gal. Oxygen

In some instances, the addition of chemicals causes sludge and frequent boiler blowdown is required. More makeup must be added, carrying more oxygen into the system. Continued dumping of pervasive toxic waste into public sewer systems or streams is a questionable procedure in view of public concern over safety hazards. Hazardous waste is a constant threat to drinking water. Pollution controls and regulations in the local community should always be consulted. In summary, if chemical treatment of system water must be accomplished, the proper equipment must be installed and constantly monitored by trained, responsible maintenance personnel. Observation of many installations reveals that chemical treatment is inconsistent and poorly monitored. The procedures followed by so-called specialists appear rather mystical to many engineers involved in maintenance of HVAC systems – specifications covering chemical treatment vary widely and are many times confusing. The responsibility for control of potential corrosion problems is rarely clearly placed – engineer, contractor, chemical "specialist" and manufacturer, all are involved to varying degrees. If a specification reads that chemical treatment should be "sufficient and proper," who determines what is "sufficient and proper"? Either overlapping responsibility or lack of responsibility is the result of this confusion. In the final analysis, it is the owner who bears the financial burden for the corrosion problems which occur.

Air Elimination Solves the Problem of Oxygen Corrosion

The diaphragm-type or bladder-type tank offers a better solution to the problem of corrosion. Because the required size air cushion is permanently sealed in, substantially all of the other air in the system can be eliminated. In the example chilled water system mentioned previously, a total of 703.5 gallons of oxygen existed in the system at startup: — 630 gallons in the air originally in the tank; 17.5 gallons in the charge water in the tank; and 56 gallons in the water in system piping and components. The use of a diaphragm tank eliminates the first two, leaving a total of 56 gallons of oxygen, a relatively insignificant amount. By the use of air elimination devices installed at the proper location, and following air elimination procedures at initial system startup (see Chapter Five), most of the 56 gallons of oxygen can be removed.

With reasonable care, the addition of makeup water can be minimized. Therefore, no opportunity exists for any significant changes in the composition of the water in the system. With proper pH control, and except in areas with abnormal water conditions, no chemicals need be added to the water heating and chilled water system.