Working with air valves

During the research and realisation of new products, CSA has always focused his efforts on:
- Listening to the customer's needs and finding the best solution both at the design and operational phases.
- Guiding our R&D department to develop ranges of modern, reliable and complementary products.
- Adopting production techniques that, even while complying with the severest quality standards, would allow us to reduce delivery times.
- Guaranteeing complete technical support for our customers and prompt after-sales assistance.

This philosophy characterizes us not only as a valve manufacturer but also as a reliable partner whom you can always depend on for consulting and solutions.

The production cycle, aimed at the constant improvement of our products and complete customer satisfaction, ensures prede-termined margins of tolerance by establishing production standards, which guarantee that the semi-finished products reach the next production stage with the required specifications.

All our valves are made of ductile cast iron GJS 400-15 / 500-7 in absolute compliance with European standards, and are suitable for PN 25-40 bar.

The manufacturing process is carried out exclusively by means of numerically controlled lathes, mills, and horizontal machining units. Subsequent step-by-step controls are based on strict quality procedures.

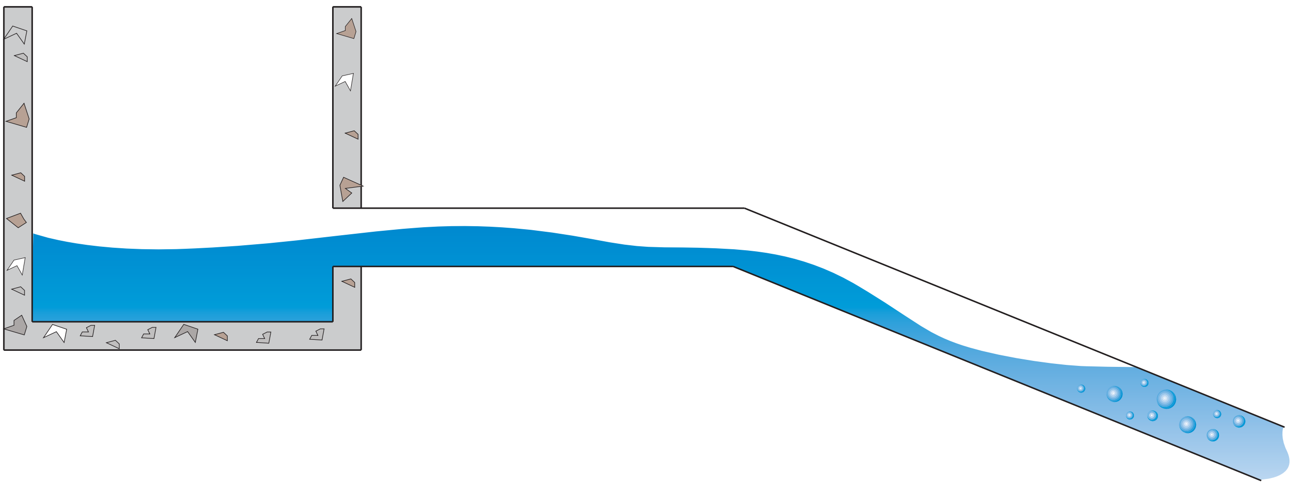
Painting, pre-treated by sand blasting grade SA 2.5 is carried out inside a fluidized bed containing epoxy powder, which guarantees maximum surface protection. All our products are tested under water pressure and certified.

The control and management of air in pipelines used for water supply is often a hidden problem, sometimes damages and inefficiencies coming from the absence of air valves are underestimated, this catalogue aims at imparting the basics fundamentals about the problems caused by the presence of air in pipelines, how to solve it and the procedure for a proper air valves sizing and location.

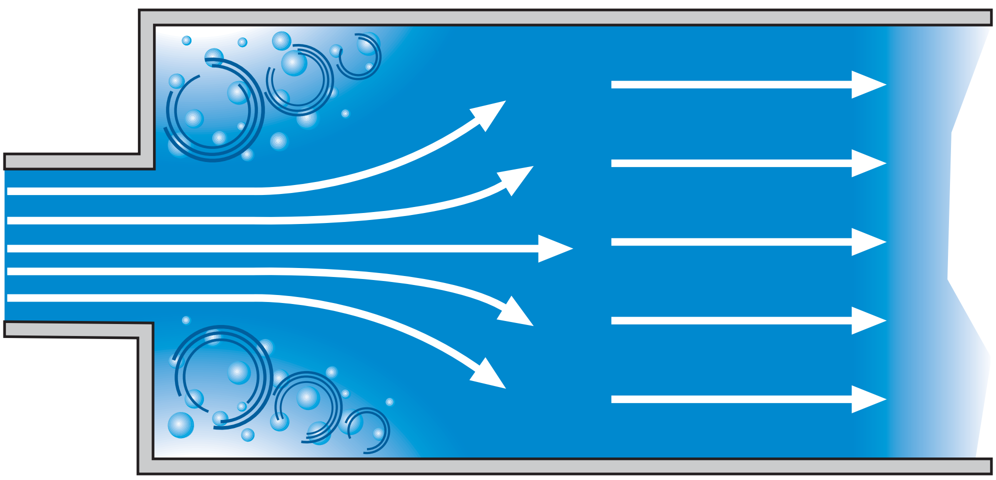
How air enters pipe systems

Water used in civil engineering applications contains a percentage of dissolved air which is approximately 2%, as a result of pressure drop or increase in temperature it can come out of solution. This effect is even greater in sewage applications because of the bacterial activity that may lead to the formation of gases.

In addition to the air coming out of solution the most common ways in which air enters our systems are:



- entrainment at the inflow or outflow locations;
- entrainment due to vortices at the inlet;
- air inlet through pumps because of low sump level or vortices;
- hydraulic jumps that may form on the descending slopes;
- negative pressure at the inlet of the pipe;
- air can enter the pipe at those sections where joints and fittings are located in case of negative pressure conditions;
- incomplete air evacuation when filling the conduct.

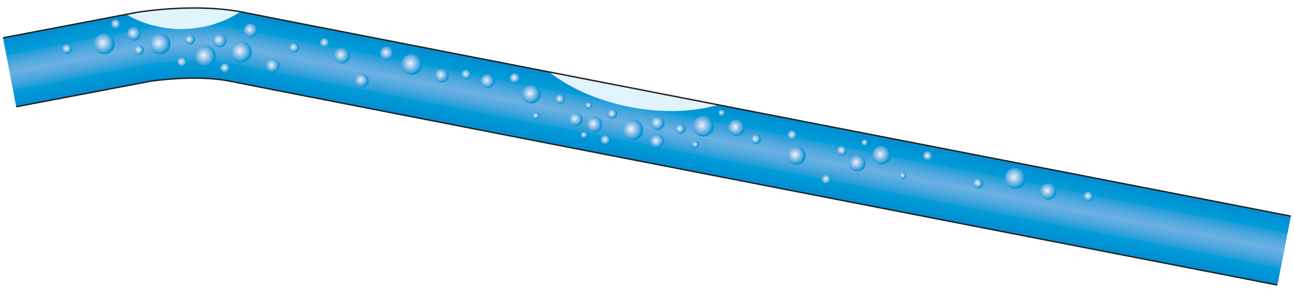


Why air is a problem

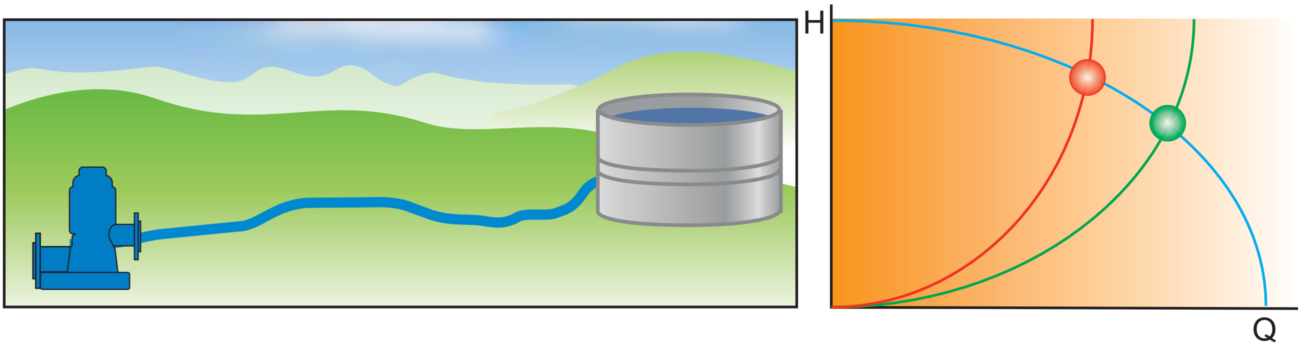
the presence of air pockets distributed along the pipe profile is responsible for the following problems:
- Air pockets reduce the effective cross section increasing headloss and reducing the capacity in terms of flow rate eventually interrupting the water supply.
-During hydraulic transients the presence of air pockets, that are strongly compressed and deformed, are likely to amplify the surge pressures experienced.
- Air pockets will lead to hydraulic jumps in the pipe and blow back effects with vibrations and structural damages of the system.

- Air will cause difficulties in measuring and filter operations.
- The presence of air will reduce pump efficiency;
- In ferrous pipes the presence of air will enhance corrosion having compressed oxygen in contact with the wet wall of the pipe itself.
- The presence of air pockets will increase the total headloss of the system requiring a higher pump's power and energy costs.

As above explained, air must be degassed or released in high quantities from the pipe system and it is also very important to let air in to avoid negative pressure problems when the following arise:
- a breakage causing water leakage;
- accidental and uncontrolled draining operations.



The following picture is showing the typical problems caused by the presence of air pockets accumulated in pumping systems.
The air pockets and the consequent reduction of the flow rate capacity is evident looking at the working point obtained by the intersection between the pump's curve and the hydraulic resistance of the system. If we indicate the design working point by green the presence of air pockets will make it move to the left, becoming red, reducing the flow rate and increasing the pump's head at the same time (with a higher cost of energy). The downside effect is also the increased cost of the pump's maintenance.

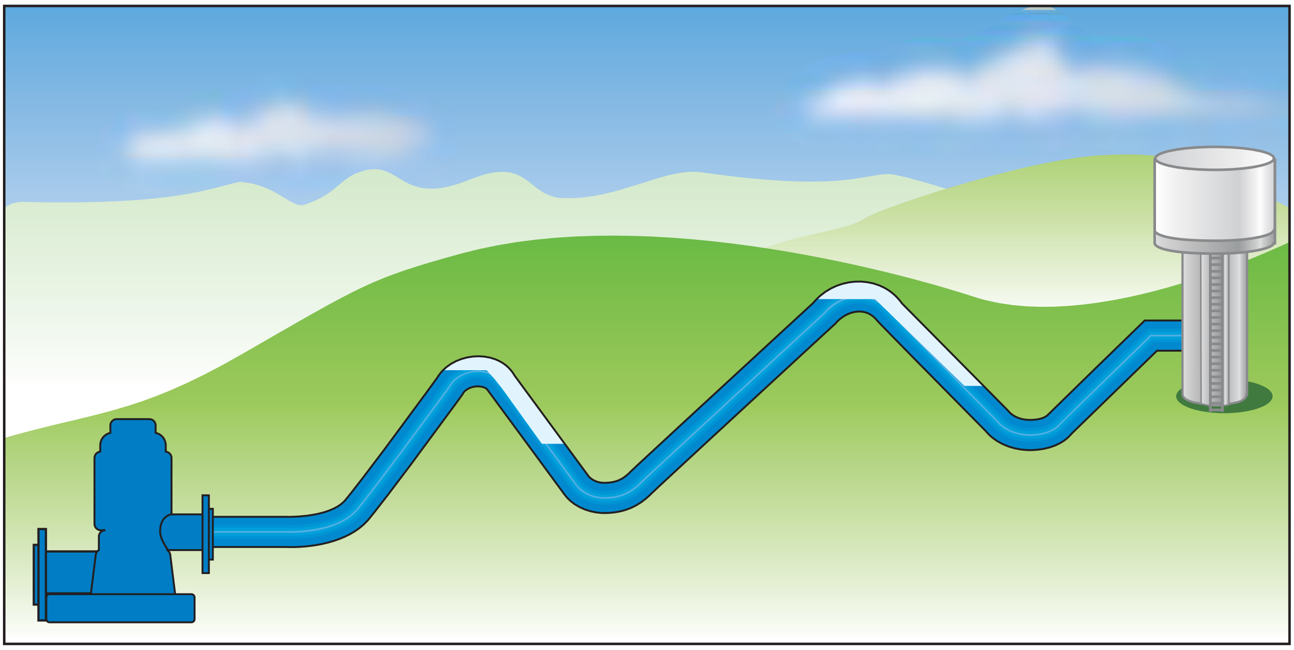


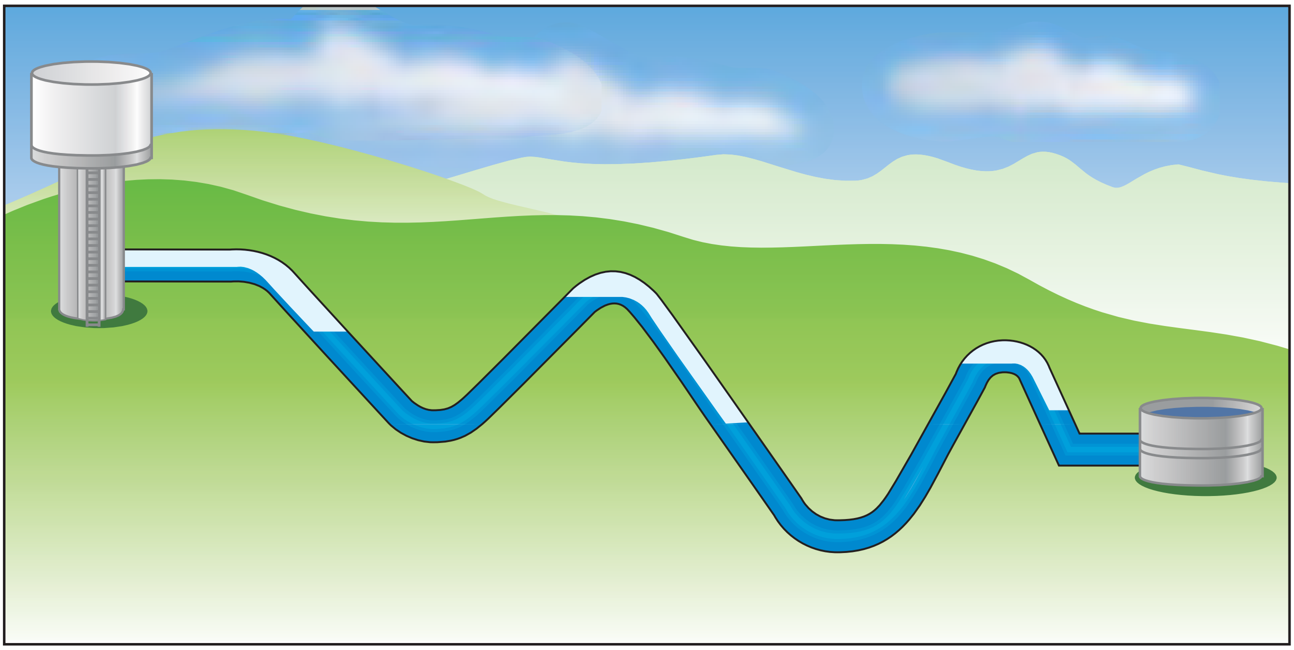
Increases of head losses caused by air

Intensive research carried out over the last 10 years along with numerical analysis reveleade that the presence of air pockets distributed along the pipe profile is responsible for the following problems:

In gravity systems the presence of air pockets results in capacity reduction, if the static head is not higher than the sum of the head loss we will have an interruption of the flow and an overflow through the upstream tank

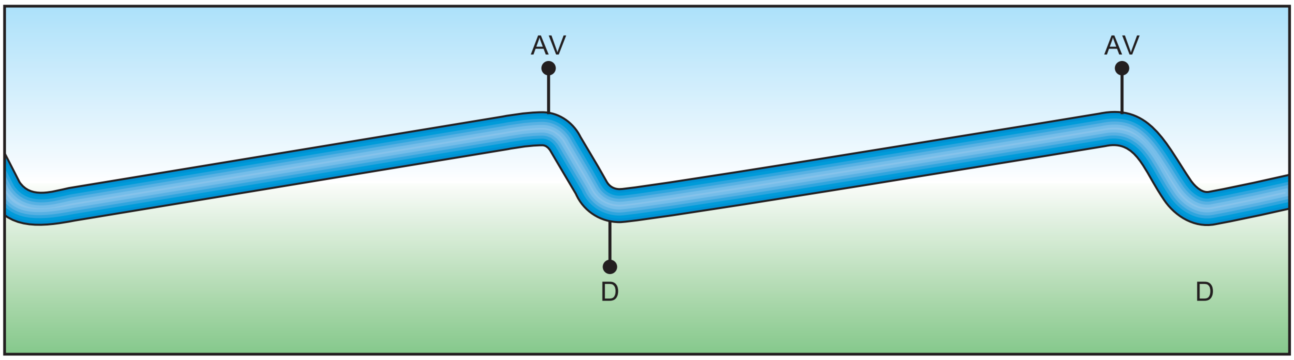
In pumping systems the air accumulation results in the rising energy consumption and flow reduction (as shown in the previous page).





Importance of pipe profiles

All pipelines must be designed to create a saw-toothed layout with slopes laid at minimum of 2-3% for downward slope and 0,2-0,3% for upward slope. This structure helps air accumulation in the highest parts and thus its discharge through air release valves properly located, nevertheless for practical reasons downward slopes with lower gradients are also used in practice as well as sub horizontal segments. This is not recommended since air would not accumulate in one point but it would travel uncontrolled along the system.



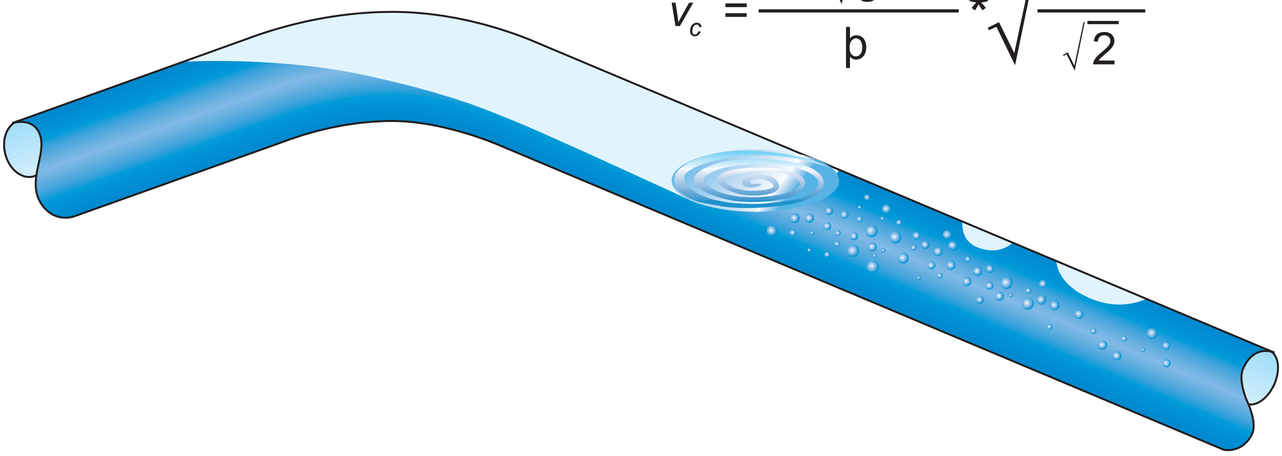
Air removal

Air entrained by different causes is conveyed through the pipeline and accumulates at the high points forming air pockets that become larger and larger as more bubbles join in. Once air pockets, accumulated on the high points, are large enough they split and part of the air goes downstream. On air pockets three forces are acting such as the buoyancy force, the hydrodynamic force and the friction force against the pipe’s wall. On descending slopes the resultant force can be directed upwards preventing the air pockets from moving downstream and creating even more headlosses.

During the design of pipeline profiles we must therefore also check and understand the movement of air bubbles and air pockets, which is still matter of investigation. Almost every reader on the subject agrees on the fact that the minimum velocity needed to flush air pockets downstream in downward sloping pipe depends on the pipe DN and pipe gradient, in addition to experimental coefficients as a results of specific tests. It is good practice and common understanding that the minimum design flow to ensure air movement in downward sloping pipes should be in the range between 0,8 and 2 mt/sec depending on the installations, pipe DN and layout.

(please consult CSA for further information).

$$v_c = \frac{4 * \sqrt{g * D}}{\text{þ}} * \sqrt{\frac{tan\alpha}{\sqrt{2}}}$$

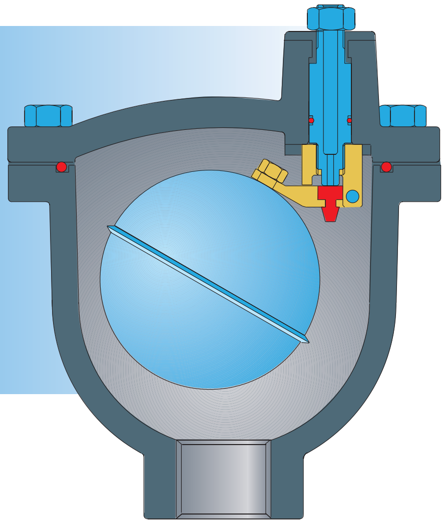


Fundamentals of air valves

Before talking about air valves sizing and to CSA methodology it is important to know the fundamentals of air valves and their definitions.

Air release valves

Air release valves, also called single function air valves, are designed only to release air pockets accumulated during working conditions. Something important we must take into account about this model is that they don't have any capacity of air inflow during pipe draining, and outflow during filling, due to the limited passage through the nozzle, therefore they won't provide any protection for the pipeline against negative pressure conditions.

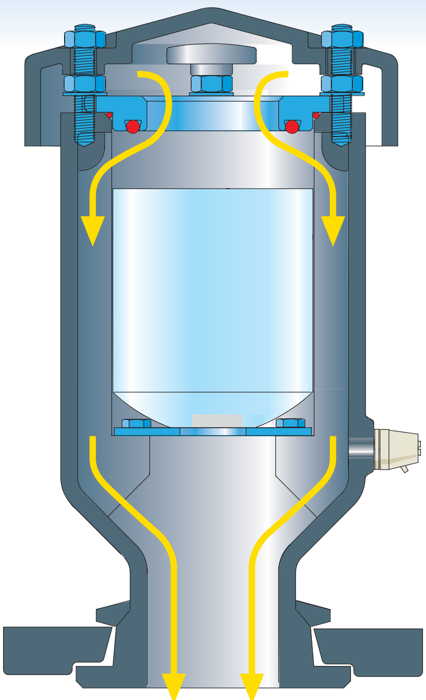


Example of CSA air release valve Mod. Ventolo

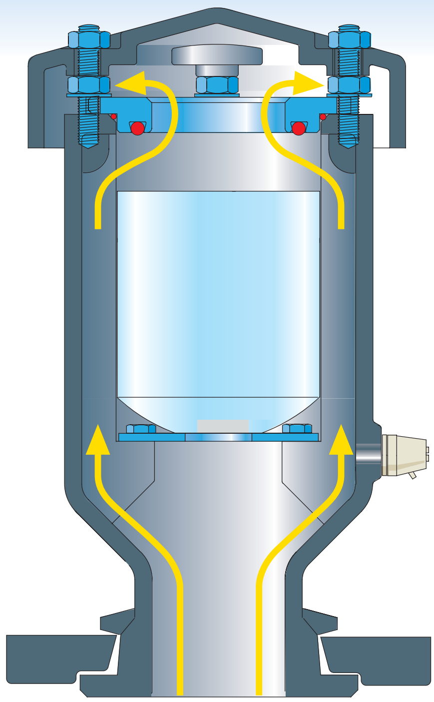
Air/Vacuum valves

Vacuum air valves, also called double function air valves, are designed to protect the pipeline during pipe draining and pipe filling.

In case of pipe draining we must allow the entrance of large volumes of air, when the pressure drops below atmospheric values, to avoid negative pressure conditions and damages to the system.



In case of pipe filling we must discharge large volumes of air to avoid the creation of air trapped in dead ends, with possible upsurges, and to speed up the filling process saving time and money.



Example of CSA air/vaccum air valve Mod. FOX 2F

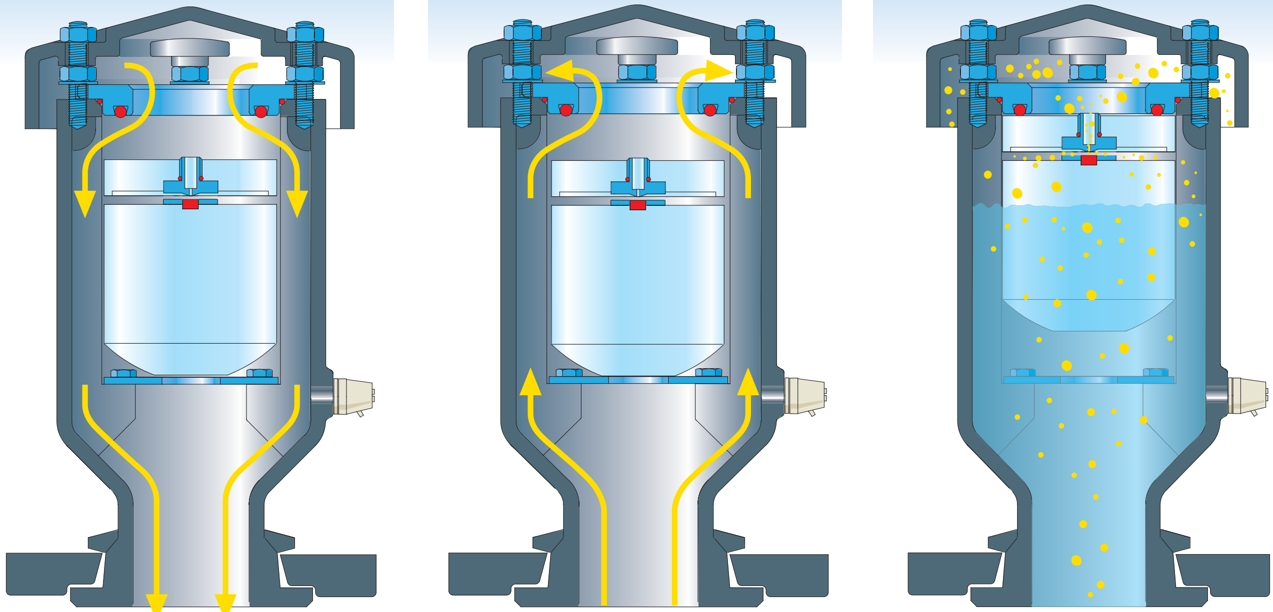
Combination air valves

Vacuum air valves, also called three functions air valves, are designed to protect the pipeline during pipe draining and pipe filling and to discharge air pockets during working conditions.

In case of pipe draining we must allow the entrance of large volumes of air, when the pressure drops below atmospheric values, to avoid negative pressure conditions and damages to the system.

In case of pipe filling we must discharge large volumes of air to avoid the creation of air trapped in dead ends, with possible upsurges, and to speed up the filling process saving time and money.

During working conditions the air valve will discharge air pockets through the nozzle

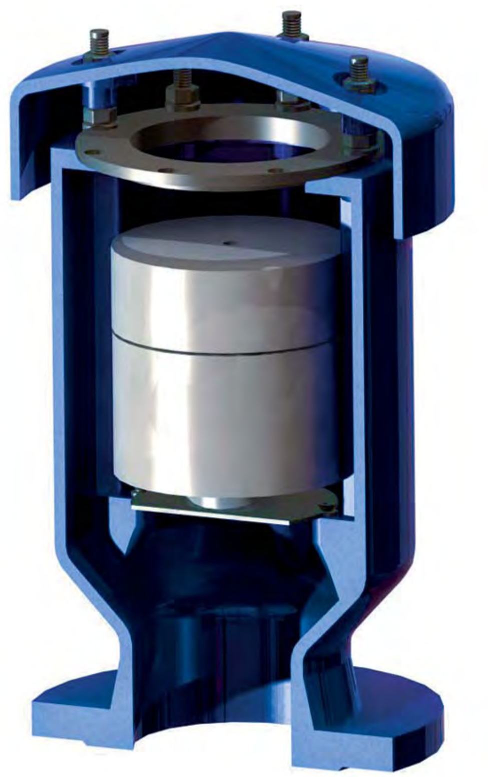


Example of CSA combination air valve Mod. FOX 3F

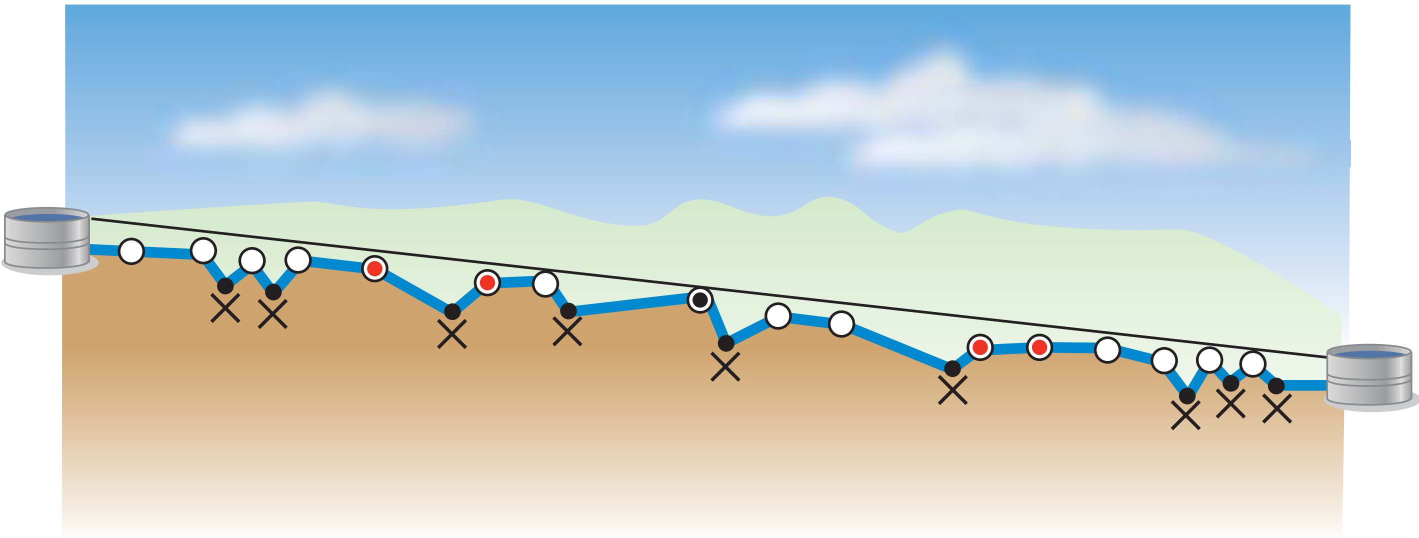
CSA technical advantages

CSA is leading the way with innovative and reliable air valves. Entirely manufactured in ductile cast iron and stainless steel some of the most significant technical benefits compared to the existing alternatives on the market are:

- unless otherwise specified full bore capacity, that is to say that the outlet passage is equal to the inlet passage through the flange.
- CSA has been the first company in the world to develop a single chamber full bore combination air valve, to avoid the problems typical of the double float design allowing at the same time for reduced space and weight with a PN 40 bar product.
- high flow capacity thanks to shapes and passages into the body studied with advanced computational fluid dynamics calculations.
- cylindrical floats and obturator in solid polypropylene to avoid deformation, calcium deposits and jamming, typical problems of spherical floats.
- air release subset in stainless steel AISI 316 with gasket compression control to minimize the risk of leakage.
- diffuser to avoid premature closure in stainless steel.
- seat completely made in stainless steel.
- nuts and bolts in stainless steel.
- body designed to be interchangeable between the 2F and 3F versions (and other models on request).
- supplied with cover in ductile cast iron or cap e filter in stainless steel. Outlet for submerged installation and conveyed exhaust available on request.



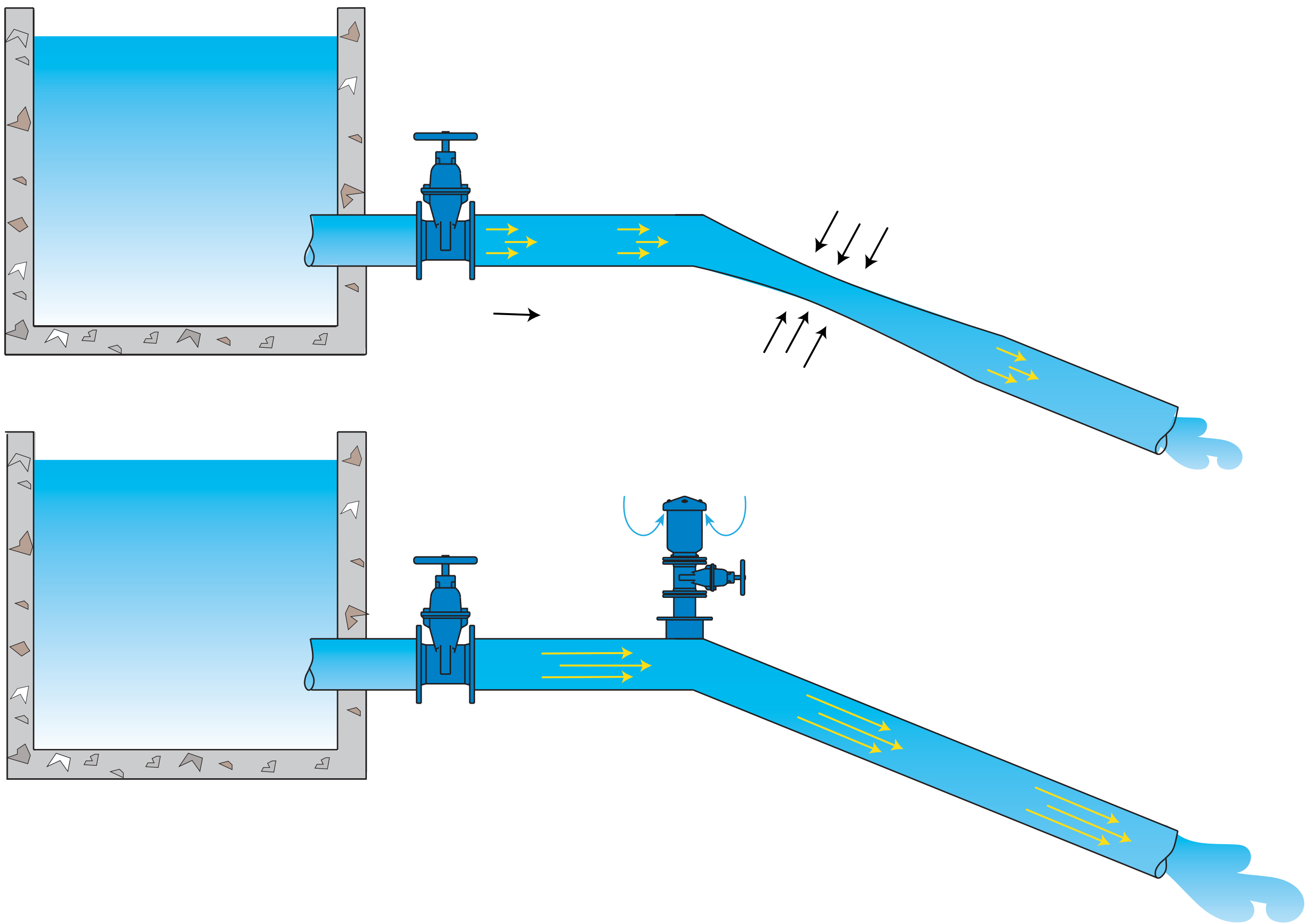
Air valve locations without considering water hammer and transient analysis.
The following picture has to be considered as a pure indication for air valves location along the profile and without considering any transients or water hammer effects, for that reason a gravity conveyance system has been chosen.



Types of air valve recommended

3	High points	Combination air valves
3	Changes in slopes descending	Combination air valves
2	Changes in slopes ascending	Vacuum air valves
2	Long ascending segments	Vacuum air valves every 600/800 mt
3	Long ascending segments	Combination air valves every 600/800 mt
3 ●	Long horizontal run	Avoid if possible if unavoidable air release valves or combination air valves every 600/800 mt

Air valves sizing.
In terms of air valves sizing we must basically calculate the air valve DN, whose air flow capacity which will be able to protect the pipe against negative pressure conditions.



To do that we must allow the entrance of air whose volume will be equal to the amount of water discharged in two situations:

Pipe burst analysis
Assuming a pipe burst on the most critical locations of our pipelines

$$Q_{burst} = \sqrt[1.852]{\frac{SD^{4.87}\ C^{1.852}}{10.69}}$$

Where :
C is the friction coefficient
S is the slope
D is the pipe DN

Pipe draining analysis
Simulating the pipeline drainage operation through the drains located on the pipeline

$$Q = C_v A_0 \sqrt{2gDH}$$

Where :
Ao is the drain section
Cv is the discharge coefficient
DH is the available pressure head

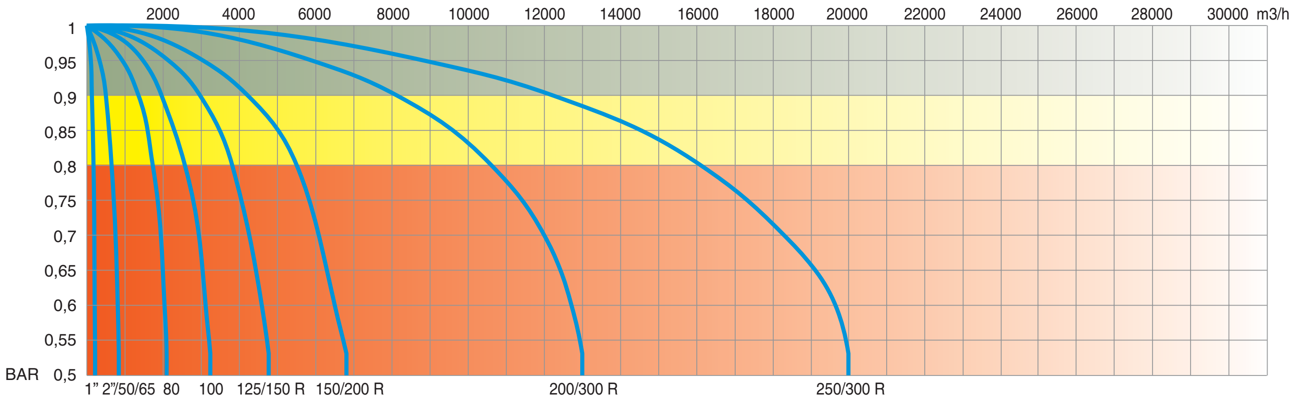
Pipe collapse pressure
The following formula has to be used purely as an indication to assess the pipe resistance to possible collapse. Please contact CSA for a detailed buckling analysis.

$$P_{cr} = \frac{2E}{(1 - M)^2} \left(\frac{S}{D}\right)^3$$

Where :
E is the Elasticity modulus
s is the pipe thickness
D is the pipe DN
M is the Poisson ratio

Just as an example below the air flow capacity of one of CSA model, namely the combination air valve FOX 3F-M. The chart is referring in particular to the inflow capacity during pipe draining. Let's assume that the burst analysis conducted on a critical section of our pipeline produced a value of 2500 m3/h of water discharged.

PORTATA D'ARIA IN ENTRATA PER SVUOTAMENTO CONDOTTA

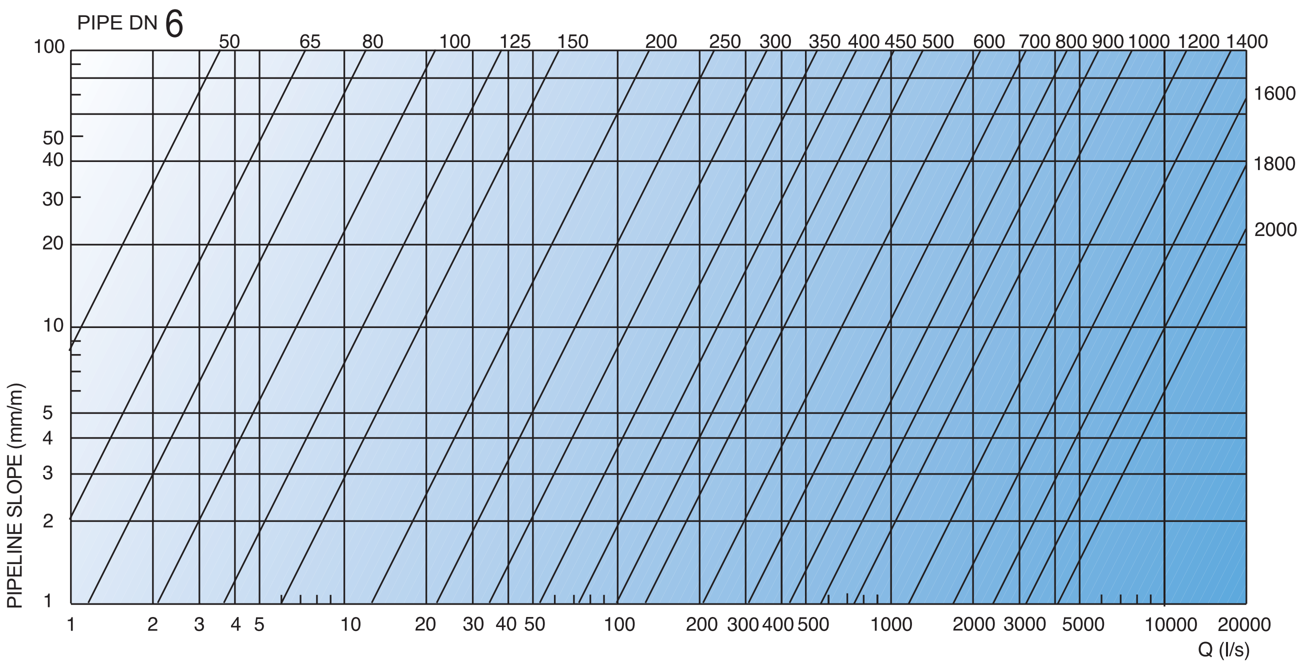


Entering the line corresponding to 2500 m3/h on the plot we have to choose the right Dn of air valve depending on the allowable negative pressure the system can tolerate. Purely as an indication we have depicted in red the part with the negative pressure which we consider to be dangerous for the pipe (that values depend on pipe material, thickness and other parameters. Please contact CSA for further information).

In yellow we will refer to a an inflow which may create problem to some situations in terms of negative pressure, with the green band we have shown the safe area designers should work with.

Going back to our example it goes without saying that using a CSA FOX 3F DN 100 air valve to cope with 2500 m/h we would produce a negative of almost 1,8 meters becoming 0,7 meters with the DN 125 mm. A DN 80 air valve in this condition would create full vacuum since the maximum capacity is way below the requested 2500 m3/h.

The procedure explained above has to be carried out throughout the entire pipeline.



For easier consultation, resulting flow rates have been traced for each DN from free discharge on given slopes for an adequate air valve sizing.

Air valves sizing

CSA has developed a sizing software fully interfaced with windows able to:

-perform steady state analysis of the profile
-calculate HGL
-model up to 9 different boundary conditions
-verify the pressure along the line.

In addition to that the software run air valves sizing and location. The software takes also into account the movement of air pockets and the locations where there are likely to accumulate, that is to provide warning messages in case of velocities lower that the required value to flush air pockets downstream of downward sloping pipes.

Water hammer

Water hammer is by definition a pressure wave, created by the sudden change in the liquid velocity, travelling across the systems with a speed obtained by using the following formula and called wavespeed.

$$a = \sqrt{\frac{\frac{K}{\rho_w}}{1 + c_1 K \frac{D}{Ee}}}$$

Where :

K is the bulk modulus of water

Rhw is the density of water

D is the pipe DN

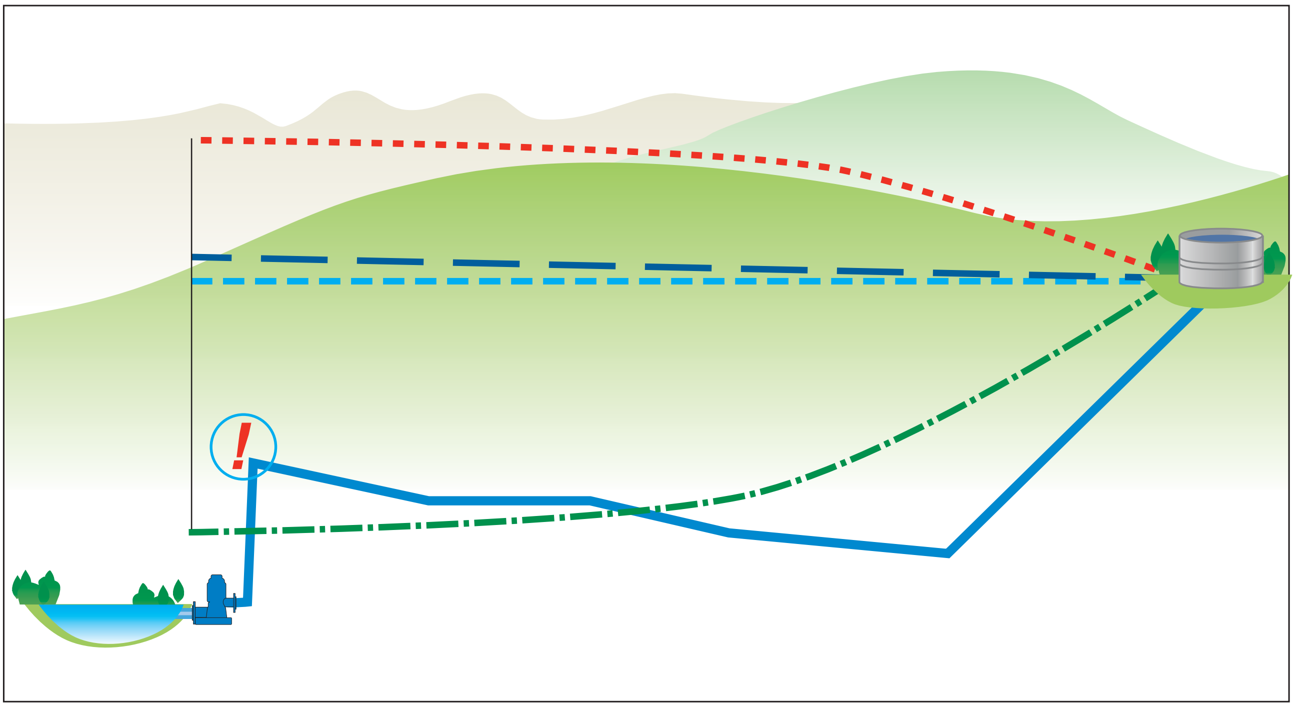
E is the elastic modulus of the pipe

e is the pipe thickness

c1 is a factor taking into account pipe restraints and anchorage

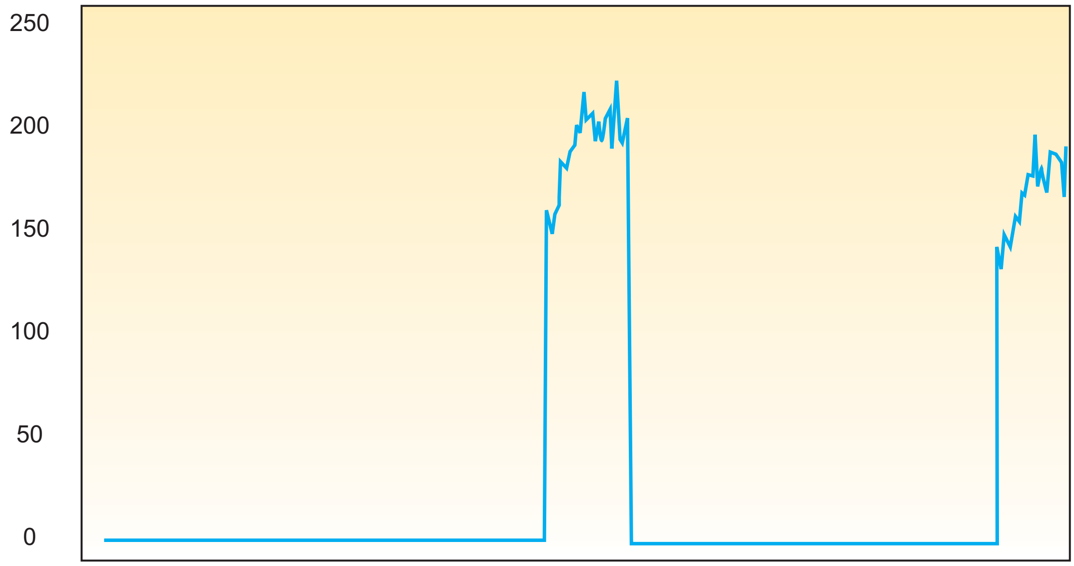
The pressure wave can be either positive or negative and changes direction and magnitude overtime depending on the pipe profile, boundary conditions, derivations and more.

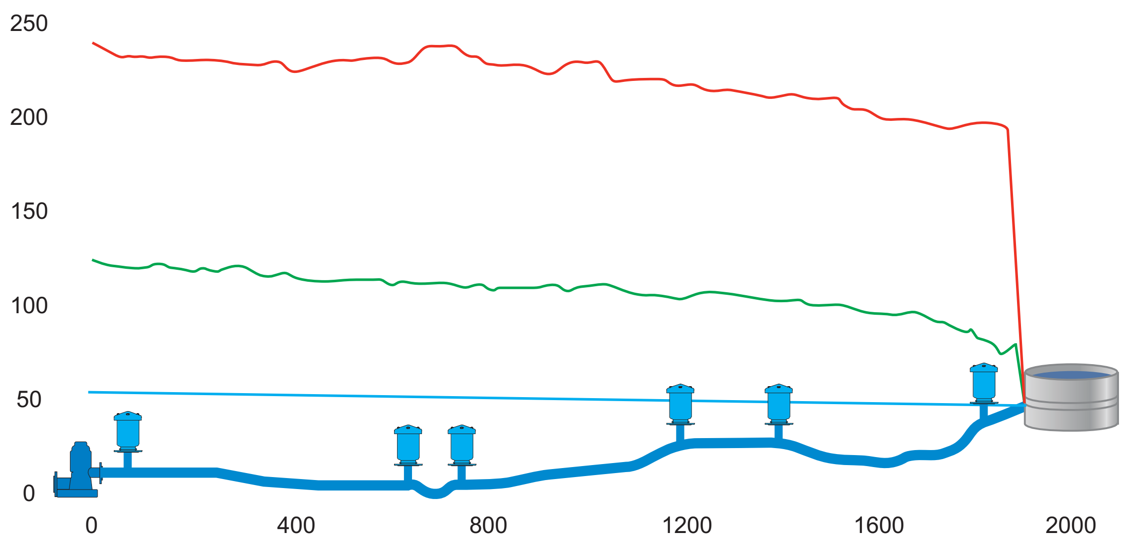
In case of pump failure the effect will be a negative pressure wave propagating downstream, due to that beside segments of the pipe subject to negative pressure conditions particular attentions has to be to paid to those locations where the HGL drops below the pipe profile to a minimum equal to the vapor pressure..should that last long enough vapor pockets will be generated with a separation of the two water columns that, once the rejoin each other closing the void, will produce pressure surges sometimes devastating for the entire system. This is called column separation. In the picture below a typical example of a pumping systems with knee where that event is likely to occur. A detailed surge analysis of pressurized systems must always be carried out, as water hammer depends on many factors. Also in gravity systems designers must consider the worst scenario that could engender and trigger critical events, as an example rapid and uncontrolled closures of sectioning devices, rapid filling of pipelines and so on.



The importance of anti water hammer air valves

Air vacuum air valves or combination air valves are likely to generate problems in case of transients (either caused by pump failure for example or rapid filling of the pipeline) because they will create upsurges during the closing phase. That is mainly related to their high air inflow and outflow capacity. Should the pressure drop below atmospheric where the air valve is located the latter will allow the entrance of large volumes of air thus avoiding negative pressure. When the water column comes back, during the second phase of water hammer, the air valve will discharge air at a very high speed followed by the incoming water column. Due to the difference in density between water and air, once water reaches the air valve, the float will be pushed up against the seat abruptly producing the same effect of an instantaneous valve closure with a free discharge outlet, having a very high velocity running through. The magnitude of the water hammer can be so high to produce pipe bursts, damages to air valves and other components. In the following graph is depicted the overpressure generated by a combination air valve in a pipeline during a transient event as a consequence of pump failure, where the spikes indicate the closure phases of the air valve. The same effects and problem occur in case of rapid pipe filling, according to a survey 40% of pipe bursts are generated by uncontrolled rapid filling.





For water conveyance systems protections, either pumping or gravity systems, it is therefore important to run water hammer analysis to asses and understand the wave propagation and determine what kind of equipments the pipeline may be in need of. With regards to air valves we shouldn't be using combination or vacuum air valves but special solutions, which CSA has been studying and designing through an ongoing research.

CSA Anti-slam technology (AS)

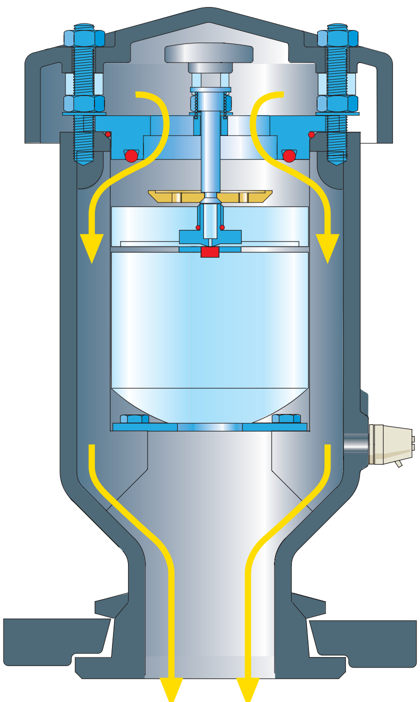
The automatism is composed of a metallic disk (with 2 or more adjustable nozzles) calculated using advanced simulation tools for water hammer analysis, a guide bar and a stainless steel counteracting spring that lays directly on the sealing seat. Such simple construction guarantees high reliability and it may fit both the 2 and the 3 functions CSA air release valves.

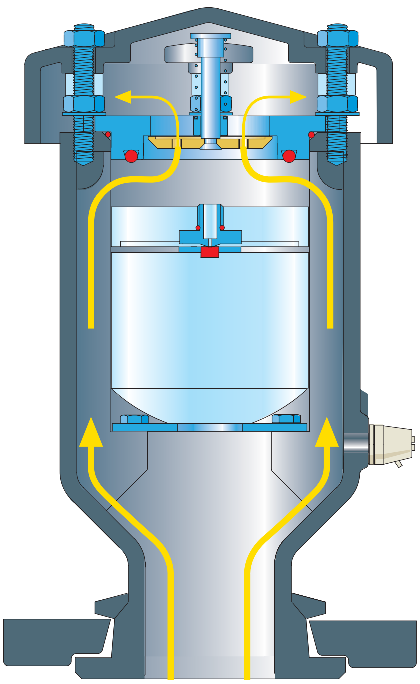
Working principle

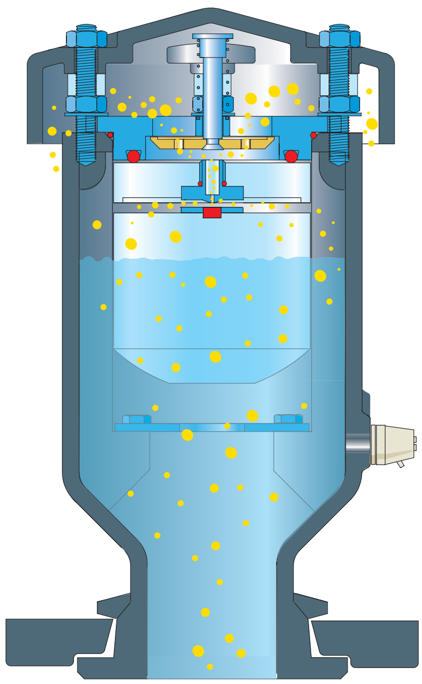
1) During vacuum condition the mobile block is laid over the aerodynamic diffuser, the antishock disk comes down pulling the stainless steel spring allowing the entrance of a large volume of air through the main orifice, to compensate for the vacuum effect.

2) When negative pressure conditions end, the stainless steel spring pulls back the anti-shock disk to close the main orifice. Internal air must therefore flow out through the small disk orifices creating a back-pressure inside the conduct that will slow down the incoming water column avoiding upsurges.

3) In working conditions the air valve will discharge air pockets accumulated along the profile through the nozzle and the anti shock adjustable holes.





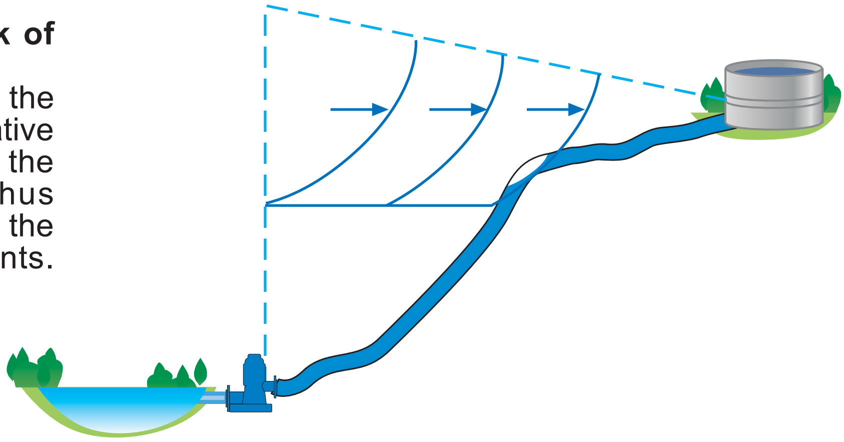


Applications

The AS technology of CSA air valves, used in two functions and three functions, make them suitable for any location and applications and proved to be the right and safer choice under many circumstances. CSA AS air valves should be used anytime and everywhere, in particular in those locations exposed to severe transient conditions as follows:

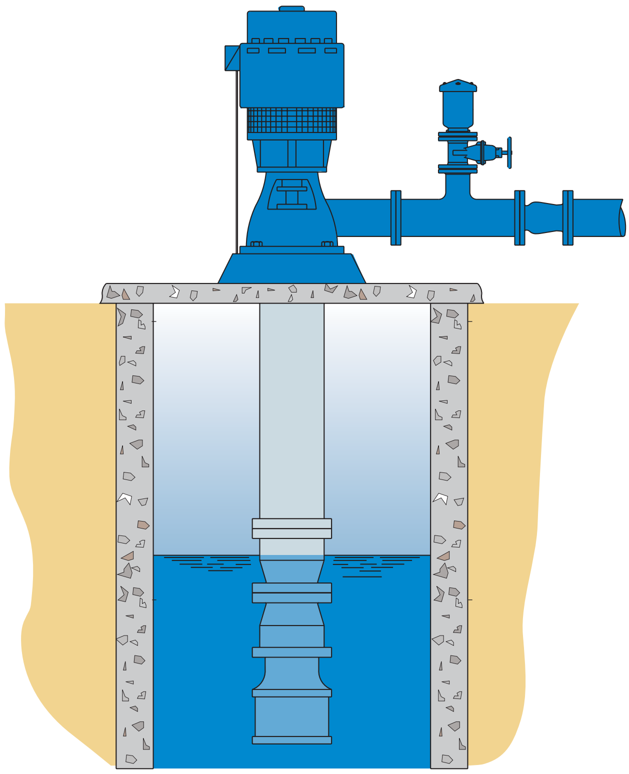
Changes in slopes with the risk of column separation

Thanks to the CSA AS technology the pipe will be protected against negative pressure conditions slowing down the approaching water columns, thus cushioning the upsurge created by the rejoining of the two pressure fronts.



Submersible pumps between the pump and the check valve

In such situation we need an air valve to discharge the air coming from the suction side during pump start up. Using a traditional air vacuum or a combination air valve we will generate a dangerous upsurges due to the uncontrolled water column approach. The AS technology will slow down the incoming water column, due to the air outflow through the adjustable nozzles, providing at the same time enough air inflow capacity to avoid negative pressure conditions in case of pump shut down.

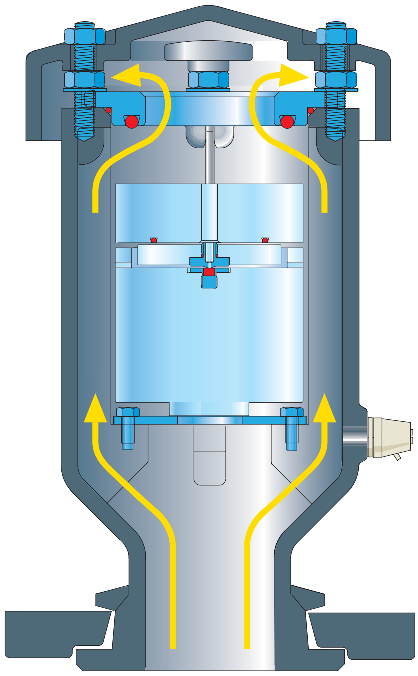


Downstream of pumps

With pumping stations, where in case of power failure the pressure is likely to drop below atmospheric, CSA AS air valve will be the right solution in terms of protection thanks to the large air inflow capacity, to avoid the risk of negative pressure conditions, slowing down the returning water front to prevent further increase in pressure.

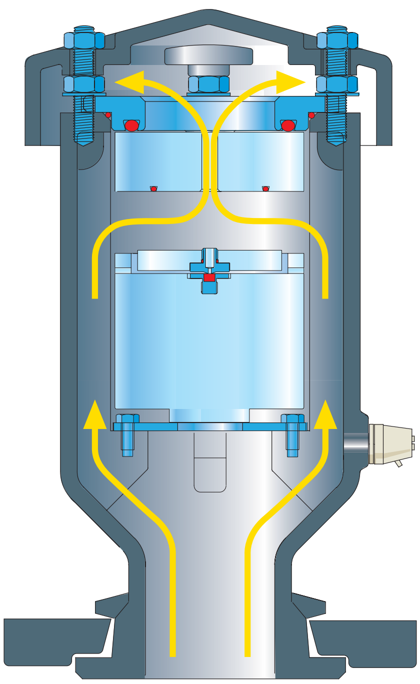
CSA RFP technology (rapid filling prevention)

The automatism is composed of three components, namely the float and the upper flat, joined together by means of the air release system, in addition to the dynamic flat. The latter has been designed and tested to sense the increase in velocity and in differential pressure and come up, reducing the outflow and creating a cushioning effect for the incoming water column, should the air speed become greater than a safety threshold.

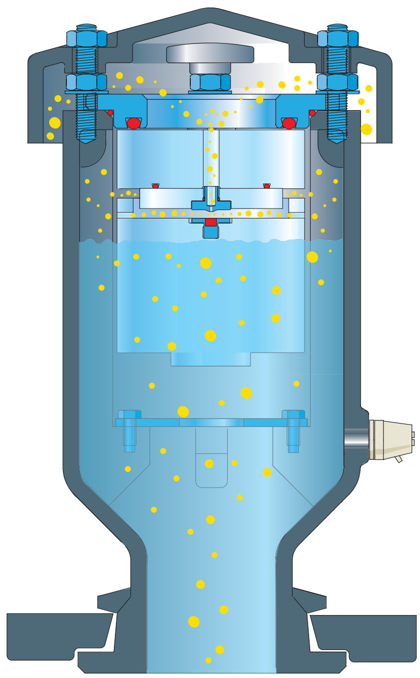


During pipe filling the air valve will discharge air through the main orifice generating a Dp which is proportional to the air flow.

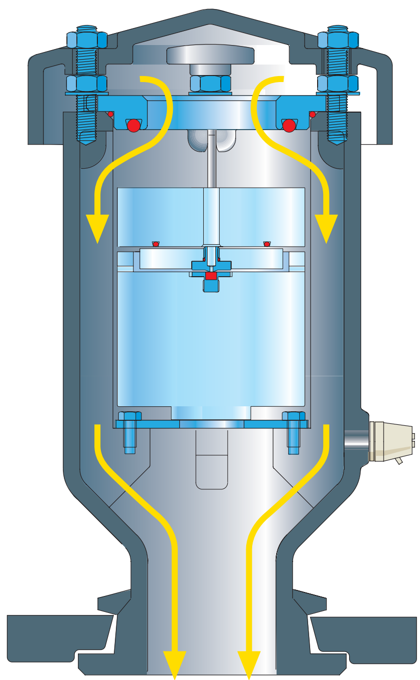
Should the air velocity become greater that 40 mt/sec the dynamic flat will come up, reducing the outflow and creating a cushion effect for the incoming water column.



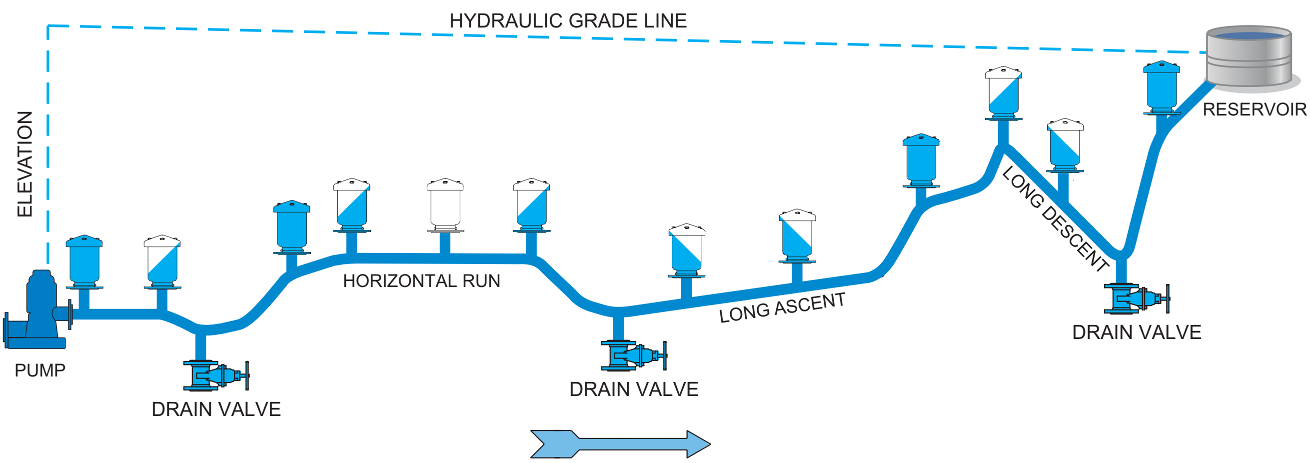
In working conditions the air valve will discharge air pockets, accumulated along the profile, through the nozzle and the orifice obtained in the dynamic flat.



During vacuum conditions the automatism is laid on top of the aerodynamic diffuser, the dynamic flat is on top of the obturator to allow the entrance of large volumes of air to avoid negative perssure conditions.

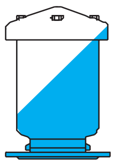


The following pictures has to be considered as a pure indication for air valves location along the profile, also considering transients effects, providing water hammer prevention. The proper choice of air valves depends on many factors such as profile, pipe materials, and other water hammer prevention devices installed. More important it is related to the results of the water hammer analysis. This is the reason why both for waterworks and sewage systems it is important to run transient analysis to asses and understand the wave propagation and determine what kind of protection the pipeline may be in need of, and to assess the effect of the air valves previously sized with the standard procedure.

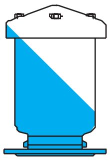


In the graph above for example we show the result of pump failure with only air valves installed as a protection tool, the plot clearly shows the location where negative pressure will occur on the pipeline therefore the air valves positioning and selection below.

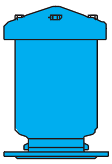
Types of air valve recommended



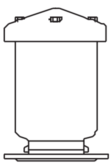
Three functions anti hammer air valves will avoid negative pressure conditions, allowing large entrance of air volumes in case of pump failure/ pipe draining, providing at the same time water hammer protection thanks to the AS technology and the controlled air outflow. They will also ensure the proper air release of air pockets accumulated in working conditions.



Three functions RFP air valves will avoid negative pressure conditions, allowing large entrance of air volumes in case of pump failure/ pipe draining, providing at the same time water hammer protection thanks to the RFP technology controlling the outflow in case of excessive air velocity. They will also ensure the proper air release of air pockets accumulated in working conditions.



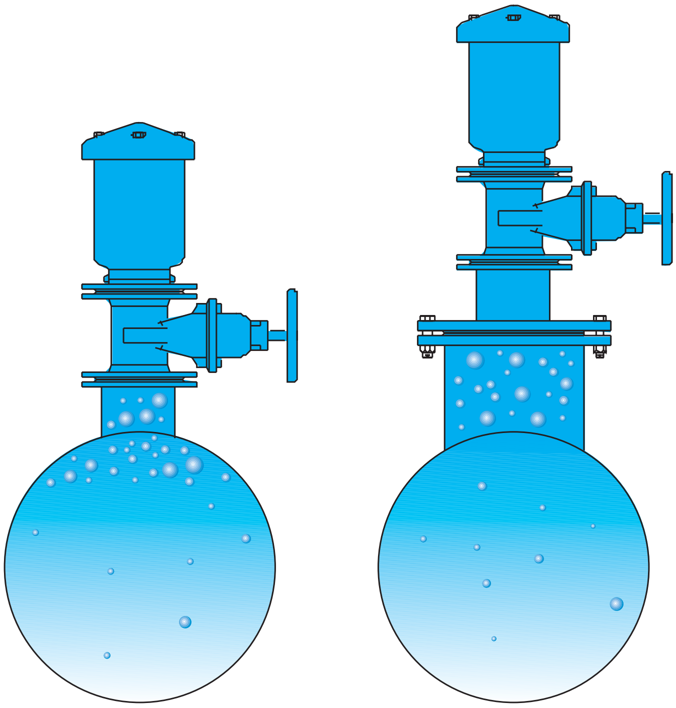
Two functions anti hammer air valves will avoid negative pressure conditions, allowing large entrance of air volumes in case of pump failure/ pipe draining, providing at the same time water hammer protection thanks to the AS technology and the controlled air outflow.



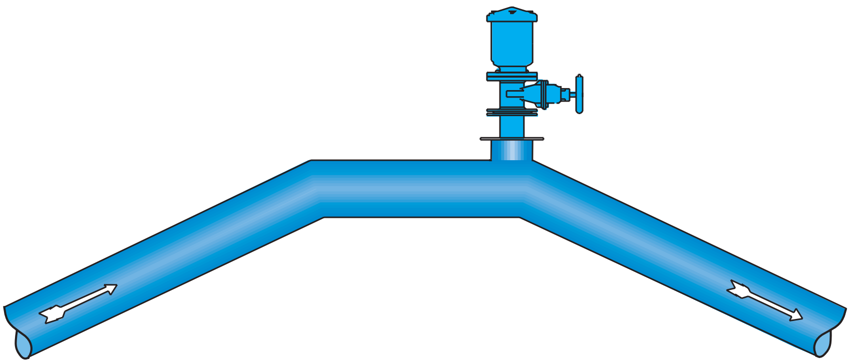
Standad single function air release valve, if the segment is more than 2 KM long three functions RFP air valves are recommended.

Installation and further details

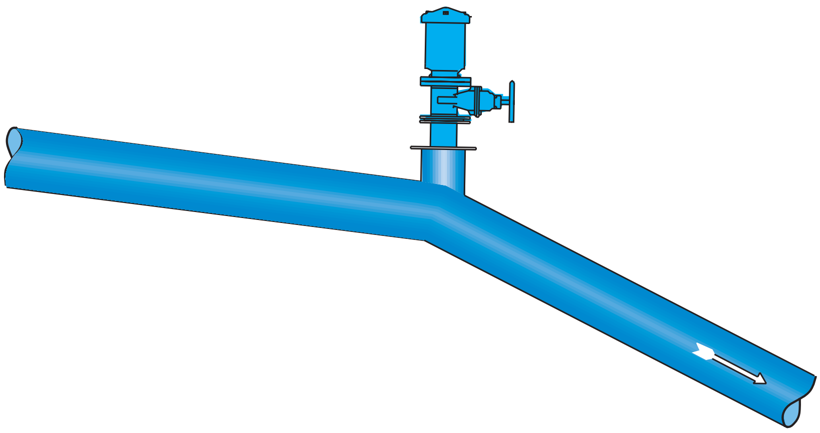
On those locations where air pockets are likely to gather it is very important to create some sort of accumulation chamber, between the pipeline and the air valve, as shown on the picture. The dimension of the chamber DN indicated depends on the pipe DN and profile, and is recommended in general up to a max of 800 mm above which vortex may occur. Please contact CSA for further information.



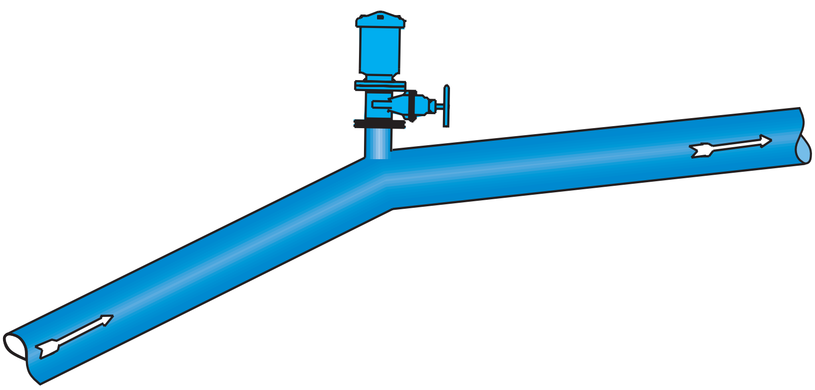
An example of how to deal with high points. A three function air valve has to be placed on top of an accumulation chamber, it is important to install the air valve on the downstream side of the high point due to the position of the air pocket which, pushed by the hydrodynamic force of water from one side and the buoyancy and friction force from the other, will be likely to remain near the change in slope.
These locations are often exposed to water hammer effects therefore anti-slam air valves are recommended.



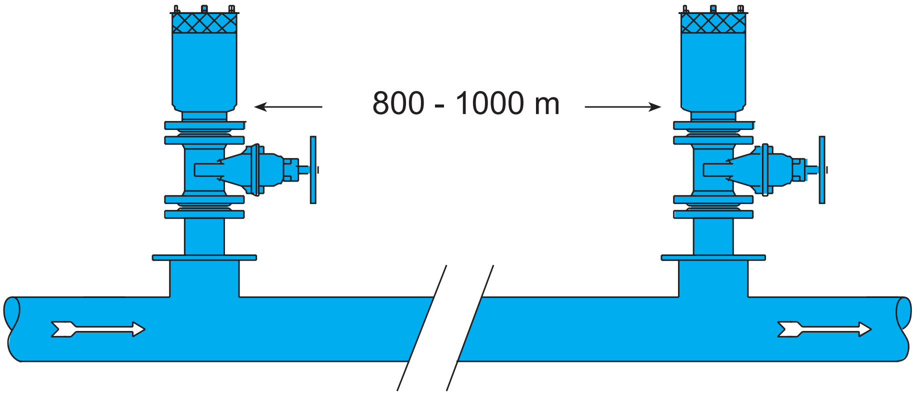
On descending changes in slope we always design on conservative assumptions, therefore air pockets are expected to accumulate on the change in slope due to low velocity conditions.
Three functions air valves will be necessary.



On ascending changes in slope air vacuum air valves will be needed since the air pockets will be always flushed upstream, these points are often exposed to water hammer conditions therefore air valves with anti-slam technology are highly recommended.

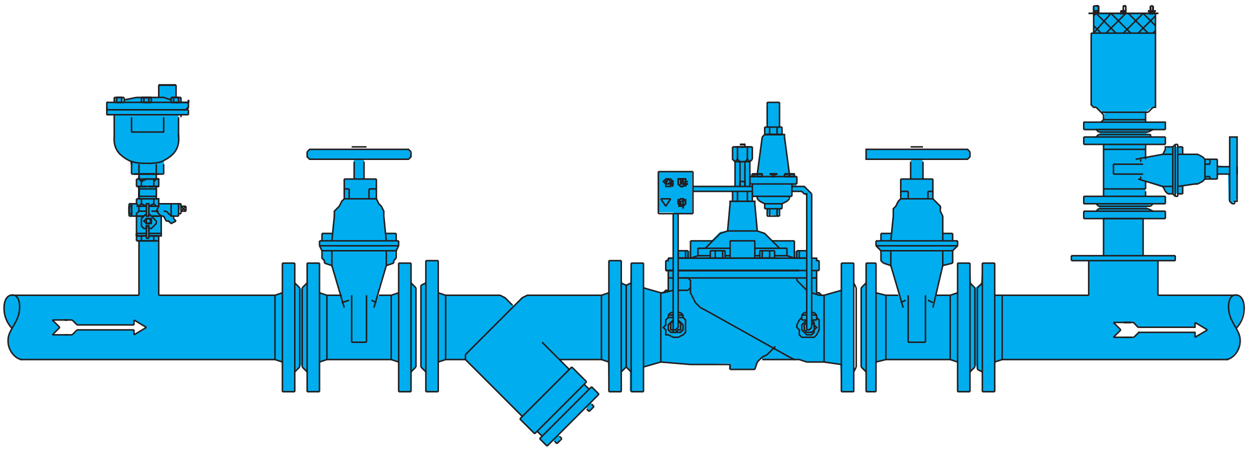


Horizontal or sub horizontal segments, either ascending or descending, have to be avoided when possible. If present in our systems air valves spaced with 800-1000 mt max have to be placed for protection against negative conditions, for the proper air release (if horizontal and descending) and especially if exposed to transient conditions.

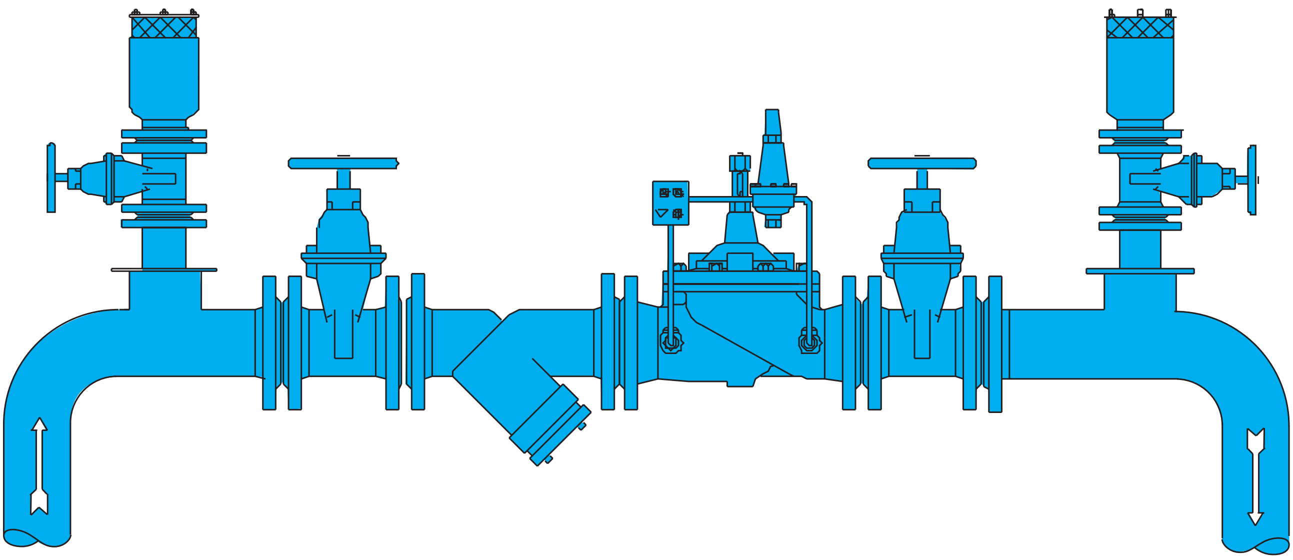


During regulation and control hydraulic control valves, direct acting PRV or PSV modulating devices are needed. Any time we do produce a pressure drop we release air out of water.

An automatic three function anti water hammer air valve is located downstream of the prv while upstream we do have a single air release, to prevent air from reaching the control chamber of the valve. Again a small accumulation below the two air valves is recommended



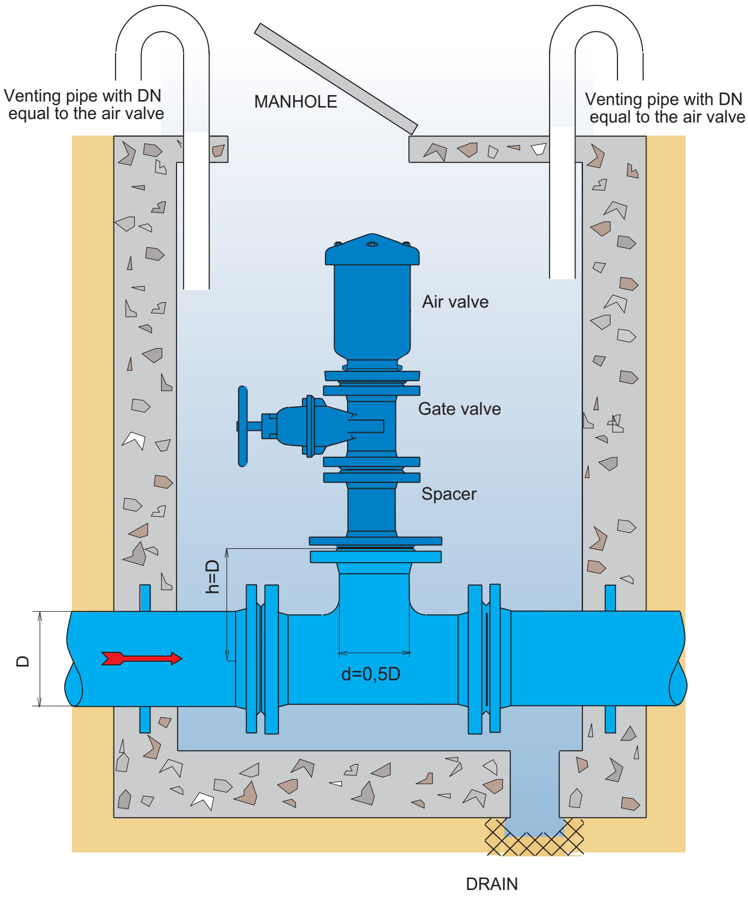
In the following installation we do have two triple function air valve, located upstream and downstream of the control valve next to changes in slope.
Also in this case accumulation chambers on both sides are recommended.



CSA

Installation

Before installation make sure to accurately clean the pipeline to avoid that any foreign bodies like stones or building material may damage the air release valves.
Air release valves must be positioned in locations wide enough and easily accessible to allow maintenance, operations and inspection. They must be placed in a perfectly vertical position, and on a “T” piece to allow for air accumulation in order to improve the air valves performances.
The pit must be equipped with a drainage system for cleaning operations, and ventilation pipes to allow air intake and out-flow for the proper air recirculation.
A sectioning device, being either a gate valve or a butterfly valve, must be provided.



Maintenance

CSA air valves are simple and sturdy and for that they don’t require any particular maintenance, their performances and life spam depends on working conditions.
For combination models we recommend to check the air release system at least twice per year, as well as the o-ring status.
Every component can be easily replaced from the top without having to remove the valve from the pipeline.
For further information please consult the installation and maintenance manual enclosed with every valve, or simply contact CSA technical support.

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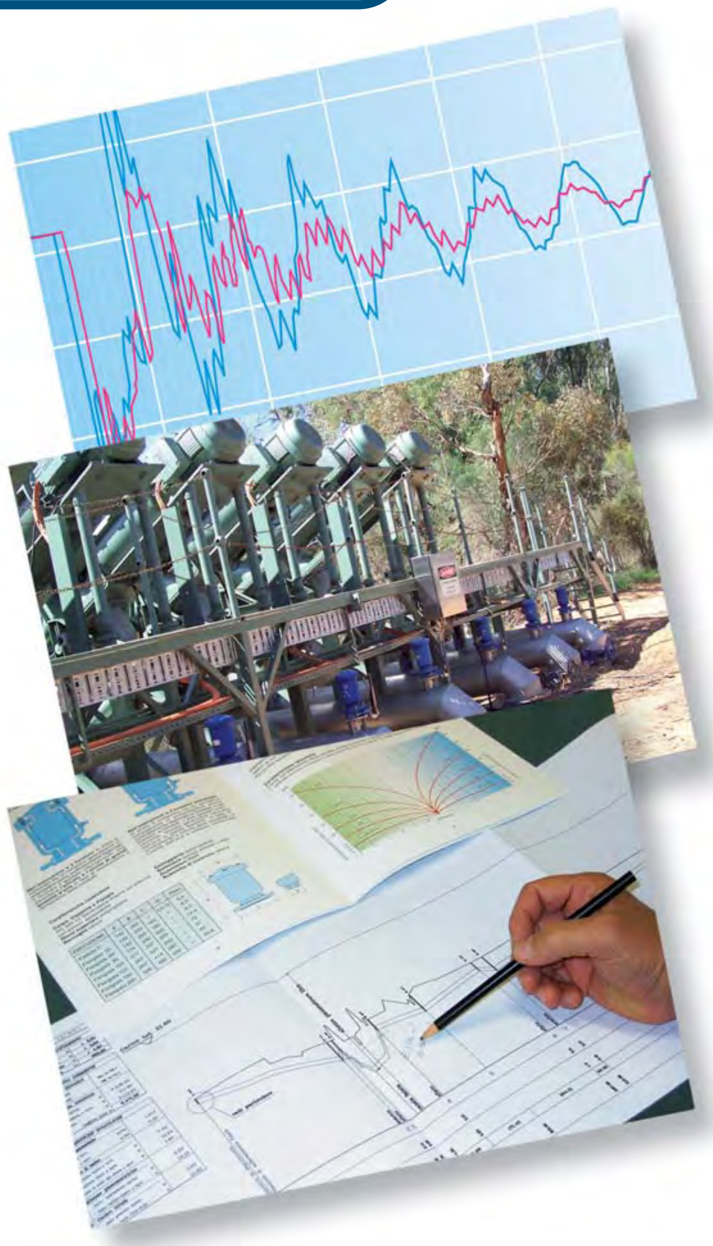
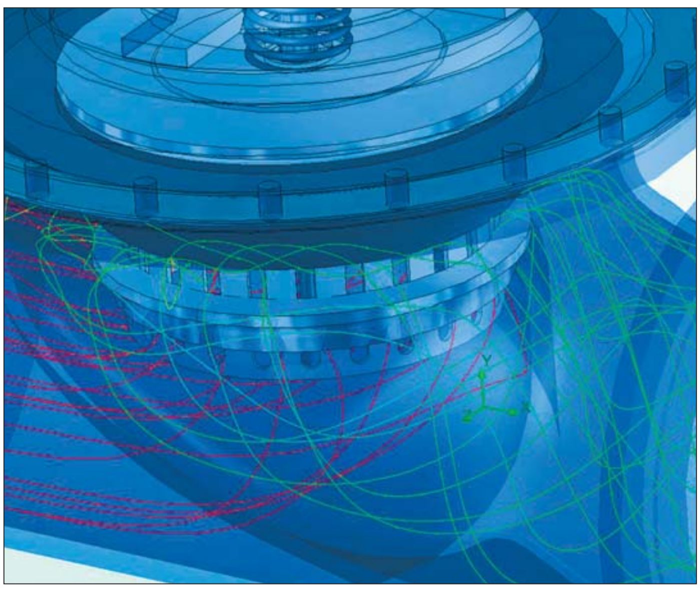


Water hammer analysis
CSA Hyconsult
CSA Hyconsult was founded to provide designers and consultants, involved in the design of water distribution and sewage systems, with accurate and unique technical support.
CSA Hyconsult offers itself as the ideal partner for carrying out hydraulic modeling and conducting transient analysis, entirely through the use of modern computational tools and advanced calculus algorithms. Simulations are essential to predict system responses to events under a wide range of conditions without disrupting the actual system.
Using simulations, problems can be anticipated in possible or existing situations, and solutions can be evaluated in order to invest time, money and material in the most productive manner.



Research and innovation
CSA has always regarded knowledge as being indispensable for the kind of research that consistently feeds innovation at all levels.
The R&D department at CSA constantly strives to improve product performance and continually searches for new solutions to meet our customer's needs.
Twenty years of experience in valve design and sizing, supported by advanced computational tools, cooperation with external entities at the highest level, and test facilities for the verification of theoretical results which are available for our customers, guarantee our professionalism and reliability.