Problems caused by air in hydronic systems can be serious and unpleasant for users and professionals dealing with the system. If these problems are not analysed in depth they can often lead to solutions that do not work in the long term. To begin with, it is very important to understand the problems that air in the system can cause.

1. Noise in the pipes and terminals
2. Insufficient flow rates or total blockages of circulation
3. Insufficient heat exchange between the emission terminals and the room
4. Corrosion of the system due to the presence of oxygen in contact with ferrous materials
5. Cavitation in the pumps and valves

1) Noise in the pipes and terminals
A basic aspect of air-conditioning or heating systems to be kept under control is noise. The air contained in the system causes noise in two ways:
   a) Noise in the pipes due to the presence of air bubbles. This is much more evident when starting the system, when the medium starts to flow through the pipes.
   b) Noise in the valves related to the micro-bubbles dissolved in the water which, while passing through the regulating parts, are subject to a sudden pressure reduction which causes a phenomenon called cavitation.
2) **Insufficient flow rates or total blockages of circulation**

In air-conditioning or heating systems the heating medium is usually moved by special "circulators". These mechanical parts transfer mechanical energy to an incompressible medium like water. A mixture of air and water is no longer incompressible and consequently the energy transfer is no longer efficient. In addition, circulation can be partially blocked by air bubbles at certain points of the system. This is particularly serious for radiant panel systems.

3) **Insufficient heat exchange between the emission terminals**

The thermal conductivity of air is significantly lower than that of water. When air gathers in the highest points of the radiators or exchange batteries, the quantity of heat transferred to the room reduces considerably. Lower output from the heat emitters can cause serious thermal imbalances and therefore insufficient comfort levels as well as higher running costs.

4) **Corrosion of the system due to the presence of oxygen in contact with ferrous materials**

Corrosion can be of two types: general corrosion and spot corrosion. Air contains around 23% oxygen which, in contact with ferrous materials, causes general corrosion of these according to the following chemical reaction:

\[
\begin{align*}
O_2 + 2Fe & \rightarrow 2Fe(OH)_2 \\
& \text{OXYGEN} \quad \text{IRON IONS} \quad \text{WATER} \quad \text{FERROUS HYDROXIDE}
\end{align*}
\]

\[
3Fe(OH)_2 \rightarrow Fe_3O_4 + H_2 + 2H_2O
\]

\[
& \text{FERROUS HYDROXIDE} \quad \text{MAGNETITE} \quad \text{HYDROGEN GAS} \quad \text{WATER}
\]

**General corrosion**

General corrosion causes the formation of magnetite $Fe_3O_4$, which occurs within the system in the form of a dark grey sludge (figure below).

**Spot corrosion**

If there continues to be oxygen in the system, the magnetite continues its chemical reaction and is transformed into haematite $Fe_2O_3$, which causes spot corrosion inside the system.
5) Cavitation in the pumps or valves
Cavitation is a physical phenomenon involving the formation of vapour zones inside a medium, which can implode producing a characteristic noise. It happens due to a local reduction in pressure to the vapour pressure of the liquid itself, which thus undergoes a change of phase, from liquid to gas, forming bubbles (cavities) containing vapour. The process dynamic is very similar to that of boiling.

**Boiling:** because of the increase in temperature, the vapour pressure rises to above the pressure of the liquid, thus creating a bubble that is mechanically stable because it is full of vapour at the same pressure as the surrounding liquid.

**Cavitation:** the pressure of the liquid falls suddenly while the temperature and vapour pressure remain constant.

This is why cavitation “bubbles” resist only until they leave the hydrostatic low pressure area: as soon as they return to a settled zone of the medium, the vapour pressure is not sufficient to counter the hydrostatic pressure and the cavitation bubble implodes immediately. The local fall in pressure occurs at the points where there is a strong increase in the speed of the medium:

1) In the pump impellers
2) In the water orifices of the regulating valves

**PROVENANCE OF THE AIR IN COOLING OR HEATING SYSTEMS**

The air in cooling or heating systems using water can have various sources:

1) Air not expelled while the system is being filled;
2) Air dissolved in the cold water used to refill the system;
3) Air that gets in while the system is running.

1) Air not expelled while the system is being filled
Before being put into operation, all hydronic systems are obviously full of air. Inaccurate design or installation of the system which “provides” for particular paths for the lines can encourage air to be entrapped during the filling phase. In particular, air tends to collect:
- in the top part of the heat emitters (fig. A)
- in pipe sections that must go round an obstacle (fig. B)
- in long horizontal pipe sections that then turn downwards
- in the top part of the risers.
2) Air dissolved in the cold water used to refill the system
   It is released only when the water in the system is heated. This quantity of air is by no means negligible.
   Example:
   - A 1000 l system (more or less a 100,000 kcal/h system) at a constant pressure of 2 bar and with a water temperature of 20°C, has around 35 litres of dissolved air in each m³ of water.
   - When heating the water from 20°C to 80°C, the number of litres of dissolved air in the water falls from 35 to 17; this means that 18 litres of air are transformed into bubbles and micro-bubbles.

3) Air that gets in while the system is running
   Lastly, this is air that can get in through the free area of an open vessel, or can filter through the vent systems, gaskets and fittings if the system works under vacuum. This latter situation occurs when the sum of the static pressure of the system and the dynamic vacuum from the pump is negative. This situation can happen, especially in the top parts of the system, that is to say where the static pressure is lower.

<table>
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<tr>
<th>SYSTEMS USED TO REMOVE AIR</th>
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<td>In general, there are two types of devices that can be used to remove air.</td>
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<th>REMOVING AIR BUBBLES AND POCKETS</th>
<th>REMOVING MICRO-BUBBLES</th>
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<td>Manual air vents</td>
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1) Manual devices to remove air bubbles/pockets
   These are the simplest valves for removing air contained in the top part of the radiator: when the valve is opened manually, the air comes out of the small opening at the side.

   They must always be installed in each terminal to vent the air that collects naturally in the top part, while filling the system and during normal operation for collecting air micro-bubbles in this specific zone.
2) Automatic devices to remove air bubbles/pockets.

These are valves with a float that controls an automatic venting mechanism. When a sufficient quantity of air collects inside the chamber containing the float, the air replaces the water and lowers the float point causing the automatic valve to open and the air to be vented. After a certain quantity of air has been expelled, water fills the chamber again and pushes the float upwards thereby closing the air vent.

The positioning of these devices must follow certain very specific rules to ensure the device works efficiently. They must be put at the top of the risers and at all points where air can stagnate.

They can also be used on radiators to make it as easy as possible to fill the system.

3) Air separator to remove micro-bubbles of air dissolved in water

Correct installation of air separators prevents problems caused by micro-bubbles: by reducing the amount of air in the water, they make it capable of absorbing, and then removing, the bubbles hiding in the critical zones of the systems.

These devices have a much larger flow section than an air vent: this structure enables a net reduction in the speed of the medium, which helps the air bubbles to rise to the top.

**Separation of micro-bubbles**

Air in the form of micro-bubbles is much harder to capture than genuine air bubbles or pockets. This is why a mesh is combined with the air separators which, by creating a swirling motion, helps the microbubbles to be released and then to merge into larger bubbles, that can be removed through the air vent.
This process is called "coalescence" and is extremely important for removing and keeping the quantity of air in hydronic systems to a minimum. As the micro-bubbles unite they form ever larger bubbles until they reach a sufficient volume for the float forces to be greater than the adhesion forces that hold them to the coalescence surface. The bubbles then rise along the coalescence surface to the chamber above the main flow of the medium, where they are collected and expelled using an automatic air vent with float.

The surface along which the micro-bubbles merge together is called the "coalescence media". Some air separators use an internal media with metal mesh while others use special polymers. In both cases, the coalescence media must have a large contact surface, making it easy for the bubbles to rise, and must produce low head losses.

The concept of coalescence inside an air separator is shown in the image below.

**Water-glycol systems**

It is also good to use air separators in systems with a water-glycol antifreeze mixture, for example: in refrigeration systems and systems with solar panels, heat pumps, and panels for anti-freeze and anti-snow ramps. Water-glycol mixtures are very viscous and are therefore very good for entrapping air bubbles and micro-bubbles, and preventing their removal.

**Installation**

Air separators must be installed in the part of the system where the solubility of gases in water is as low as possible: this is why in heating systems they should be fitted near the heat generator outlet, while in cooling systems they should be placed before the chiller inlet.