

Air in Hydronic Systems



Typical CHW system layout with air separator and air vents

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There is considerable confusion about the effects of air present in HVAC water systems. Many solutions for air removal are available, each claimed to be better than the other. Each solution has its own importance and relevance, depending on the application.

Effects of Air Presence

The presence of air in a hydronic system can create several problems, like:

- Corrosion of system components due to oxidation of metals
- Inefficient heat transfer in heat exchangers or coils
- Cavitation of pump impellers
- Inadequate flow due to mixture of water and air
- Complete loss of flow due to entrapped air
- Improper functioning of control and balancing valves
- Noise in piping, fittings and pumps

Forms of Air Presence

There are basically three ways in which

air can exist in a water system:

- Air entrapped at high points
- Air in the form of air bubbles (entrained)
- Air dissolved in water

Entrapped air

A hydronic system is full of air before it is filled with water; the incoming water pushes the air out. Air being lighter migrates towards the high points and some air may get entrapped (see Figure 1) due to improper piping system layout design. Such high points could be at the top of the risers, stationary pockets near heat-exchangers or at locations where the horizontal piping first rises and then bends downwards to clear some obstruction like another pipe or structure element. Stationary air pockets may also form due to merging of smaller bubbles released due to change in pressure, temperature or low flow velocity.

Entrained air

Air bubbles may form part of water stream for many reasons, like release of

dissolved air due to change in temperature and/or pressure, improper conditions at pump suction, etc. These bubbles may keep moving with the water stream depending upon water velocity. In downward flow, air bubbles will tend to rise and, therefore, the water velocity should be sufficient, so as not to let the bubbles rise, but to carry them along. A minimum flow velocity of 0.7 meters per second is recommended to entrain air bubbles in the pipes with downward flow.

Dissolved air

Water has a natural affinity for air; the absorption of air by water is governed by Henry's law, which states that at any fixed temperature, the solubility of a gas in a liquid is directly proportional to the absolute pressure. As per the law, solubility

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Amrish Chopra has 35 years of experience in the field of air conditioning projects, related controls and hydronic components.

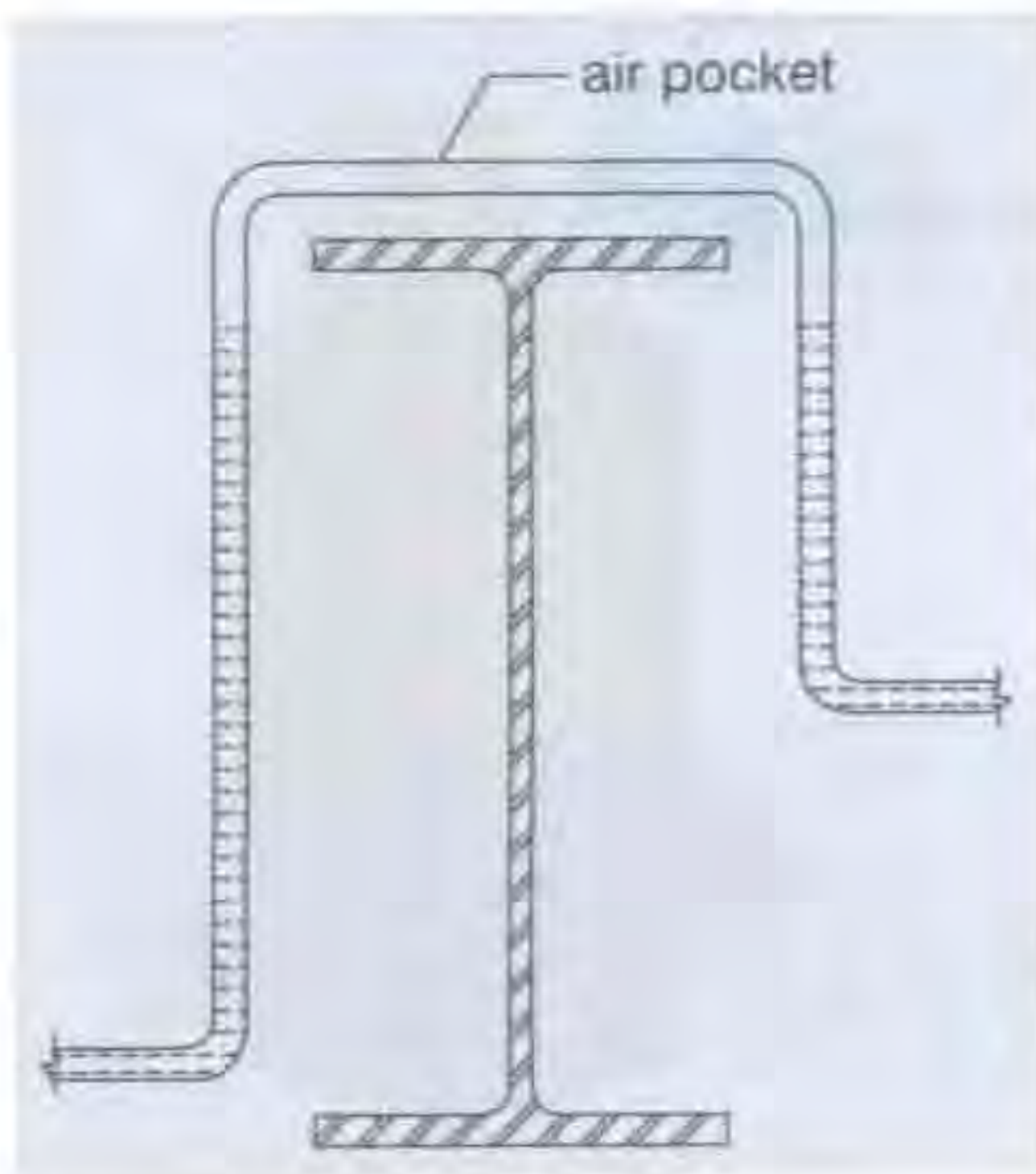


Figure 1: Air pocket

of a gas in a liquid also varies with temperature and for most HVAC applications, with water operating temperatures between 0°C and 95°C, it is inversely proportional.

In other words, it could be stated that solubility of air in water varies directly with pressure and inversely with temperature.

Air Removal Strategy

In nature, water is always in contact with air; it remains in contact with air till the whole system is filled and all the free air is expelled and, therefore, water after the initial filling of a system could be assumed to be saturated with air. The solubility of oxygen in water is higher than that of nitrogen; air dissolved in water contains approximately 35.6% of oxygen compared to 21% in air. Oxygen present in the water immediately starts reacting with metals leading to corrosion, making it imperative to remove air as fast and efficiently as possible.

It is best to install the air removal device at a location, where the pressure is lowest and the temperature highest, to take advantage of minimum solubility under those conditions.

It is important to keep the water in such unsaturated state, so that even if there is a change in temperature and/or pressure, it should not release any air, and should also be able to dissolve free air present anywhere in the system and transport it to the air removal device.

Further ingress of air has also to be minimized; poorly designed hydronic systems could keep replenishing the air and oxygen. Change in operating temperature of water results in change of water volume necessitating an expansion tank. In some systems, an open type expansion tank is used; this is installed at the highest point. This allows continuous interface between air and water, resulting in substantial presence of air and related problems. The optimum solution is to provide a closed expansion tank with a rubber bladder to prevent air and water interface. The pressure of gas charged in the expansion tank must ensure positive pressure even at the highest operating point to prevent ingress of air either through float air-vent or otherwise.

Deaeration Methods and Devices

Air could be present in the system before filling; it could enter after filling, as in practice it is very difficult to design a perfectly closed system to prevent any ingress of air. It could be present in the form of air pockets, bubbles entrained in the water, dissolved in the water; therefore, air removal devices play an important role by continuously scavenging the air out of the system water.

Air-vent

Manual air-vents are small valves, which can be operated by a small handle or a key. When opened,

air is forced up by the system pressure through the valve seat and is released to atmosphere. As these air-vents have to be operated manually, they are mainly useful during the initial commissioning only or have to be monitored on a regular basis.

An automatic air-vent is generally float type and provides instantaneous and automatic response to the presence of an air pocket. It contains an air chamber, a float assembly and an air valve (see Figures 2a and 2b). As air accumulates within the chamber, the float descends opening the valve connected to it through a linkage. As the air is released, water rises into the chamber and lifts the float to close the valve. Automatic air-vent may be equipped with a cap to protect the valve mechanism from debris. This cap must be kept loosened, not fully closed, to enable the vent to operate properly.

Manual or automatic air-vents should be installed at all locations where there is a likelihood of entrapment of air, like the top of all risers, inlet and outlet of heat-exchangers and tanks and where there is a change in piping elevation.

Float type air-vents keep closed only till the time the chamber is full of water; if for any reason the water level drops these will allow air intake. Therefore, it is important to keep the system pressurized at all times, through proper location and selection of pressurized expansion tank.

Air purger

Air purger or air scoop (see Figure 3) is a device to separate large sized bubbles from water. This device is installed in a horizontal pipe line and the vanes forming part of the main body deflect the air bubbles to the collection chamber at the top, to be released through an auto air-vent. Water velocity has to be kept below 1.5m/sec. to help separation of air bubbles due to buoyancy. Air purger is unable to separate micro-bubbles.

Air separation by fluid velocity reduction

This process of air separation is explained by Stokes' law, which states that separation occurs when the buoyancy of the air particle exceeds the gravitational force and the frictional force created by the movement of water.

Centrifugal air separator

In a centrifugal air separator (see Figure 4), water is made to enter at the periphery of the shell to create a whirlpool. The centrifugal force pushes the denser water to the periphery with air being separated out at the centre. Low water velocity in the shell facilitates the rise of air bubbles to the top where those are removed

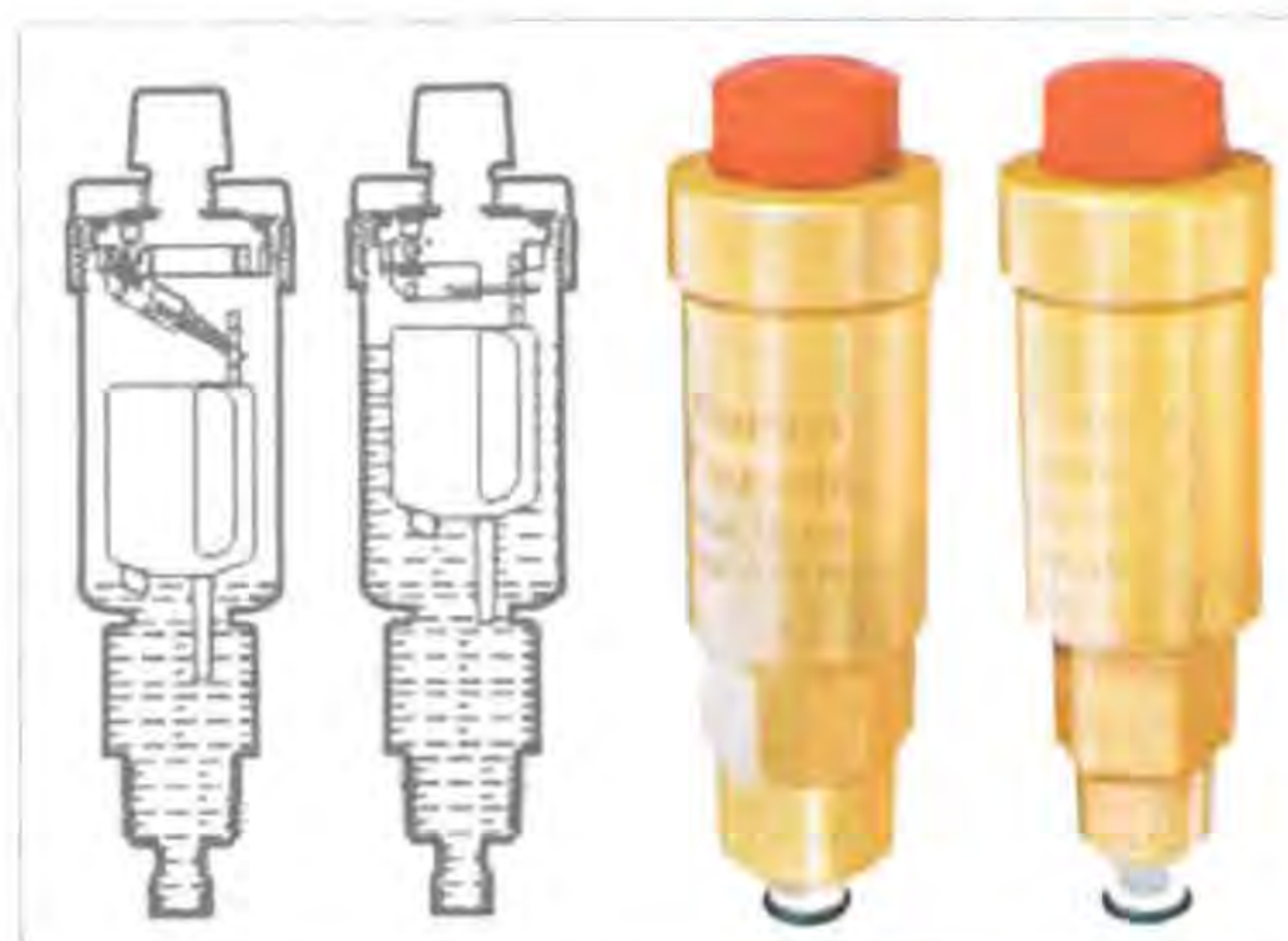


Figure 2a: Float air-vent



Figure 2b: Large capacity air-vent

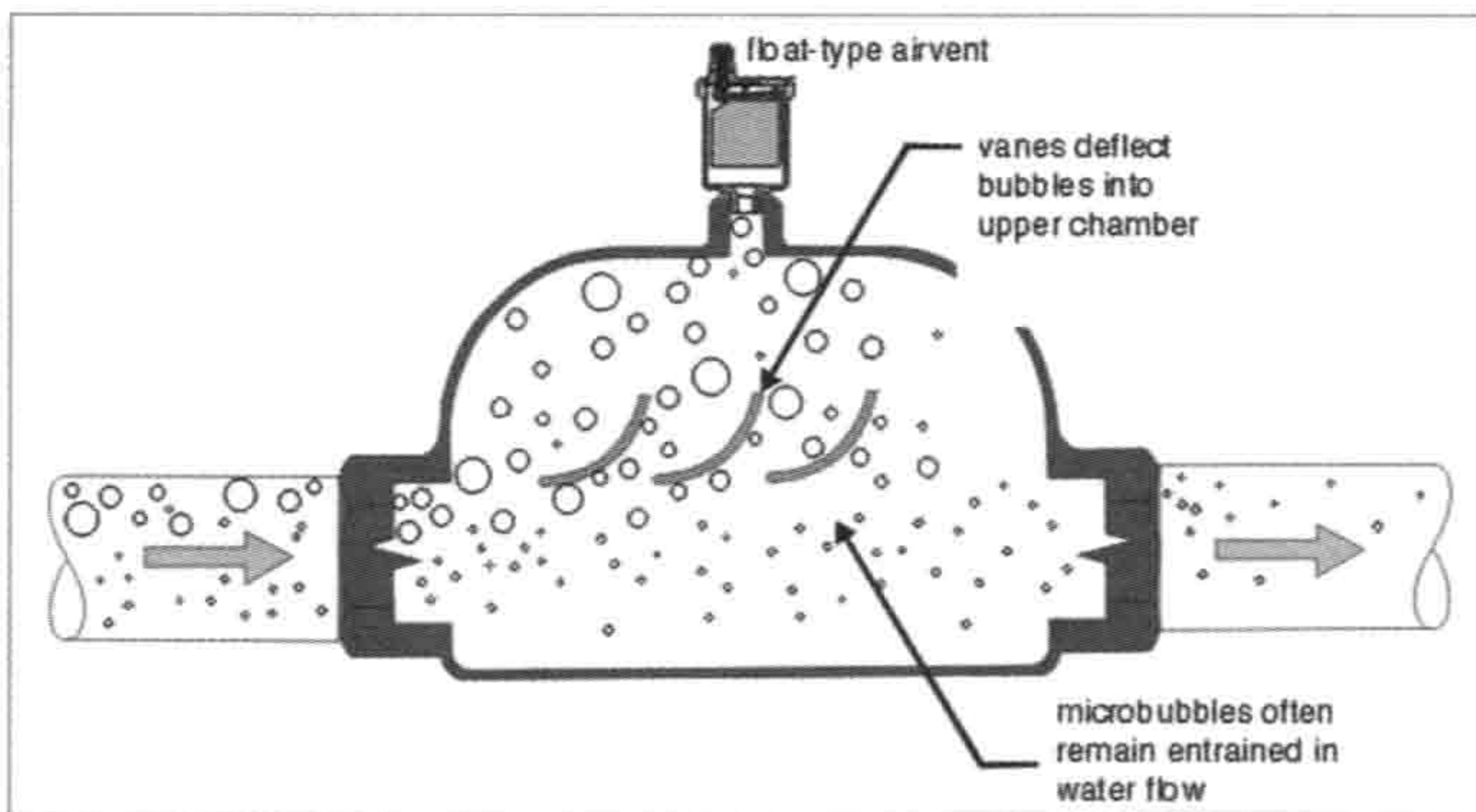


Figure 3: Air purger

through a high capacity float air-vent. A centrifugal air separator is capable of removing all the well-formed bubbles and most of the micro-bubbles from the system.

Coalescence type air separator

Individually, micro-bubbles are very small and cannot be seen, but collectively they could make the water appear milky. They have very low buoyancy and can easily be entrained by water, even moving at very low velocity, and are thus difficult to separate. However, they have a tendency to stick to a surface and this is known as coalescence effect. The coalescence type air separator (see Figure 5) takes advantage of this effect and is filled with a media, called coalescence media, to provide maximum surface contact to the water flow.

The larger air bubbles get separated due to low water velocity in the separator, where as micro-bubbles cling to the media and join together to form larger bubbles which easily separate from the surface, and rise to the top to be vented out through a float air-vent. These air separators are more efficient at removing micro-bubbles but have higher pressure drop resulting in higher pump power consumption.

For maximum air separation efficiency, an air separator should be installed where the system pressure is minimum, closer to the pump suction.

Air separation by pressure reduction

The solubility of air in water decreases with pressure; whenever pressure of water is reduced, air tends to bubble out and then can easily be removed.

Hydronic systems generally operate at pressures higher than atmospheric pressure, and water contains a much higher percentage of dissolved air. When water is released from the pressurized system to a membrane tank at atmospheric pressure the excess dissolved

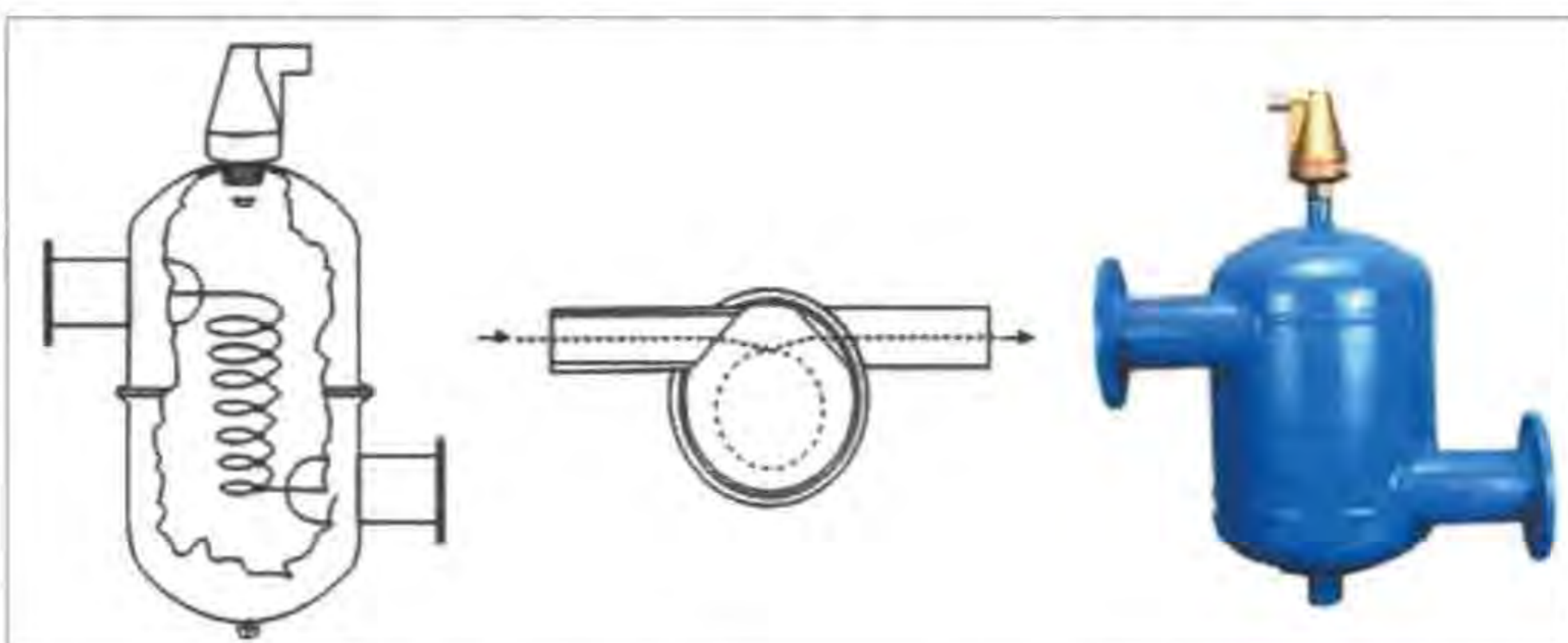


Figure 4: Centrifugal air-separator

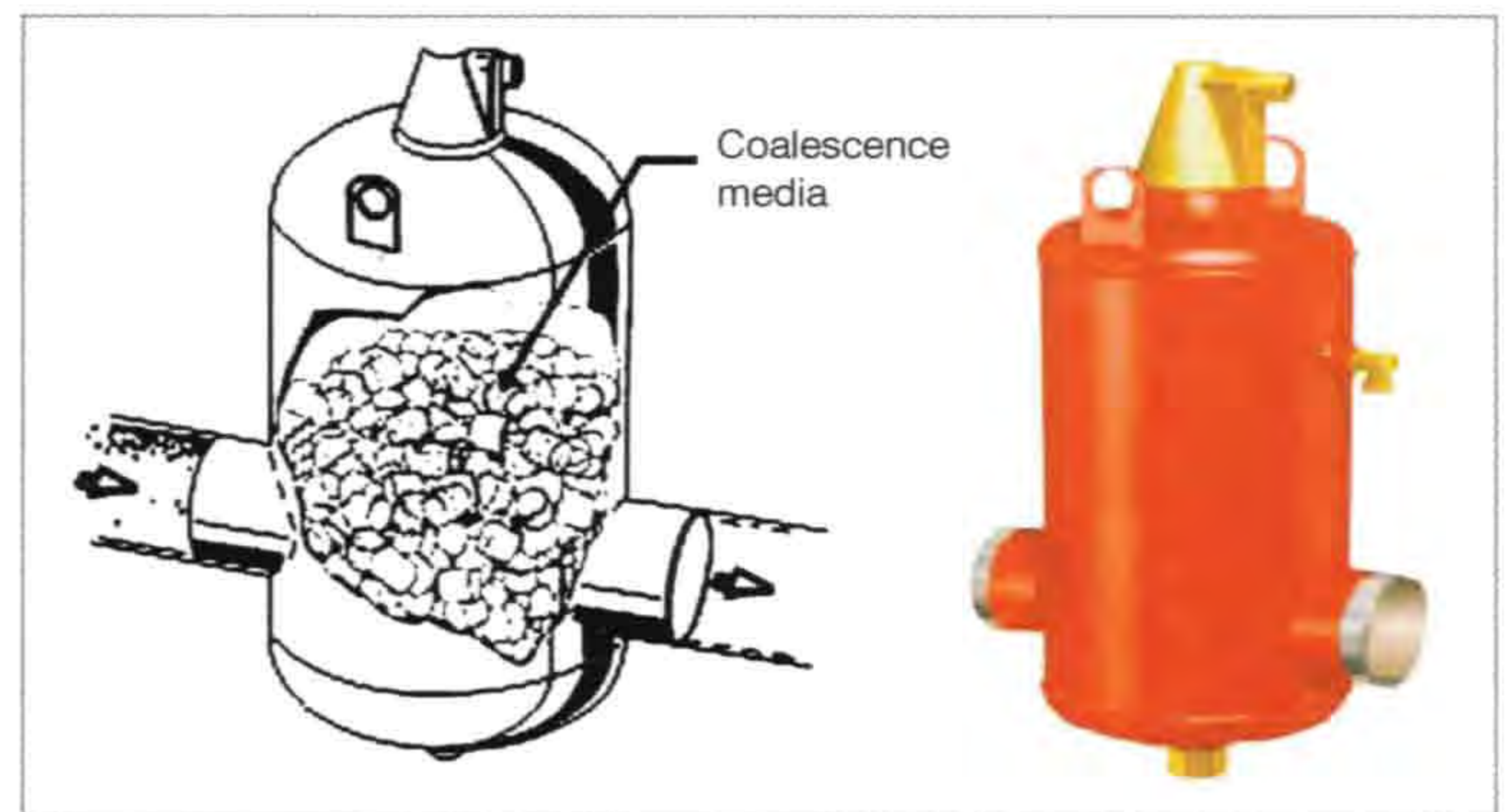


Figure 5: Coalescence air-separator

air bubbles out, rises to the top and is expelled out through a float air-vent. This water then can be pumped back to the system, where due to increase in pressure it becomes unsaturated.

A vacuum tube degasser is used to reduce the pressure of water below atmosphere to make it more effective in removal of all type of bubbles and even a part of dissolved air (see Figure 6).

It is more suitable for applications using high temperature water, because it can prevent release of air even at the interface between high temperature elements or tubes and water.

Optimum Solution

The decision about which device to be used can not be taken in isolation; it has to take into account the type and use of the system. A device may be best in isolation, but not the best solution for a system. System designers have to be careful, and overkill can result in higher initial as well as running costs.

Table 1 gives an idea about solubility of air in water.

Table 1: Solubility of air by volume (%)

Temp. (°C) Pressure (atm.)	5	10	25	50
1	3	2.2	<2	<2
3	8	7	5	3.5
6	16	13	10	7.5

At 25°C and ambient pressure, water contains less than 2% of air by volume, but its capacity to absorb air increases substantially with increase in pressure and/or reduction in temperature. At 10°C and 6 atm. it can absorb 13% of air by volume. Therefore, the important system design considerations should be to prevent any contact between water and air once the system is pressurized and becomes operational, and to keep scavenging the air out of the system continuously to keep water in unsaturated state. It can be achieved by:

- Removing interface between water and air by using a membrane type expansion tank
- Proper pressurization of system to prevent ingress of air
- Use of sufficient number of float air-vents to prevent entrapment of air
- Use of a deaerator

In chilled water systems, deaeration should be carried out at the return header before the pump suction. At this point, the temperature is highest and the pressure is lowest, and therefore, the solubility of air in water is at its lowest making it easiest to

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Figure 6: Vacuum tube degasser

remove air. At any other point in the system, solubility being higher, water will tend to absorb air, if available, and bring it back to the deaerator. In a well designed and maintained system, with little or no air ingress, after a while, a little or no air at all may come out of the deaerator giving an impression that it has stopped working. In fact, the water may be already unsaturated, making it impossible for the deaerator to remove more air.

Hot water systems require more careful handling as the lowest pressure is at

the pump suction, but the highest temperature is inside the boiler, at interfaces between high temperature elements and tubes transferring heat, and water. Such systems require higher level of deaeration to prevent separation of air at high temperature.

Where, When and What?

It is often difficult for a young application engineer to decide where and when to use which device. Here is some help.

An automatic float vent should be used at all high points in the system like the top of all risers, top end connection of all heat exchangers like cooling coils and long horizontal pipe runs. Auto air-vents are generally available in different air release capacities; it is better to use a larger number of smaller capacity air-vents at more number of locations, than a few large capacity air-vents. Large capacity air-vents (see Figure 2b) are most suitable for equipment like air separators, or where large amounts of air release are expected. Smaller capacity auto air-vents may slow down the initial system filling up and may be supplemented with manual air-vents. Manual air vents should be shut off once the system becomes operational.

For chilled water application in low rise, say less than 40m height, buildings with pressurized expansion tanks, centrifugal air separator is most suitable because of low initial cost and low pressure drop. It does not make much sense to install an air separator in a system with an open expansion tank, as whatever air is removed by the air separator gets replenished in the open tank. The air separator should be installed in the pump suction header.

In high rise buildings with large water volume, it makes more sense to use unpressurized expansion tanks and deaerate the water by reducing its pressure, by releasing some water from the pressurized system to the unpressurized tank.

For systems with high temperatures, say above 70°C, coalescence air separator may be a better option for its better micro-bubble removal efficiency, with vacuum degasser being a choice for even higher temperature systems. An air scoop or purger is often used at the outlet of a boiler to capture the air released due to high temperature.

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