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# Deaeration and dirt separation to control system water quality

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**Air will always be present in water systems** used in buildings. However, without the proper control and removal of the majority of the air, the system is likely to be inefficient and, in severe cases, may fail to operate.

Excessive trapped air can make a system difficult and expensive to commission and in operation leads to noise and system damage, particularly where there are significant changes in pressure (pumps and valves). A corrosion inhibitor will slow down corrosion of metals and alloys but air (with its incumbent oxygen) will cause some corrosion and the resultant "sludge" (together with any other debris in the pipework system) will reduce the performance of heat transfer surfaces and can impede the water flow.

This article will consider the need for deaeration and dirt separation and provide examples of equipment that can be used to remove dirt and air from piped water systems.

## Air in systems

Air will be present in piped water systems both as a result of incomplete purging after the system is filled and due to the release of dissolved air. The amount of air dissolved in the water will depend on the temperature and pressure – this may be determined and explained using Henry's Law which states that at a particular temperature, the amount of gas that will dissolve in a liquid is proportional to the partial pressure of that gas over the liquid (see Example 1). Hence the graphs as shown in Figure 1 [2] can be derived that indicate the volume of air that can be dissolved in water at different temperatures and pressures. The graph clearly shows that the maximum air is dissolved in water at higher pressures and lower temperatures.

For example, a heating system open to atmospheric pressure that is initially full of water at 10°C potentially has about 22 litres air dissolved for every cubic metre of water (22 $l/m^3$). When the system is heated to 80°C, the volume of dissolved air falls to about 6 $l/m^3$ – this released air (16 $l/m^3$) circulates around the system to create air pockets at high points such as tops of radiators.

Similarly, considering the effect of pressure, for example, at a system temperature of 80°C, for every reduction of 1 bar pressure (equivalent to a pipe rise of 10 m in a building) there is potentially about 10 l air released for every cubic metre of water. Hence, water in pipework higher in a building where the static pressure is lower, will release dissolved air.

Problems that can occur in piped water systems as a result of trapped air include:

- problems with commissioning systems (such as unreliable pressure readings) resulting in increased time and set-up costs
- production of magnetite "sludge" and haematite
- reduced heat transfer from heat emitters because of a reduction in water content and obstructed waterways
- "cavitation" in pumps and valves (see below)
- increased system noise.

These can delay practical completion (and increase the cost of a job) and if the air remains trapped there will be ongoing costs and loss of time in venting the system.

## Cavitation

The principal places where cavitation occurs in piped water systems are pumps or at restrictions such as valves.

When the pump impeller rotates in the water, low static pressure areas are formed as the water velocity increases. As the pressure reduces, there may be a possibility of the water vaporising (if the "net positive suction head" is insufficient) and this is what is normally referred to as cavitation, ie, the forming of cavities through the formation of vapour. But there will also be some release of air (depending on the amount of dissolved air in the water) to form small bubbles of air that may cause "pitting corrosion". When the bubbles later collapse on the discharge side of the pump, they can cause very strong local shockwaves in the fluid, which may be audible and may even damage the blades. A large slug of air can reportedly shatter impellers. The change in pressure across obstructions such as valves and measuring orifices can create similar conditions.

When air is present on pump seals, upon start up the water vaporises leaving the salts present on the seal faces which can cause rapid damage.

**Example 1: How much oxygen from the air will dissolve in 25°C water at atmospheric pressure (1 atm)**

- **Air is principally:**

**Oxygen – $O_2$ 21% with a molar mass of 32 g/mol**

**Nitrogen – $N_2$ 79% with a molar mass of 28 g/mol**

- **Henry's Law Coefficients [1] at a temperature of 25°C:**

**Oxygen – $O_2$ : 756.7 atm/(mol/litre)**

**Nitrogen – $N_2$ : 1600 atm/(mol/litre)**

**Dissolved gas = (gas partial pressure/Henry's coefft) × molar mass**

**By Dalton's Law, the gas partial pressure can be determined from the (pressure × fraction of the gas)**

**Hence dissolved $O_2$ = ([1 × 0.21]/756.7) × 32 = 0.0089 g/litre and as water has a density of about 1000 kg/m³ this is the same as 0.0089 grams oxygen per kilogram water**

## Removal of air from piped water systems

Following a proper design process and using a combination of manual and automatic air vents, the bulk of air can be removed from the piped water system.

However, no matter how well the system is set up there will always be air pockets trapped in the system (that may only be displaced when the system is in operation), as well as dissolved air and microbubbles. Microbubbles in water systems have been measured [3] smaller than 1 µm. When water is being pumped around the system, microbubbles cannot be removed by AAVs as the whole mass of water/air passing under the connecting tee does not allow the air to rise.

Centrifugal separators are small and cheap and rely on relatively low centrifugal forces. They can separate out the larger air bubbles but will not be able to remove microbubbles.

To remove microbubbles from water streams requires specific laminar flow regimes so that they can attach to a "packing" (for an example see Figure 2) and then be removed from the system by buoyancy forces outside of the main water flow. Microbubbles do not readily coalesce and cannot rely on a system that simply assumes that they will combine into larger bubbles. Deaerators need to be large enough to provide a volume where the water is outside of the turbulent water flow and so allow the separation of microbubbles that would otherwise pass through the system and cause problems as previously discussed.

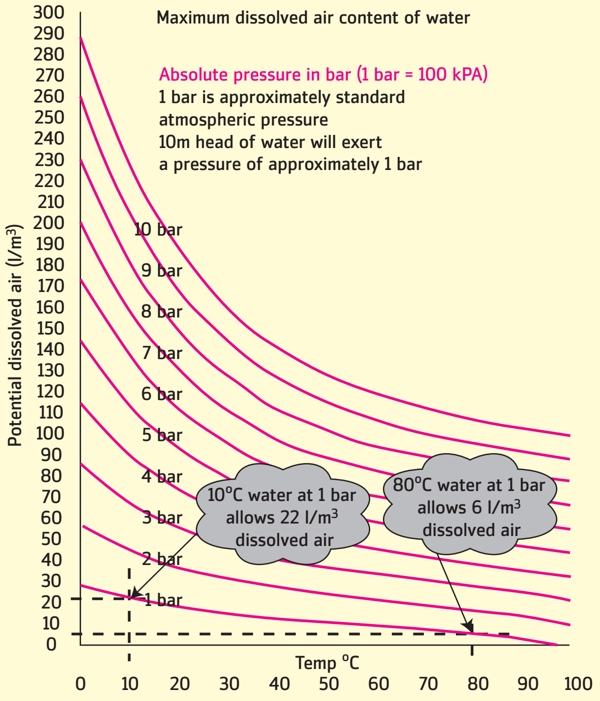

Figure 1 Air dissolved into water

Figure 2 Cutaway of a temperature differential deaerator

The deaerator should always be installed at the hottest point in the system (on a boiler flow or a chiller return). (Chilled beams or ceilings require further consideration to locate the hottest point.) For the deaerator to work properly it must be located where the static pressure is not excessive – manufacturers will advise as to this practical limit.

The deaeration process removes air from the water at the hottest point of the system. As the water circulates, the temperature falls and the water absorbs air pockets. These are then re-released at the heat transfer surface to be subsequently removed by the deaerator. This continues until all air pockets are removed to ensure no more air can come out of solution within the circulating system.

Temperature differential deaerators are virtually maintenance free.

Where the static pressure is too high for the installation of a temperature differential deaerator (Figure 2), sidestream devices – known as pressure differential deaerators – can be used that take a proportion of the flow and reduce its pressure (using a separate vacuum pump). Pressure differential deaerators expose a small volume of water to a vacuum of 0.05 bar absolute, deaerate it and return it to the system. This is repeated until the whole system is fully deaerated. The unit operates automatically and maintains a high level of deaeration throughout the system life. Pressure differential deaerators require annual maintenance and solenoid valve diaphragm replacement each year. They are particularly appropriate for basement located boilers.

## Accumulation of dirt in system

Dirt will enter the system while it is being fabricated (eg, sand, fibres from cloths, swarf from pipe cutting and welding slag). The systems should be properly flushed prior to use (see BSRIA AG 1/2001.1 [4] for details); however, inefficient flushing will leave some of this debris in the pipes. Once in operation there will also be accumulation of scale and particles from corrosion – the dissolved oxygen causing the corrosion. The reaction between iron, water and oxygen will form magnetite and if oxygen is then present, the magnetite is converted to the much more voluminous hematite. (This will also inevitably lead to pitting corrosion at numerous locations throughout the system.)

The build up of sludge and "dirt" in a system will reduce effective operation. Problems will include:

- heat exchangers (eg, boilers and radiators) can become obstructed both impeding the flow of water and reducing the heat transfer
- pump seals and glands will be exposed to the scouring effect of the particulate matter in the water and will wear more quickly
- increased system noise
- strainers becoming blocked causing increased pressure drops hence additional pumping costs or loss of capacity
- low velocity pipework (such as underfloor heating) can accumulate debris so reducing the heat transfer surface.

## Dirt removal from the system

A common method of reducing particulates in piped water systems is to incorporate a filter or a "strainer". There is always a compromise when using strainers – large mesh sizes allow larger particles to pass through and a small mesh will store a larger volume of particulates that can lead to obstruction of the waterway. To prevent problems, strainers require regular maintenance if the system performance is not to suffer. Where there are large amounts of material circulating in the water stream (for example in open systems such as cooling tower circuits and swimming pools) sidestream filtration can be used. However, these filter only a proportion of the circulating water and allow debris to circulate until it is removed on a subsequent circulation (if it has not already settled somewhere else in the system).

Dirt separators (Figure 3) can remove particles down to 0.5 µm (compared with strainers that only remove down to 1600 µm). Manufacturers have reported that during the normal commissioning period, the separator will remove 98% of all circulating material – that can then be "blown down" through the valve at the base of the separator at the end of the commissioning period. It then remains in situ to continue to remove any dirt from the system and since it is a full bore device with large waterways, its water pressure drop is relatively small and with proper maintenance will remain so. Dirt separators only require blowing down (5 to 10 seconds) monthly for the first two to three months, then a quarter-yearly blow down.

Fitting dirt separators in existing systems has reportedly shown impressive reductions in solid matter. An independent test [5] showed that the particulates in an existing system that was simply protected with strainers were reduced from 620 g/m³ (sized 5–10 µm) to less than 1 g/m³ of all particulates larger than 0.45 µm after installation of a dirt separator.

A combined deaerator and dirt separator (Figure 4) can be used to provide both air and dirt separation, reducing the cost and space requirements of separate devices. The largest units available in the UK have a 600 mm nominal bore.

## Conclusion

By using properly installed and maintained air and dirt separators the problems arising from air and system sludge can be almost erased. Hence, the wear on equipment will be reduced and maintenance costs will be smaller. Apart from operational benefits, commissioning and setting up of the systems is likely to be far more consistent. Inhibitors have been widely used to control problems resulting from air in water systems but, by deaeration, the cause is virtually eliminated. ■

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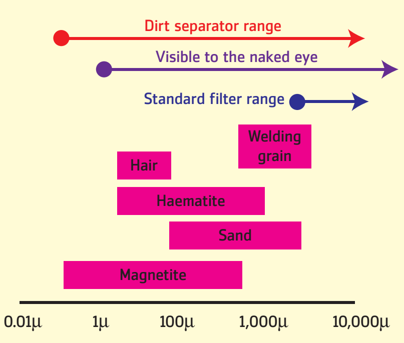

Figure 3 Dirt removal sizes for water systems

Figure 4 Cutaway of combined air and dirt separator

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