white paper

Optimizing Air Removal in Hydronic Systems - When Good isn't Good Enough

Over the past 60 years, as hydronic HVAC system design continued to evolve, more efforts have been made toward increasing system life and maximizing energy efficiency.

Hydronic heating and cooling systems remain a popular option for design engineers and building owners due to superior energy efficiency, flexibility and reliability when compared to other HVAC solutions. However, the presence of air within a hydronic system can create problems, potentially offsetting some efficiency gains and contributing to system corrosion.

Over the years various technologies have been developed to remove air from hydronic systems. These technologies include manual air vents, automatic air vents, air separators and vacuum deaeration.

Technology	Mode of removal	Target Air Removal
Manual Air Vent	Manual interaction, open vent to remove locally collected air	Free Air
Automatic Air Vent	Float operated; air collects at the vent and is automatically vented to atmosphere	Free Air
Inline Separator	Utilizing either coalescing media or double thrust function to boost air removal	Free & Entrained Air
Vacuum Deaerator	Fluid is subjected to negative pressures	Free, Entrained & Dissolved Air

Why remove air from hydronic systems?

Two of the most common answers to this question are **noise** and **air locking**. While both of these symptoms should be avoided, they are temporary and easily remedied. However, **system efficiency** and **system corrosion** can have a more significant negative impact if ignored.

System Efficiency

System Efficiency is a measure of how much energy is lost via transfer from the heat source (e.g., boiler or chiller) to emitter (e.g., radiator or fan coil). Maximizing system efficiency really means minimizing energy losses.

When seeking to improve the efficiency of a hydronic system, many opt to use more efficient boilers, chillers or pumps and other measures such as insulating pipes. Although these measures are encouraged as best practices, the effect of entrained air is often overlooked when evaluating system efficiency.

Hydronic systems use water to transfer heat. Water absorbs and transfers heat with high efficiency due to a relatively high thermal capacity and thermal conductivity. Air performs poorly by comparison and therefore when it mixes with water there is a negative impact on system performance.

Thermal Capacity and Conductivity of Water and Air

Thermal Capacity – A measure of how much heat energy is absorbed by a material to increase its temperature by one degree Celsius. A high thermal capacity means water can store a large amount of heat energy similar to how batteries store electricity.

Thermal Conductivity - The measure of a materials ability to transfer and distribute heat. A high thermal conductivity allows water to effectively conduct and transfer heat.

Thermal Capacity (68˚F)	Water	Air
	4.18 kJ/(kg K)	1.01 kJ/(kg K)
Comparison	Water has 4x greater capacity than air	

Thermal Conductivity (68˚F)	Water	Air
	598.03 mW/m K	25.87 mW/m K
Comparison	Water has 23x greater conductivity than air	

Values from engineering toolbox

The values in the tables above show that water can hold approximately four (4) times more heat energy than air at the same mass. This means water has a greater energy density, taking up less space to store an equivalent amount of heat.

Thermal conductivity of water, by comparison, is noted to be 23 times higher than air. This means that a system fluid containing air will not only take longer to absorb energy but will be less effective at transferring it as well.

What does this mean? Hydronic systems with excessive air are less efficient, resulting in energy waste leading to higher operating costs.

Potential Energy Savings

Conditions must be perfect for a system to operate at peak efficiency. This means a system free of air and degradation. As discussed previously, the presence of air is detrimental to system performance. For example, microbubbles circulating within heating systems may cause a 1-2% efficiency loss in the boiler (or other heat sources).

The table below outlines the potential energy savings of common air and dirt removal technologies in hot and chilled water systems. All values represent theoretical maximums. The actual values will vary depending on system conditions.

Technology	Hot Water System	Chilled Water System
Inline Air Separator	4.8%	1.9%
Inline Dirt Separator	5.6%	5.6%
Combined Air/Dirt Separator	9.0%	7.2%
Vacuum Deaerator	13.0%	13.0%

Flamco calculation tool for energy savings

This table highlights the limitations of using only inline separation on chilled water systems. In these systems, a large portion of the air is dissolved within the circulating fluid, and therefore cannot be removed by conventional means. For these systems, vacuum deaeration offers significant improvements for system efficiency while also mitigating corrosion.

Corrosion in Hydronic Systems

System Corrosion is a leading factor affecting the overall system health and lifespan of hydronic systems. Corrosion occurs when oxygen in the water reacts with system metals, weakening them and typically forming a metal oxide. The prevention and management of system corrosion should be a top priority throughout a building's lifecycle.

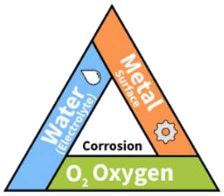
System corrosion also plays a large role in reducing system efficiency. When uncontrolled, corrosion creates layers of deposits along the walls of pipes, heat exchangers and other system components (similar to plaque build-up in arteries). This build-up reduces heat transfer between the system fluid and other surfaces, significantly affecting the performance of pumps, boilers and chillers.

The Corrosion Equation

System corrosion can be summarized by the following equation:

Water + Heat + Metal + Oxygen = Corrosion

But what role does each element play in the system?



The Corrosion Triangle

Element	Role in Hydronic System
Water	System fluid used to circulate heat around the hydronic system.
Heat	The energy circulated throughout the hydronic system.
Metal	Steel, brass, copper, iron, etc. Piping and components are the infrastructure in hydronic systems.
Oxygen	Transfers heat around the system (poorly).

Can something be removed to avoid corrosion?

Solving The Corrosion Equation

One solution that might be considered, is to reduce the amount of metal in the system (less metal, less corrosion, right?). Unfortunately, not only does this not reduce corrosion, but it also causes rapid corrosion of any remaining metal components. The oxygen levels in the system remain the same, only now there is less corrodible material.

The only reasonable solution to avoid corrosion in hydronic systems remains the removal of oxygen. Afterall, if there is no oxygen, there is no corrosion. Without oxygen all the common forms of corrosion will not occur. However, some microbial influenced corrosion (MIC) may still occur in the absence of oxygen. Thankfully this is a much less frequent problem and can be easily overcome.

It is already well understood that modern inline separators are optimized to remove free and entrained air. However, these technologies are unable to removed dissolved air, this requires a bit more thought and a quick lesson on physics.

Removing Dissolved Air

As noted previously, modern inline separators, regardless of technological strategy, are effective at removing both free and entrained air. But what can be done to address the challenge of dissolved air in hydronic fluid?

To understand how to remove dissolved air from hydronic systems, it is important to understand what conditions promote its existence.

Henry’s Law states that dissolved air is released from water when:

» Water is heated
» Water pressure is reduced

When applying Henry’s Law to system design, it is likely to have large amounts of dissolved air exists in chilled water and high-rise systems. See Figure 1.

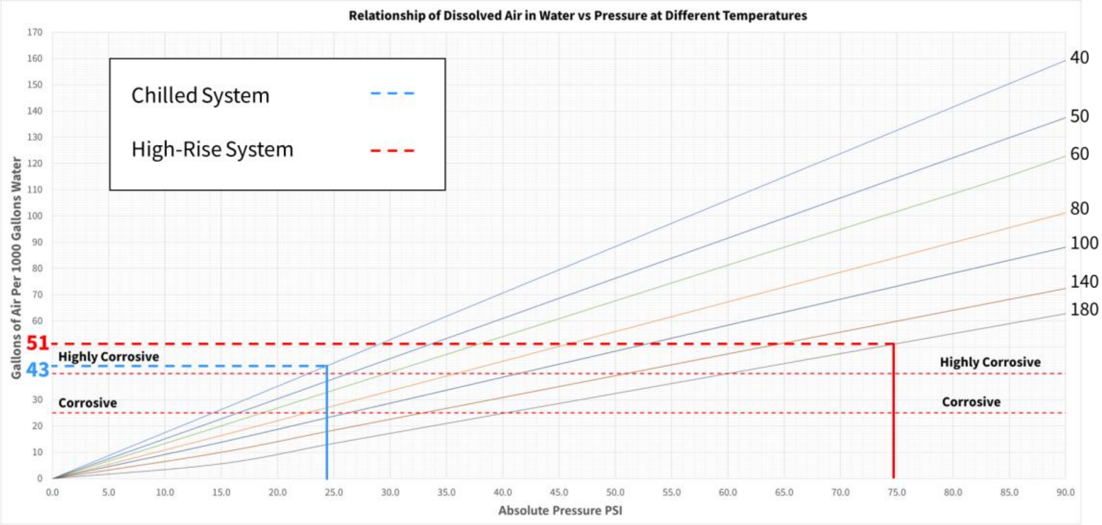


Figure 1 – Henry's law (amount of dissolved air in water at different temperatures and pressures)

Figure 1 shows a linear relationship between pressure and the amount of dissolved air. When the pressure is reduced, the amount of dissolved air decreases. This is the key to removing dissolved air from hydronic systems.

Air Removal Strategies for Modern Hydronic Systems

Several options exist for the removal of free air, entrained air, and dissolved air in both hot and chilled water applications. Some strategies such as inline separation are considered "passive" while newer technologies like vacuum deaeration are considered "active". In the following section, these strategies will be discussed in more detail.

Inline Separation – This is the universally accepted standard for air removal within hydronic systems. Air only, or combination air and dirt separators, often meet design specification requirements. These are "passive" devices that remove air without user inputs or special controls. They are effective at removing free air, and more modern designs can remove smaller microbubbles entrained in the system fluid.

As Henry's Law indicates, by strategically locating the separator at the point of lowest pressure and highest temperature, the air removing potential is maximized.

Atmospheric Deaerator - Atmospheric deaeration, an "active" deaeration strategy, is an extended functionality of pump controlled "expansion automats" (commonly used in Europe). Atmospheric deaeration is a process in which the pressurized system fluid is cyclically fed into an atmospherically pressured tank (see figure 2). When the system fluid enters the tank, its pressure drops to 0 PSI. Due to this reduction in pressure, dissolved gases are released (Henry's Law). By locating an automatic air vent at the top of the tank, these gases can be vented to atmosphere. Once the fluid has been deaerated it is returned to the system via a pump (see figure 3). This process can be set to run continuously or intermittently as required to meet system demands.

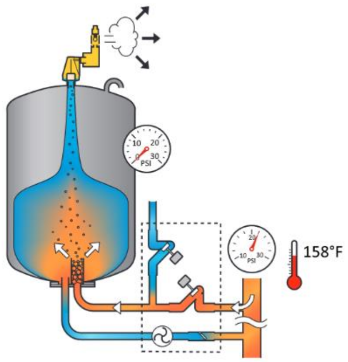


Figure 2

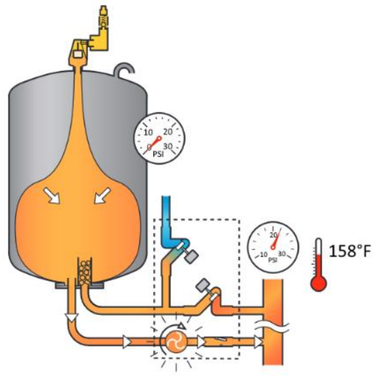


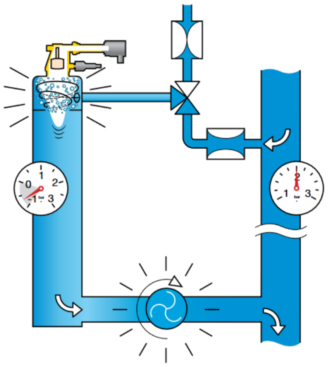
Figure 3

Vacuum Deaerator - Vacuum Deaerators, also “active” deaeration, take atmospheric degassing to the next level. Utilizing a series of controls and pumps, vacuum deaerators subject the system fluid to negative pressures. This further increases the amount of dissolved air that can be removed from the system. Due to the effectiveness of these deaeration appliances, vacuum deaerating can bring dissolved air levels down to approximately 8 ml/l (0.008%) with the small amount of remaining oxygen being removed by minimal corrosion in the system.

Vacuum deaerating can be simplified down to a 2-step process as demonstrated below.

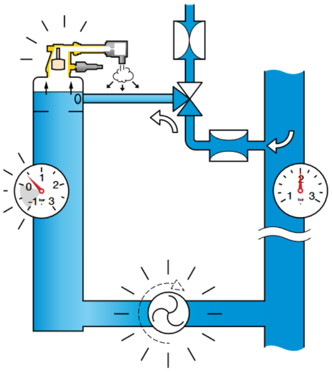
Step 1 – Creating a vacuum

A sample of water is taken from the system and placed inside a cylinder. Pumps work on the fluid and a vacuum is created within the cylinder. The reduction in pressure causes dissolved gases to be released from the fluid which collects above the water line.



Step 2 – Deaeration

Pressure is slowly returned to the cylinder allowing released gases to vent via an automatic air vent.



Not all active vacuum deaerators work in this way, but the concept remains the same; take a sample of water, subject it to a vacuum, release gases and repeat.

Conclusion

There is no one solution to optimize hydronic HVAC systems. Each system has its own unique challenges that must be overcome. Design temperatures and pressures determine the impact of air in a system. It is important to match suitable air removal technologies and products to the specific system demands.

While inline or “passive” separation is effective at removing free air and microbubbles under the right conditions, its effectiveness is reduced in chilled water and high-pressure applications where much of the air is dissolved in the water.

Dissolved air is incredibly corrosive, often resulting in the premature failure of wetted systems and components. These financial consequences are easy to measure. However, many operators overlook the financial impact due to reduced heat transfer and increased energy consumption over the building’s lifespan.

Fueled by global trends of urbanization and digitalization, high-rise buildings and mission critical chilled water application demand continues to grow. These applications are more suited for “active” air removal solutions such as Vacuum Deaeration.

Vacuum deaeration has been implemented globally for over 20 years. As technical standards are updated and new building requirements develop, the message is clear. Sometimes good isn’t good enough. For these systems, Vacuum Deaeration is taking air removal to the next level.

aalberts hydronic flow control

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