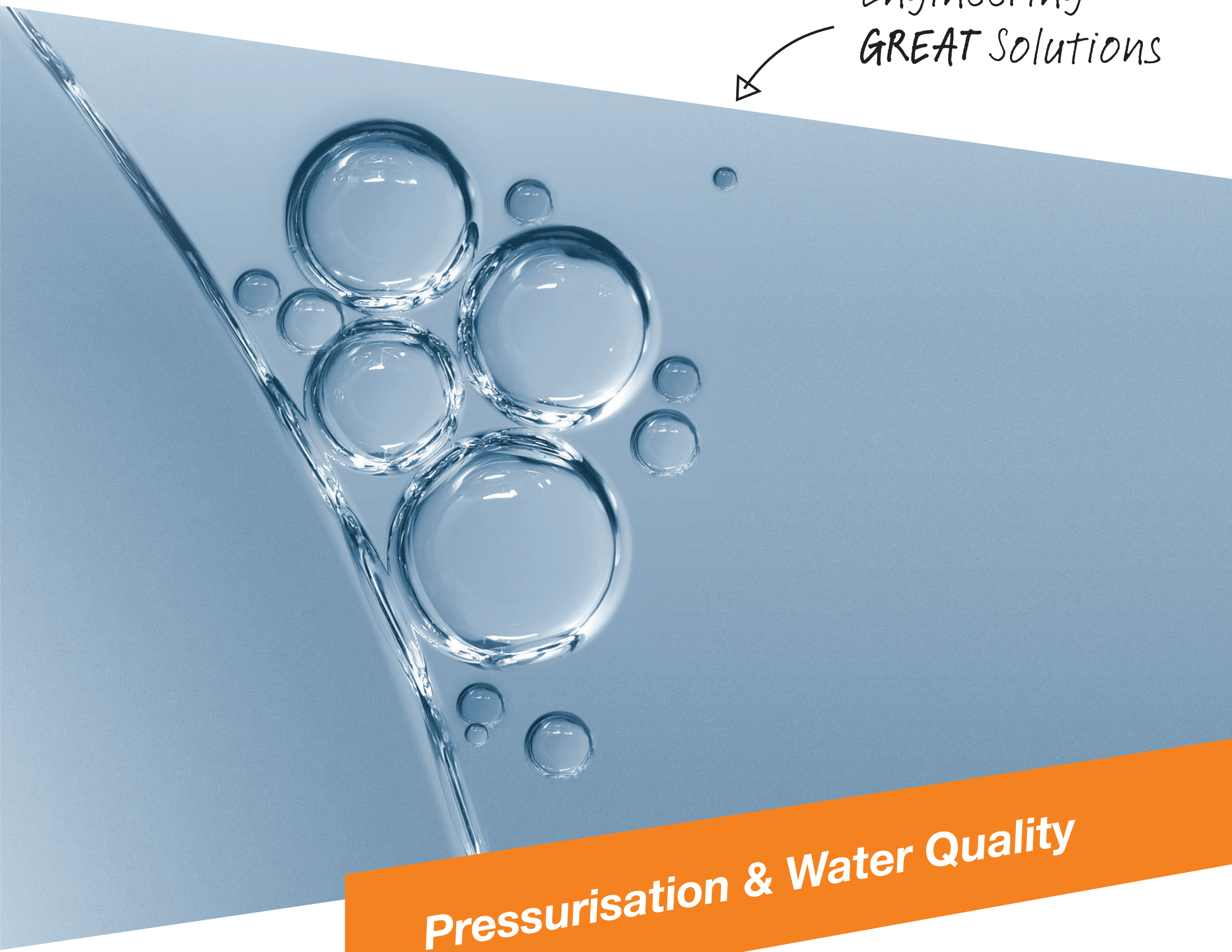
Air:

Problems, Causes, Technology

Hydronic Engineering Handbook

Engineering GREAT Solutions



Pressurisation & Water Quality

IMI Hydronic Engineering

www.imi-hydronic.com

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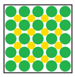
Introduction

About air and gases

Gases can cause a lot of problems in heating and cooling systems – corrosion, dirt, noise, circulation problems and a reduction of the heating performance.

What do we mean by gases in this context and where do they come from?



Air makes up the greatest proportion. But also CO_2, CH_4 and H_2 are often present.

The following is molecularly dissolved in the filling water:
14,3 ml/l N_2 ●
7,8 ml/l O_2 ●

During the first fill of the system, the water absorbs air from the atmosphere. This consists of ca. 78% nitrogen N_2, 21% oxygen O_2 and 1% trace gases. Approximately 22.1 ml/l air and small quantities of carbon dioxide CO_2 enter the systems |1| in dissolved form. Air may also enter the system through commonly used plastic or rubber materials or negative pressure.

Nitrogen N_2 ●
is the main cause of the classic «air problems».

Nitrogen builds up as an inert gas after initial filling of the system and during operation. This is often caused by trapped quantities of residual air that dissolve with increasing pressure. Up to 40 ml/l have been measured in systems. This is three times the natural concentration. This exceeds the solubility in water during the heating-up phase. The consequence – free nitrogen bubbles. It has been proven that they are one of the main causes of the classic «air problems» |1|.

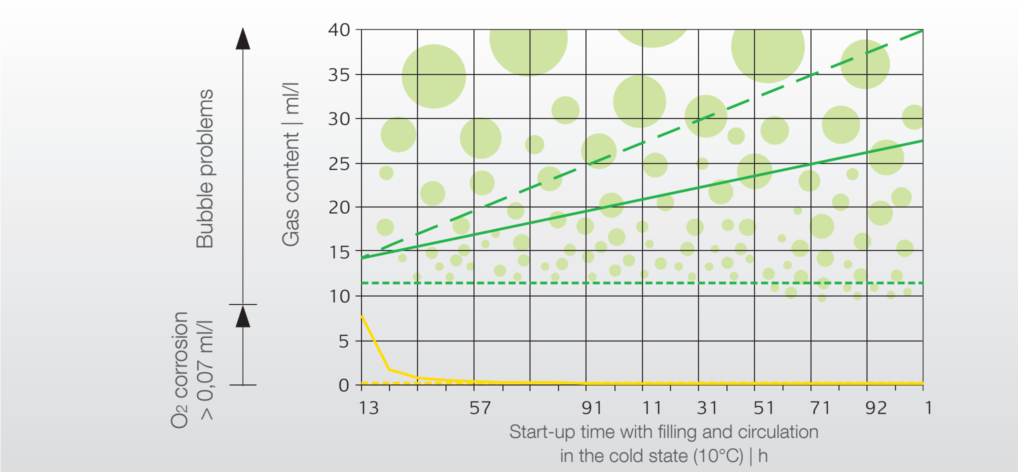
Oxygen O_2 ●
is the main cause of corrosion.

Oxygen is a highly reactive gas. In systems with a high proportion of steel the oxygen content is reduced due to corrosion from 7.8 ml/l to 0.07 ml/l a few hours after the filling. This corresponds to the limit value for corrosion of 0.1 mg/l |2|. This is a clear sign of the dangerous nature of oxygen and the reason for closed systems! Other gases, such as methane CH_4 or hydrogen H_2 are increasingly detected. Different materials, in connection with inhibitors, may lead to the formation of such gases and to corrosion.

Methane CH_4 and hydrogen H_2 are, apart from air, the most common causes for problems.

The air problems are illustrated in the following saturation diagram. While the nitrogen causes bubble problems the dissolved oxygen may lead to corrosion.

Behaviour of nitrogen N_2 and oxygen O_2 during the start-up



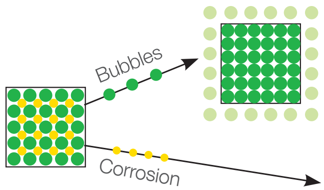
- N_2 enrichment to max. value after filling process, measured acc. to |1|
- N_2 enrichment to saturation value after filling process at 10°C, 0,5 bar, HENRY › **page 9**
- N_2 limit value for the prevention of bubbles at 70°C, 0,5 bar
- O_2 reduction due to corrosion after filling process
- O_2 limit value for the prevention of corrosion
- Nitrogen N_2 may build up far above the saturation value.
- Nitrogen N_2 in form of bubbles must be specifically removed from the system.
- Oxygen O_2 corrodes under the limit value of 0.1 mg/l = 0.07 ml/l. The ingress of additional air must be prevented by sealing the system.

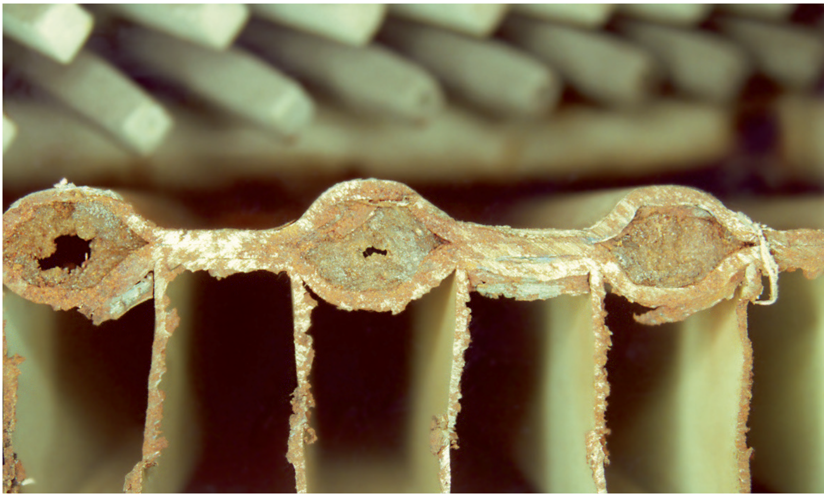
Damage

Corrosion and erosion

Corrosion destroys material. On the one hand, this results in deposits of rust and/or magnetite and, on the other, in erosion caused by corrosion particles that are carried along with the flow. Free gas bubbles increase the risk of erosion. The consequences are:

- Leaking pipes, radiators and boilers.
- Blocked fittings, control valves, pumps.
- Reduced cross sections, lead to a decreased flow performance.
- Reduced heating performance of boilers and heat exchangers.





Circulation problems

Free gas bubbles may substantially affect the circulation. On the one hand, the capacity of the heat transfer medium is reduced – where there are gas bubbles no water can exist. On the other hand, turbulent flow conditions at thermally stressed components can result in operational failures. The consequences are:

- Reduced performance or even failure of the pump. Pumps «drown in air».
- Unpredicatable behaviour of control valves, in particular during light load conditions.

Noise

Free gases lead to noise in the system. The consequences are:

- Flow noise in pipes and fittings.
- Gurgeling» radiators at higher levels.

Reduced heating performance

Gases may impair the heat transfer in two different ways. The consequences are:

- Reduction of the heating performance due to the isolating effect of the gas bubbles on heating surfaces.
- Failure of the radiators at high levels due to the extreme accumulation of air that eventually stops circulation.

Symptoms

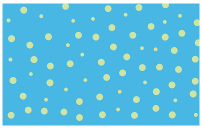
PNEUMATEX VENTOTEST
Have the gas content of your system measured and assessed with our proven Ventotest. Please contact your responsible customer service partner.

Gases may occur in the water as free bubbles or in a molecularly dissolved form. HENRY's law describes the solubility. A gas over-saturation is given above the Henry curves*. Here, dissolved gases come out of solution as bubbles. In case of a gas undersaturation, all gases are dissolved.

Accumulation of air

in stagnant water at high points.

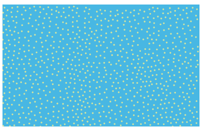
During the filling of a system the lighter air is displaced by the water and rises to the top. If the venting is not performed properly the air accumulates at the higher points. Under pressure the air can – at least partially – dissolve in the water again. This results in an over-saturation. Subsequently during the heating up process the water's solubility decreases and bubbles are generated that circulate with the flow.



Gas bubbles

in flowing water.

Gas bubbles are carried along in the flow. In most cases, the flow in pipes is greater than the buoyancy of the bubbles. Therefore, the separation is only possible with specific devices which can trap these bubbles.



Micro bubbles

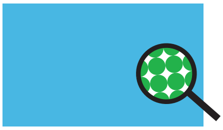
are extremely small and occur in a large number.

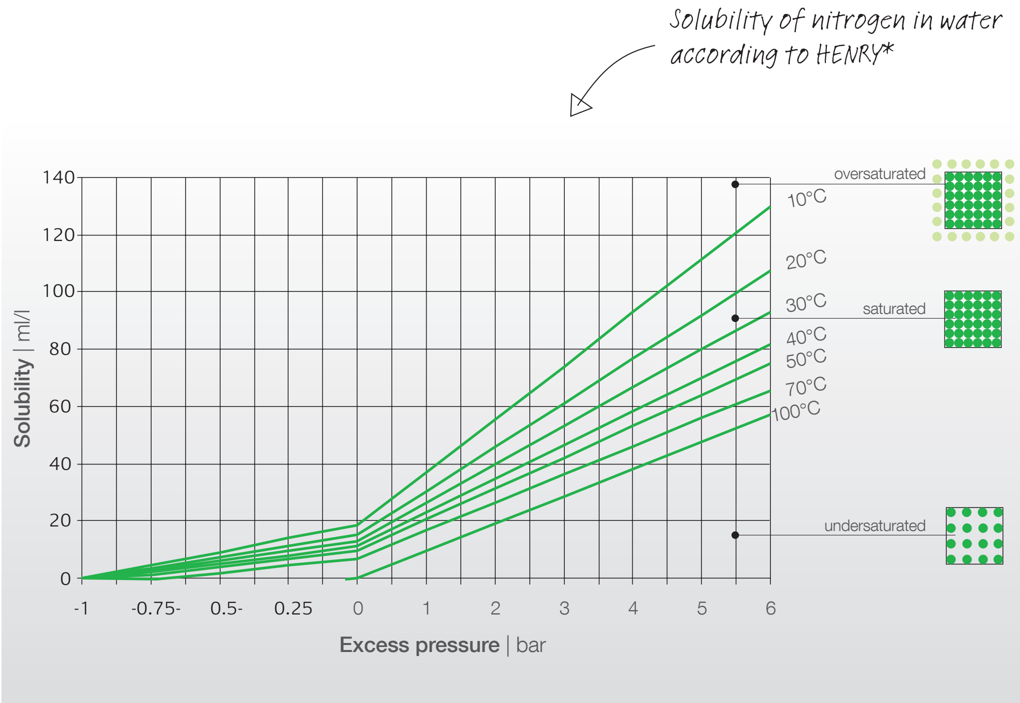
They can hardly be seen with the naked eye. The water appears to be milky white. They are carried along by the flow in such a manner that they can only be captured by special separation devices. Larger bubbles «grow» if solid particles are present. The tendency to stick to surfaces makes the separation process more difficult and increases the risk of damage.

Dissolved gases

are invisible.

The gas molecules are bonded between the water molecules in such a manner that they can only be removed by means of a pressure reduction or temperature increase. Due to the pressure and temperature differences in a system, dissolved gases can desorb into bubbles.



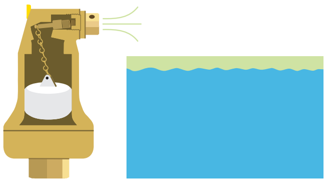


There is a specific HENRY diagram for each gas.

The diagram applies to 100% nitrogen above the water, partial pressure N_2 = 1 bar abs.

The solubility for the atmospheric saturation is 78% of the diagram values. This corresponds to the gas share of nitrogen in the air, partial pressure N_2 = 0.78 bar abs.

Effective protection



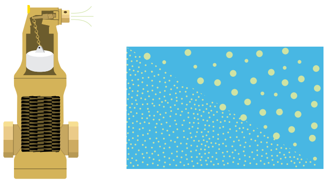
Pneumatex Zeparo
leakfree air vents stay dry!

Air vents

Air vents automatically vent accumulated gases to the outside. The water must be calm. Otherwise, the bubbles are carried along in the flow. Therefore, air vents are not suited for operational venting when directly installed on flow-through pipes. A relief valve is actuated which, in most cases, is float operated. The initial venting during the filling of systems, the decentralized venting of radiators and the venting during draining are preferred applications.

Separators for air

Classic separators for air reduce the flow speed. Existing bubbles can rise to the top in the calmer water and are separated. They are then expelled by means of an automatic air vent. The separation efficiency of these devices is low. It can be improved by means of a baffle.



Pneumatex Zeparo for micro
bubbles combine all proven
separating principles!

Separators for micro bubbles

Separators for micro bubbles can be designed in a very compact manner. They are suited for the operational degassing. Different separation principles can be combined to increase efficiency.

- Reduction of the flow velocity.
- Mechanisms which help bubbles to rise.
- Devices which aid the coalescence of gas bubbles.

Degassers

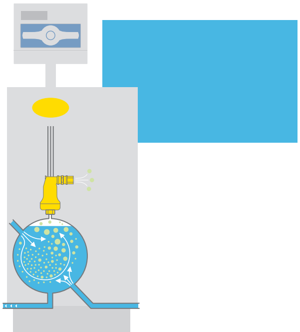
Degassers remove dissolved gases from the water during the system operation. Principally there are two different methods:

Thermal degassers – higher temperatures reduce the solubility. Such systems are mainly used for hot water and steam. In building services, this principle is not applicable due to insufficient temperatures. However, thermal degassing effects at hot boiler walls can be used by means of a micro bubble separator. › **page 24–27**

Pressure step degassers – lower pressures reduce the solubility. Pressure step degassers have been successfully used for some years for the effective degassing of HVAC systems in buildings. The principle:

- Draw off a sample of gas saturated water from the system and reduce the pressure – dissolved gases come out of solution in the form of micro bubbles.
- Venting gas bubbles to the atmosphere.
- Inject deaerated water back into the system.

If this process is continuously repeated the entire water content can be conditioned to be highly absorptive. A distinction is made between vacuum and atmospheric pressure step degassers.



Pneumatex Vento vacusplit degassers work in the vacuum. Pneumatex Transfero with oxystop degassing work in the partial vacuum.

Closed systems

Prevention is the most effective protection.

- The «air supply» through make-up water must be minimized. Systems must not leak.
- The «air supply» through the atmosphere must be prevented.
  A reliable totally closed pressure maintenance and system technology is a must!
- Gases that inevitably build up into the system must be vent off to the outside in a targeted and safe manner.

System selection

Venting and degassing systems are indispensable components of the modern system. Only careful initial venting prior to the startup and effective degassing during system operation results in stable operating conditions. This applies in particular to spread out systems with a long, intricate horizontal or vertical pipe work, fan coils and chilled ceilings.

A careful system selection must be made according to the working principles and the performance characteristics of the vents, separators and degassers. The most important selection criteria for making a selection are shown in the table below:

	Initial venting prior to start-up	Operational degassing	Minimizing corrosion	Minimizing erosion	Minimizing circulation problems	Avoiding noise	Ensure full heating performance
Air vent	⊞	□	⊟	⊟	□	□	□
Separator for micro bubbles	⊞*	■	⊟	■	■	■	■
Pressure step degasser vacuum	⊟	⊞	■	⊞	⊞	⊞	⊞
Pressure step degasser atmospheric	⊟	⊞	□	⊞	⊞	⊞	⊞

suited very well ⊞
suited, with limitations ■
conditionally suited □
not suited ⊟
Only for installation at high points *

Pressure step degasser or separator for micro bubbles

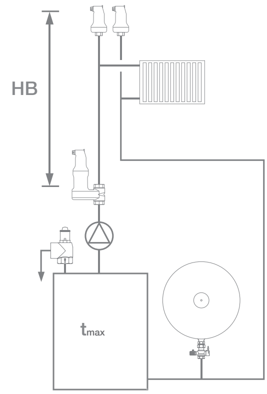
Consideration: System parameters

Pressure step degassers reduce the pressure using a pump to below atmospheric pressure. Dissolved gases come out of solution in the form of micro bubbles which can then be vented to the atmosphere. This degassing is independent of the system parameters and can, therefore be applied universally.

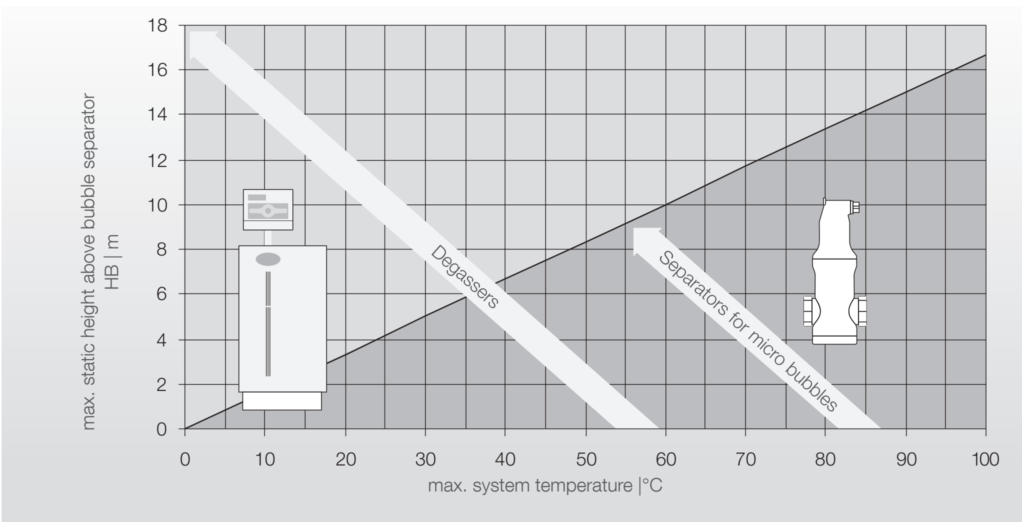
Separators for micro bubbles are passive devices. They can only vent bubbles that are already present in the system. The ideal position is at places with a low pressure or high system temperature. Here bubbles are generated naturally. If the static height HB is exceeded the gases remain partially in dissolved form and can not be effectively separated.

TIP

Separators for micro bubbles are more efficient the lower the static height HB and the higher the system temperature t_{max} at the point of installation.



Application of separators and pressure step degassers



Separators for micro bubbles are only fully functional below the line.

Consideration: Gas undersaturation and degassing speed

A system free of bubbles can only be realized if there is no gas oversaturation at any point of the system. Thus, the gas undersaturation presents a measure for the solubility of gases in water. In case of gas undersaturation, free gases can be absorbed. In this context, this process is also called absorption degassing. Gas ingress caused by water make-up or system repairs can be buffered without the formation of bubbles. › **page 8–9**

Separators for micro bubbles

Under normal conditions micro bubble separators can not achieve undersaturation at the point of installation. However, large parts of the system which are at higher pressures can become absorptive.

Pressure step degassers

Depending on the pressure difference, pressure step degassers can separate dissolved gases and achieve a state of gas undersaturation at every point of the system. Theoretically, total undersaturation up to –100% can be achieved in the vacuum. Atmospheric and partial vacuum degassers work at a partial vacuum of approximately –15 to –25%. The degassing effect is higher than with comparable micro bubble separators.

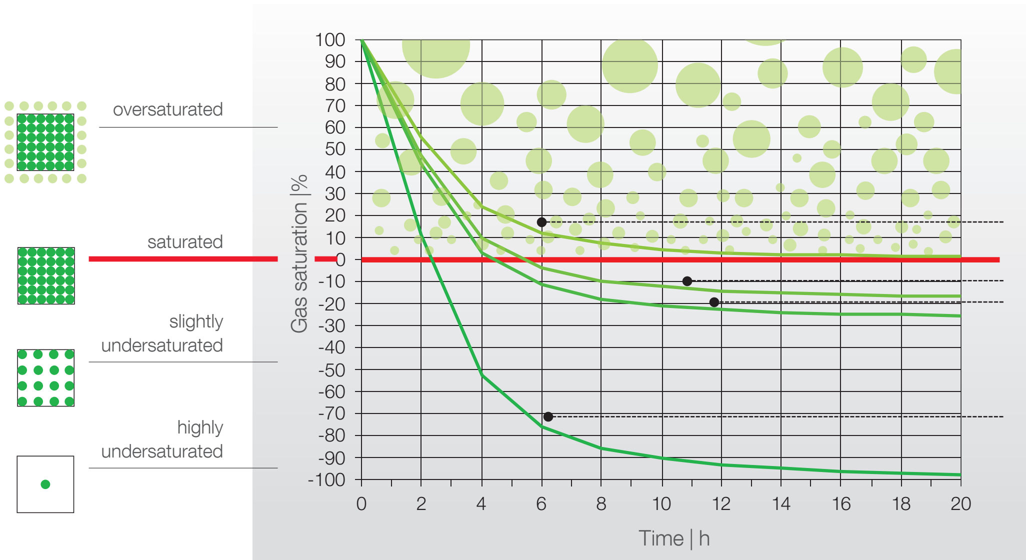
Advantages:

- Minimization of the corrosion through the partial separation of reactive gases, such as O_2, H_2, CO_2. The reduction of the O_2 content to approximately 20% of the initial value is limited to the water make-up water for vacuum degassers. Due to the extreme speed of reaction, O_2 reacts with steel before it can be separated.
- The resulting gas undersaturation creates a buffer against gas ingress with an undersaturation of only 10 ml/l, 50 litres of air can be absorbed in a 400 kW system with a water content of 5000 litres without the formation of bubbles!

TIP

If highly undersaturated water, high degassing rates and corrosion protection are paramount, pressure step degassers are the first choice.

Theoretically achievable gas saturation with degassers and separators for micro bubbles



1 Separators for micro bubbles
2 Saturation curve
3 Atmospheric degasser
4 Degasser partial vacuum –0,1 bar
5 Degasser absolute vacuum

Air vents as separators?

NOT RECOMMENDED

Air vent for operational venting › 1 to 3

Air vents are designed in such a manner that accumulated gases are vented off. However, they are not able to separate bubbles from flowing water. Therefore, air vents are only suited for the initial venting during the filling of systems. For degassing separators and degassers must be used.

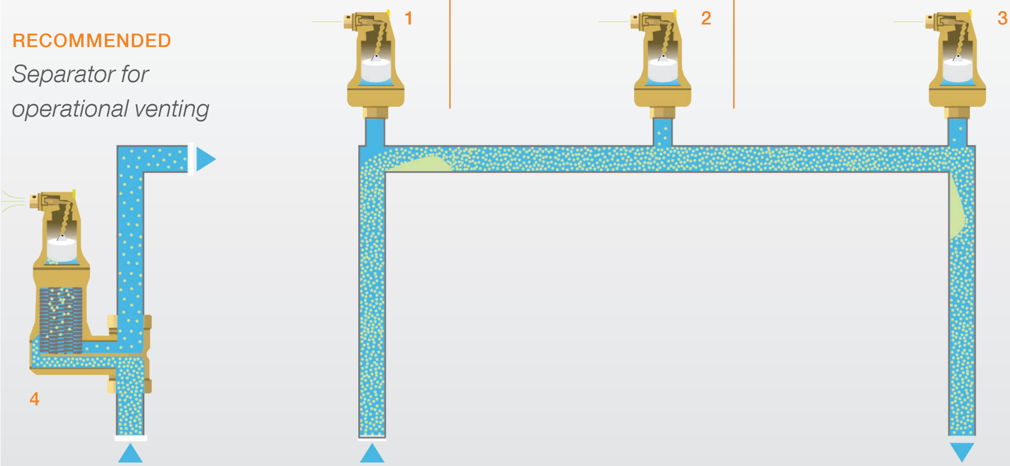
The bubbles are almost completely entrained within the flow. The worst of all options.

Only few bubbles find their way into the air vent. The separation efficiency is low and only relevant with d/D ≃ 1 and flow speeds w ≤ 0,5 m/s.

Due to the turbulence in the bend only a few bubbles are led into the air vent.

RECOMMENDED

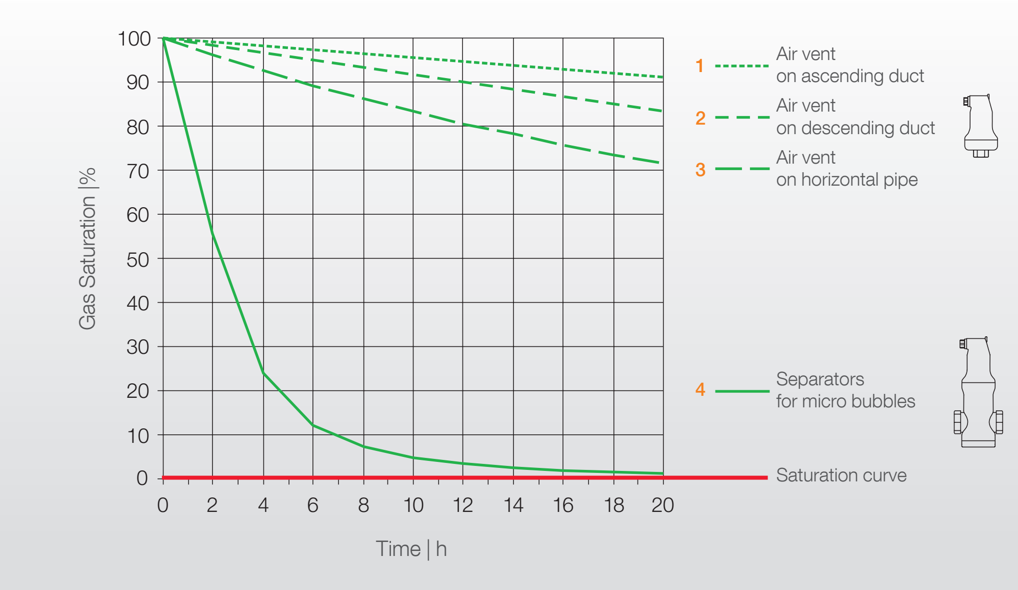
Separator for operational venting



The separator is completely flow-through. Gases are separated from the water and vented through the air vent. The professional solution with a high separation efficiency.

› page 24–27

Comparison: achievable gas saturation with degassers and separators



Air vents are not recommended for the continuous venting.

TIP

Separators are ideally suited for continuous venting. Automatic air vents should only be used at high points to help filling and draining.

Recommendations

RECOMMENDED

Micro bubble separators which are installed at the top of an installation can be used both for venting during filling as well as continuous degassing.

Air vents for venting during initial filling prior to the start-up

Manual venting is difficult, in particular in complex systems, and is not recommended. Too many residual air pockets remain in the system. Automatic air vents that are positioned at all high points ensure efficient initial venting. This is very important for the following reasons:

- Residual air pockets are dissolved, at least partially, during the operation of the system due to the higher pressures and circulate throughout the system. During the heating up process they can be separated again in form of bubbles at the hottest part of the system, such as in the heating flow.
- Enclosed residual air quantities may interrupt the circulation in branch pipes. Without flow the micro bubble separators are ineffective!

TIP

Air vents for the initial venting and separators or degassers for the continuous degassing ensure optimum operating conditions from start-up.

Separators for micro bubbles or degassers for continuous operation

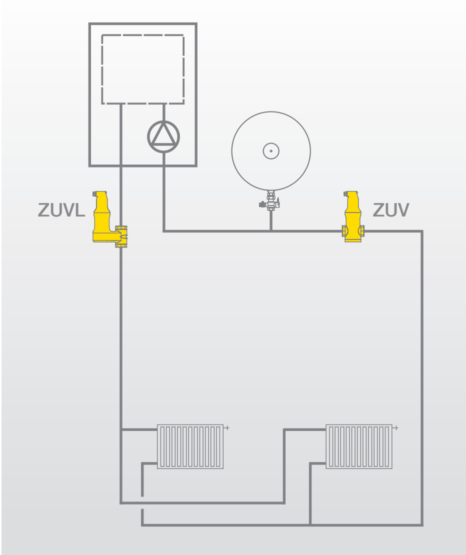
After initial venting, circulation is ensured at all system points. Thus, the basic requirements for the operational degassing using degassers or separators are met.

NOT RECOMMENDED

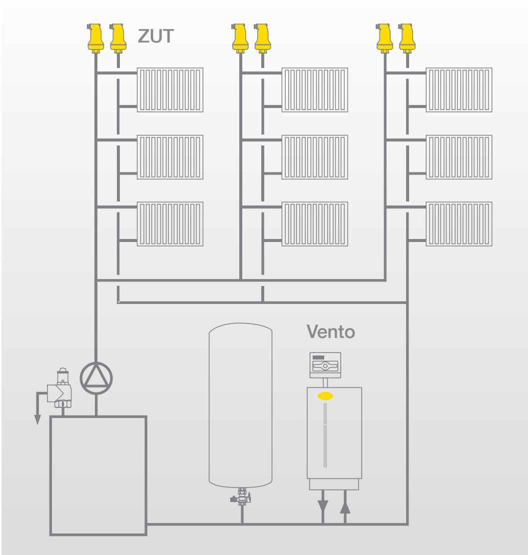
Degasser in combination with separator for micro bubbles

It does not make sense to combine both systems. If a separator for micro bubbles meets the selection criteria, in particular with respect to the «static height» › **page 13**, the additional installation of a pressure step degasser is not recommended. If the decision was made in favour of a degasser it does not make sense to install additional separators for micro bubbles in the system.

Venting at the top of risers, central continuous venting



Zeparo Separators at high level for venting and degassing

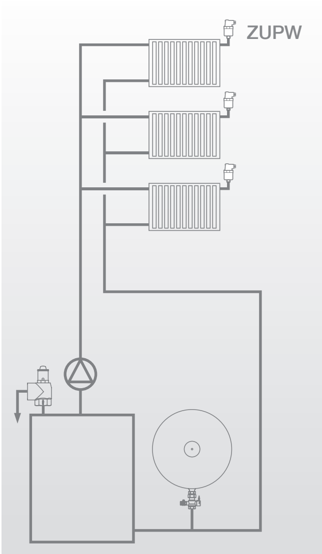


The perfect combination:
Air vents on the risers for the initial venting
+
Zeparo separator or Vento degasser for the continuous degassing

Our solutions: Automatic air vent

Application	• Venting during initial filling at high points. • Venting of high-lying radiators (only for small systems).
Installation	• In the flow and return at the top of risers. • At high points in the system. • On the opposite side of the radiator connection
Gas undersaturation	• Not possible.
Corrosion	• No active influence.
Erosion	• No active influence.
Circulation problems	• No active influence.
Noise	• No «gurgling» with installation on radiators.
Reduced heating performance	• Full heating performance with installation on radiators.
PNEUMATEX TYPES	• Zeparo Universal Top ZUT 10–25, ZUTX 25 • Zeparo Universal Top ZUTS 15 – especially for solar systems • Zeparo Universal Purge ZUP 10, ZUPW 10 – particularly suited for radiator venting
PNEUMATEX QUALITY	• *leakfree:* Zeparo air vents are equipped with a leakfree safety package. This ensures gases are vented safely without leaks.

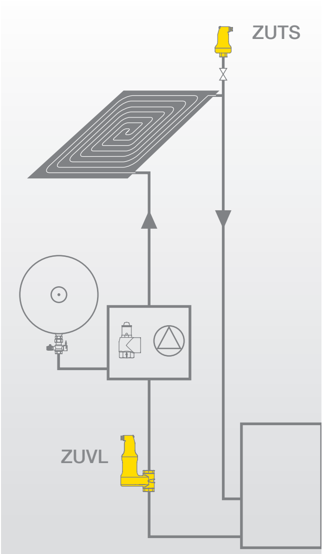
Direct radiator venting



Decentralized initial and operational venting of a heating system directly at the radiators with Zeparo ZUPW 10.

The radiators act as separators.

Only recommended for small systems that are not very complex.



Initial venting of a solar system with Zeparo ZUTS.

Degassing with Zeparo ZUVL separator.

Solar air vents for high temperatures

Automatic air vent

Automatic air vents are the interface between a system and the atmosphere. Reliable functionality and safe operation are of utmost importance. These characteristics in connection with high performance define the leakfree safety package.

› ZEPARO KATALÓGUS

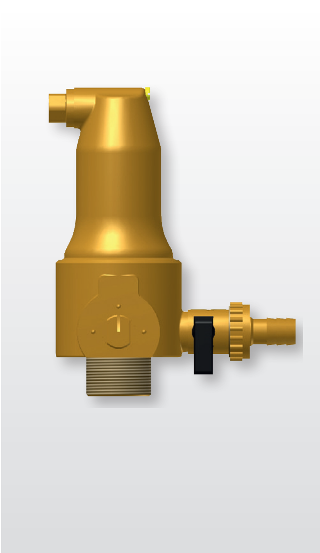
ADVANTAGES

- Safe, leakfree venting of gases.
- Stable float guiding in a large, flow-balanced chamber. Dirt and water are kept away from the precision valve even in case of high pressure systems.
- No leakages, no scale build up.
- No operational and replacement costs due to leaking air vents.
- Reliable, best air performance even in case of high pressure systems.

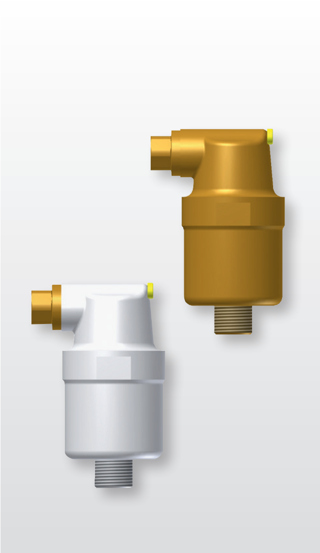
ZEPARO LEAKFREE

Wider range of types with principle Zeparo leakfree

Zeparo Universal Top
also as solar version



Zeparo Universal Top eXtra



Zeparo Universal Purge

Our solutions: Separators for micro bubbles

Application	• Continuous degassing in heating systems and cooling water systems. • Their use is restricted by the static height HB above the separator (› **page 13**).
Installation	• Preferably centrally in the flow immediately after the boiler. • For cooling water systems in the warmer return to the chiller.
System capacity	• Up to DN 300.
Benefits	• Simple installation, no moving parts.
Gas undersaturation	• An operation with gas undersaturation, at the point of installation, is not possible. Systems which are prone to a large amount of gas ingress should be fitted with a pressure step degasser.
Corrosion	• No active influence.
Erosion	• Minimized as there are few free gases in the system.
Circulation problems	• Minimized as there are few free gases in the system.
Noise	• Minimized as there are few free gases in the system.
Reduced heating performance	• No circulation problems due to air pockets and only few bubbles ensure maximum heating performance.
PNEUMATEX TYPES	• DN 20–40 – Zeparo Universal Vent ZUV, ZUVL • DN 50–300 – Zeparo Industrial Omni ZIO

Also combined separators for micro bubbles and sludge available:

- DN 20–40 – Zeparo Universal Kombi ZUK
- DN 50–300 – Zeparo Industrial Kombi ZIK and Zeparo Extended Kombi ZEK

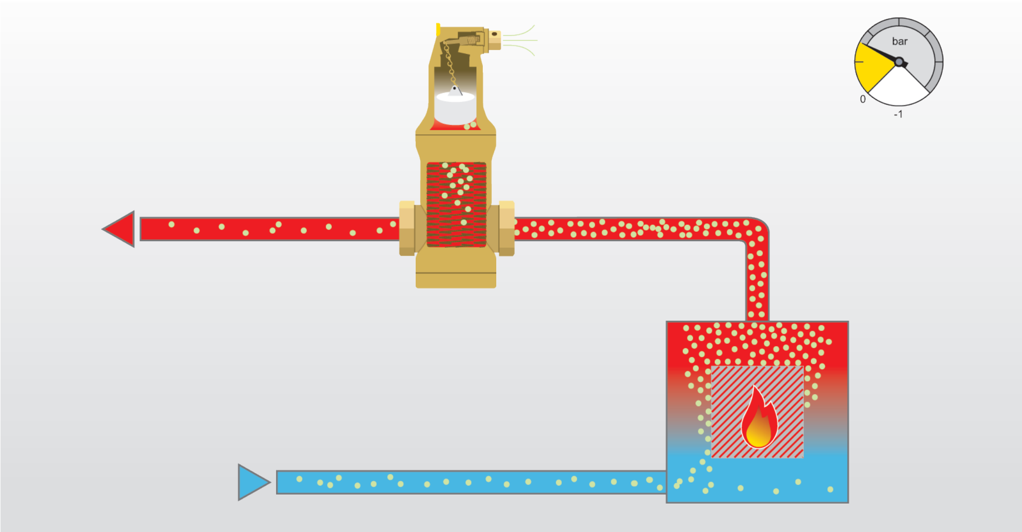
Combined separators for micro bubbles and sludge with oxygen reduction anode

- DN 25 – Zeparo Universal Redox ZUR

helistill: Zeparo separators are equipped with a helistill separator element. It combines all previously known separation principles and ensures an excellent separation efficiency.

PNEUMATEX QUALITY

Zeparo ZUV with helistill separation at system pressure



Central continuous venting of a heating system immediately after the boiler by means of Zeparo ZUV.

The boiler acts as thermal degasser. In part, temperatures far above the flow temperature are achieved at the boiler heating surfaces.

After a short duration, the circulation water is, deaerated and free of bubbles.

The combined, innovative separation principle

heli… as in helicoidal stands for the tangential dynamics during the separation process.

…still stands for the required calming during the defined separation of the gases and solid components.

› ZEPARO DATASHEET & RANGE CATALOGUE: The characteristics of this unique principle of the bubble and sludge separation.

ZEPARO HELISTILL

leakfree air vent › page 22
For venting of the separated gases

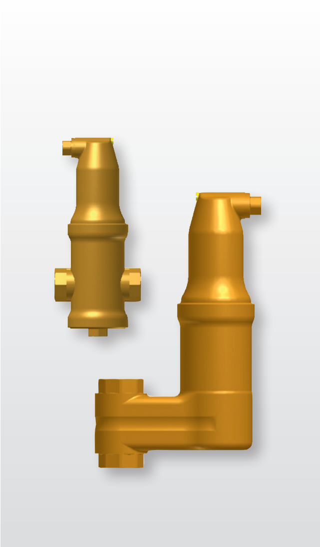
helistill separator
Optimum combination of all known separation principles:

- Reduces flow speed
- Baffle
- Centrifugal effect
- Coalescence

Connection

- Brass version
  up to DN 20–40 with threaded connection DN 22 with compression fitting
- Steel version DN 50–300 with weld ends or flange connections

Wider range of types with principle Zeparo helistill



- Zeparo Universal Vent
- Zeparo Universal Vent Lateral

- Zeparo Industrial Omni

- Zeparo Universal Collect
- Zeparo Universal Kombi
- Zeparo Industrial Kombi
- Zeparo Extended Kombi

Our solutions: Pressure step degassers

Application
- Universally applicable continuous degassing in heating and chilled water systems.

Installation
- As partial flow degassing in a bypass in the return of the system.

System capacity
- Standard systems up to approximately 200 m³.

Benefits
- Device with pump and microprocessor control. Additional process parameters, such as pressure, water make-up, gas content, can be monitored and controlled with advanced units.

Gas undersaturation
Diagramm › page 15
- Vacuum degasser: nearly −100%
- Partial vacuum degasser: below −25%
- Atmospheric degasser: ca. −15%

Corrosion
- Minimizing by separating reactive gases, such as O_2, H_2, CO_2.

Erosion
- No erosion due to gas bubbles possible.

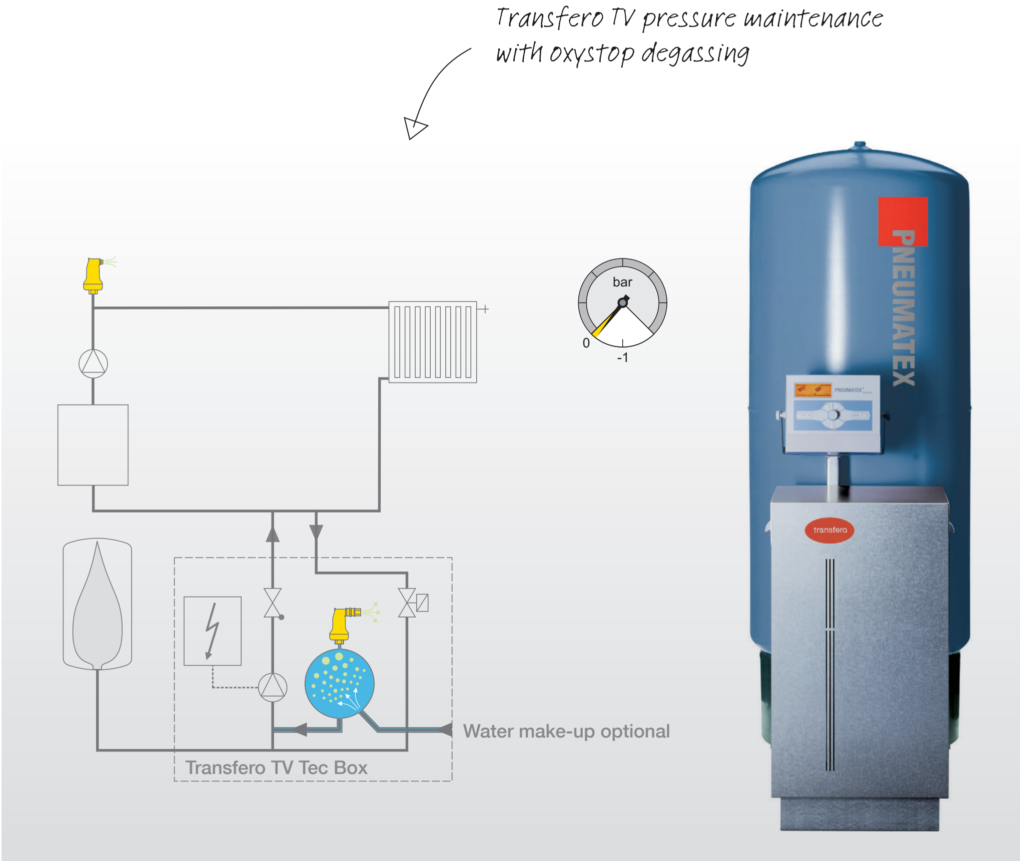
Circulation problems
- Prevented in a stable and safe manner by undersaturated water.

Noise
- No noise caused by gas bubbles.

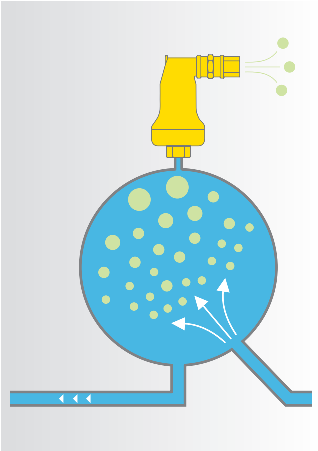
Reduced heating performance
- No circulation problem and increased heating performance due to bubble free water.

PNEUMATEX TYPES
- *Vacuum degasser:* Vento V and Vento VP with built-in water make-up.
- *Partial vacuum degasser:* Transfero TV and TPV with built-in water make-up.
- For Transfero, the degassing module V is integrated into the TecBox of the pump pressure maintenance.

PNEUMATEX QUALITY
- *oxystop*: Transfero pressure-maintaining stations TV and PV integrate oxystop degassing with partial vacuum up to ca. −0.1 bar.
- *vacusplit*: Vento vacuum degassers use the vacusplit atomizing process with spin effect for the total separation of dissolved gases.



Optionally available as Transfero TPV with water make-up.

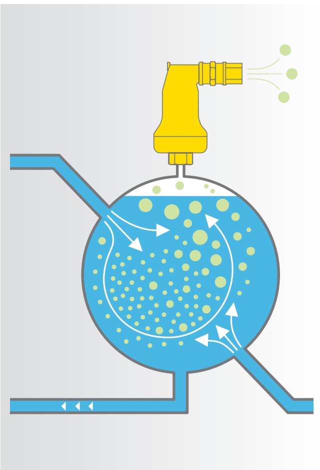


› VENTO DATASHEET & RANGE CATALOGUE

The effective degassing with partial vacuum

Degassing of the system and water make-up water in a special vessel up to approximately atmospheric gas saturation. This ensures absolutely bubble-free water.

- Gas undersaturation below –25%.
- Oxygen reduction in the water make-up water in heating systems by ca. 10%.



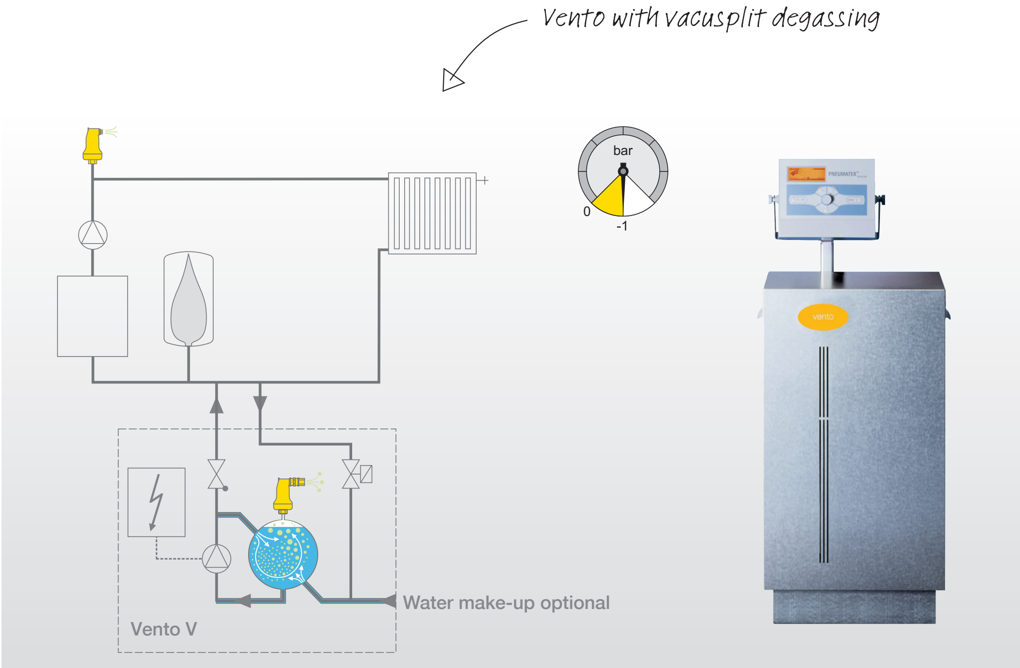
How safety and effectiveness combine into quality.

› VENTO DATASHEET & RANGE CATALOGUE

The most effective spray degassing a vacuum

Degassing of the system and water make-up water in a vacuum vessel with degassing programs for permanent operation and Eco automatic operation or Eco interval operation.

- Gas undersaturation nearly –100%.
- Oxygen reduction in the water make-up water by ca. 80%.



Optionally available as Vento VP with water make-up.
The pressure maintenance is no component of the Vento.

Units

- Pressures are – unless otherwise specified – always gauge pressures.
- The gas contents in the water in ml/l are referred to the standard state at 0°C, 0 bar.
- Nitrogen N_2: 1 ml/l = 1,25046 mg/l
- Oxygen O_2: 1 ml/l = 1,42895 mg/l

References

|1| «Gase in kleinen und mittleren Wasserheiznetzen» Technische Universität Dresden, Institut für Energietechnik, koordinierter Schlussbericht, AiF Forschungsthema Nr. 11103 B, November 1998

|2| «Vermeidung von Schäden in Warmwasserheizungsanlagen, wasserseitige Korrosion» VDI 2035 Bl. 2, Beuth Verlag GmbH, September 1998

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Air:
Problems, Causes, Technology
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How do air and other gases get into heating and cooling systems? What are the most effective remedies? This technical guide answers these and many more questions about «air» in systems. IMI Hydronic Engineering has the most complete range of automatic air vents, microbubble separators and pressure step degassers and therefore can offer the best solution for every air problem. Profit from the extensive IMI Hydronic Engineering know-how and don’t give air related system problems a chance!